CLIMATE CHANGE

24/2019

Submission under the United Nations Framework Convention on Climate Change and the Kyoto Protocol 2019

National Inventory Report for the German Greenhouse Gas Inventory 1990 – 2017

German Environment Agency - UNFCCC-Submission

For our Environment

Umwelt Bundesamt

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Imprint

Publisher:
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Study completed in:
15 April 2019

Edited by:
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Publication as pdf:
http://www.umweltbundesamt.de/publikationen

ISSN 1862-4359

Dessau-Roßlau, May 2019

Contact

This report was produced in the framework of work of the National Co-ordination Agency (Single Entity) for the *National System of Emissions Inventories* (Nationales System Emissionsinventare; NaSE), sited within the Federal Environment Agency (UBA). Contributions for the chapters on agriculture, and on land use, land-use changes and forestry, were prepared by the Thünen Institute (TI).

The electronic version of this report, along with the pertinent emissions data in the Common Reporting Format (CRF) (Version 1.0.1, based on the CSE database, and with trend tables last revised as of 19 December 2018), is available on the website of the Federal Environment Agency:
http://www.umweltbundesamt.de/themen/klima-energie/treibhausgas-emissionen

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List of Abbreviations

AbfAblV	Ordinance on Environmentally Compatible Storage of Waste from Human Settlements and on Biological Waste-Treatment Facilities (Abfallablagerungsverordnung)
ABL	Old German Länder
AGEB	Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen)
AK	Working group (Arbeitskreis)
ALH	All other deciduous/broadleaf trees with high life expectancies (BWI tree-species group)
ALN	All other deciduous/broadleaf trees with low life expectancies (BWI tree-species group)
ANCAT	Abatement of Nuisances from Civil Air Transport
AR	Activity data (=AD)
ARD	Afforestation, reforestation, deforestation
ATKIS	Official topographic-cartographic information system (Amtliches Topographisch-Kartographisches Informationssystem)
AWMS	Animal Waste Management System
BAFA	Federal Office of Economics and Export Control
BAT	Best Available Technique
BDZ	Federal Association of the German Cement Industry (Bundesverband der Deutschen Zementindustrie)
BEF	Biomass-expansion factor
BEU	Balance of emissions sources for stationary and mobile combustion processes (Bilanz der Emissionsursachen für stationäre und mobile Verbrennungsprozesse)
BGR	Federal Institute for Geosciences and Raw Materials (Bundesanstalt für Geowissenschaften und Rohstoffe)
BGS	Fuel, gas and electricity industries of blast furnaces, steelworks and rolling mills; and forging plants, press works and hammer mills, including the various other plants (without their own coking plants) publicly connected to such operations
BGW	Federal Association of the German Gas and Water Industry (Bundesverband der deutschen Gas- und Wasserwirtschaft)
BHD	Diameter at breast height (= DBH; tree-trunk diameter at a height of 1.30 m above the ground)
BHKW	Combined heat and power (CHP) unit (Blockheizkraftwerk)
BKG	Federal Agency for Cartography and Geodesy (Bundesamt für Kartographie und Geodäsie)
BImSchV	Statutory Ordinance under the Federal Immission Control Act
BML	cf. BMEL
BMU	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BMEL	Federal Ministry of Food and Agriculture
BMVEL	cf. BMEL
BMVG	Federal Ministry of Defence
BMWA	cf. BMWi
BMWi	Federal Ministry for Economic Affairs and Energy
BoHE	Main survey on soil use (Bodennutzungshaupterhebung)
BREF	BAT (Best Available Technique) Reference Documents
BSB	Biological oxygen demand (= BOD; Biologischer Sauerstoffbedarf)

BSB_5	Biological oxygen demand within 5 days (BOD_5)
BV Kalk	German Lime Association (Bundesverband der Deutschen Kalkindustrie)
BÜK	Soil-overview map (Bodenübersichtskarte)
BWI	National Forest Inventory (Bundeswaldinventur)
BZE	Forest Soil Inventory (Bodenzustandserhebung im Wald)
C_2F_6	Hexafluorethane
CAPIEL	Coordinating Committee for the Associations of Manufacturers of Industrial Electrical Switchgear and Controlgear in the European Union
CFC	Chlorofluorocarbons (= Fluorchlorkohlenwasserstoffe (FCKW))
CFI	Continuous Forest Inventory
CH_4	Methane
C_{org}	Organic carbon stored in the soil
CO	Carbon monoxide
CO_2	Carbon dioxide
CORINAIR	Coordination of Information on the Environment, sub-project: Air
CORINE	Coordinated Information on the Environment
CRF	Common Reporting Format
CSB	Chemical oxygen demand (COD)
D	Germany (Deutschland)
DBFZ	Deutsches Biomasseforschungszentrum (German centre for biomass research)
DEHSt	German Emissions Trading Authority (Deutsche Emissionshandelsstelle)
DESTATIS	Federal Statistical Office (official abbreviation: StBA)
DFIU	Franco-German Institute for Environmental Research, at the University of Karlsruhe (Deutsch-Französisches Institut für Umweltforschung an der Universität Karlsruhe)
DG	Landfill gas (Deponiegas)
DGMK	German Association of Oil, Natural Gas and Coal Science (Deutsche Wissenschaftliche Gesellschaft für Erdöl, Erdgas und Kohle eV.)
DIN	DIN standard (Deutsche Industrienorm)
DIW	German Institute for Economic Research (Deutsches Institut für Wirtschaftsforschung)
DLR	German Aerospace Center (Deutsches Zentrum für Luft- and Raumfahrt)
DMKW	Diesel-engine power stations (Dieselmotorkraftwerke)
D_N	Nitrogen in wastewater
DOC	Degradable organic carbon Degradable organic carbon)
DOC_F	Fraction of DOC dissimilated (converted into landfill gas) Fraction of DOC dissimilated)
DSWF	"Forest Fund Database" for the former GDR (Datenspeicher Waldfonds)
DTKW	Steam-turbine power stations (Dampfturbinenkraftwerke)
DVGW	German Association of the Gas and Water Industry (Deutsche Vereinigung des Gas- und Wasserfachs eV.)
D7	Tree-trunk diameter at a height of 7 m above the ground
EBZ	Energy Balance line in the BEU (Energiebilanzzeile)
EEA	European Environment Agency
EECA	European Electronic Component Manufacturers Association
EEG	Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz); promulgated in Federal Law Gazette Part I No. 40 of 31 July 2004, p. 1918 ff.)
EF	Emission factor
EI	Emission index = emission factor

E_{KA}	Inhabitant connected to wastewater-treatment system (Einwohner mit Kläranlagenanschluss)
EL	Fuel oil EL (EL = easily liquid)
EM	Emission
EMEP	Co-operative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe
EMEV	Emissions-relevant energy consumption (Emissionsrelevanter Energieverbrauch)
ERT	Expert Review Team
ESIA	European Semiconductor Industry Association
ETS	EU Emissions Trading Scheme
EU	European Union
EU-EH	ETS (Europäischer Emissionshandel)
EUROCONTROL	European Organisation for the Safety of Air Navigation
EUROSTAT	Statistical Office of the European Communities
EW	Population (Einwohnerzahl)
FA	Combustion systems (Feuerungsanlagen)
FAP	Specialised contact person in the NaSe (Fachlicher Ansprechpartner)
FAL	Federal Agricultural Research Institute (as of 2008: cf. TI)
FAO	United Nations Food and Agriculture Organisation of the United Nations
FCKW	CFC (Fluorchlorkohlenwasserstoffe)
F gases	Fluorinated greenhouse gases
FHW	District heating stations (Fernheizwerke)
FKW	Perfluorocarbons (PFC)
FKZ	Research project number (Forschungskennzahl)
FV	Responsible expert (Fachverantwortlicher) in the NaSE
FWL	Thermal output from combustion (Feuerungswärmeleistung)
GAS-EM	GASeous EMissions (programme for calculation of agricultural emissions)
GEREF	GERman Emission Factor Database
GFA	Large combustion systems (Großfeuerungsanlagen)
GG	Total weight (Gesamtgewicht)
GIS	Gas-insulated switching systems
GMBL	Joint Ministerial Gazette (Gemeinsames Ministerialblatt)
GMES	Global Monitoring for Environment and Security
GMKW	Gas-engine power stations (Gasmotorkraftwerke)
GPG	Good Practice Guidance
GSE FM-INT	GMES Services Elements Forest Monitoring: Inputs for national greenhouse-gas reporting
GT	Gas turbines
GTKW	Gas-turbine power stations (Gasturbinenkraftwerke)
GuD	Gas and steam turbine power stations (Gas- und Dampfturbinenkraftwerke)
GWP	Global Warming Potential
HFC	Hydrofluorocarbons (= HFKW)
HCFC	Hydrochlorofluorocarbons
HFC	Hydrofluorocarbons (HFC)
Hi	Net calorific value (Heizwert)
HK	Key category (Hauptkategorie); is applied to both emissions sources and sinks
HS-GIS	High-voltage gas-insulated switching systems
IAI	International Aluminium Institute
IE	Included elsewhere

IEA	International Energy Agency
IEF	Implied emission factor
IfE	Institute for Energy and Environment (Institut für Energetik und Umwelt)
IFEU	Institute for Energy and Environmental Research (Institut für Energie- und Umweltforschung)
IKW	Industrial power stations (Industriekraftwerke)
IMA	Interministerial Working Group (Interministerielle Arbeitsgruppe)
IPCC	Intergovernmental Panel On Climate Change
IS08	Inventory Study 2008 (Inventurstudie 2008)
K	Fuel input for power generation (direct drive)
k.A.	No entry (keine Angabe)
KP	Kyoto Protocol
KS	Sewage sludge (Klärschlamm)
KTBL	Association for Technology and Structures in Agriculture (Kuratorium für Technik und Bauwesen in der Landwirtschaft)
l	Level (= Level assessment pursuant to IPCC Good Practice Guidance)
LF	Agriculturally used land (landwirtschaftlich genutzte Flächen)
LKW	Truck (Lastkraftwagen)
LTO	Landing/take-off cycle
LUCF	Land Use Change and Forestry
LULUCF	Land Use, Land Use Change and Forestry
MBA	Mechanical-biological waste treatment (MBT; Mechanisch-Biologische Abfallbehandlung)
MCF	Methane Conversion Factor
MS	Medium voltage (Mittelspannung)
MSW	Municipal solid waste
MVA	Waste incineration plant (Müllverbrennungsanlage)
MW	Megawatt
N	Nitrogen
N_2O	Nitrous oxide (laughing gas)
NA	Not applicable
NASA	National Aeronautics and Space Administration
NaSE	German National System of Emissions Inventories (Nationales System Emissionsinventare)
NBL	New German Länder (neue Bundesländer)
NE	Not estimated
NEAT	Non-energy Emission Accounting Tables
NEC	Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on national emission ceilings for certain air pollutants National Emission Ceilings).
NEV	Non-energy-related consumption (nichtenergetischer Verbrauch)
NF_3	Nitrogen trifluoride
NFR	New Format on Reporting, Nomenclature for Reporting to the UN ECE
NFZ	Utility vehicles (Nutzfahrzeuge)
NH_3	Ammonia
NIR	National Inventory Report
NMVOC	Non-Methane Volatile Organic Compounds
NO	Not occurring
NO	Nitrogen monoxide
NSCR	Non-selective catalytic reduction

OCF	One-component foam (installation foam)
OX	Oxidation factor
PAH	Polycyclic aromatic hydrocarbons (= PAK)
PAK	Polycyclic aromatic hydrocarbons (Polycyclische aromatische Kohlenwasserstoffe; = PAH)
PARTEMIS	Measurement and prediction of emissions of aerosols and gaseous precursors from gas turbine engines
PCDD/F	Polychlorinated dibenzo-dioxins/- furans
PF	Process combustion (Prozessfeuerungen)
PFC	Perfluorocarbons (= FKW)
PKW	Automobile (Personenkraftwagen)
PU	Polyurethane
QK	Quality control (QC; Qualitätskontrolle)
QS	Quality assurance (QA; Qualitätssicherung)
QSE	Quality System for Emissions Inventories
REA	Flue-gas desulphurising plant (Rauchgasentschwefelungsanlage)
ROE	Oil equivalent (OE; Rohöleinheit)
RSt	Raw steel
RWI	Rheinisch-Westfälisches Institut für Wirtschaftsforschung
S	Fuel input for power generation
S	Heating oil, heavy (high viscosity; "Heizöl S")
S&A Report	Synthesis and Assessment Report
SA	Heating oil, heavy (high viscosity; low sulphur content; "Heizöl SA")
SE	Sampling error
SF_6	Sulphur hexafluoride
SKE	Hard-coal units (Steinkohleneinheiten)
SNAP	Selected Nomenclature for Air Pollution
SO_2	Sulphur dioxide
StBA	Federal Statistical Office (Statistisches Bundesamt Deutschland)
STEAG	STEAG Aktiengesellschaft (a large power producer in Germany)
T	Trend (= trend assessment pursuant to IPCC Good Practice Guidance, in the category overview tables)
TA Luft	Technical directive on air quality control; First General Administrative Provision on the Federal Immission Control Act (Clean Air Directive; Technische Anleitung zur Reinhaltung der Luft)
TAN	Total Ammoniacal Nitrogen
THG	Greenhouse gases (GHG; Treibhausgase)
TI	Johann Heinrich von Thünen Institute
TI-AK	Johann Heinrich von Thünen Institute, Institute of Climate-Smart Agriculture (Institut für Agrarklimaschutz)
TI-WO	Johann Heinrich von Thünen Institute, Institute of Forest Ecosystems (Institute für Waldökosysteme)
TM	Dry matter (Trockenmasse)
TOC Total Organic Carbon	
TREMOD	Traffic Emission Estimation Model
TS	Siccative (Trockenstoff)
TÜV	Technischer Überwachungsverein (Certifying body for technical and product safety)
TVF	Tonne of utilisable production (Tonne verwertbare Förderung)
UBA	Federal Environment Agency (Umweltbundesamt)

UN ECE	United Nations Economic Commission for Europe
UN FCCC	United Nations Framework Convention on Climate Change
UN	United Nations
UStatG	Environmental Statistics Act (Umweltstatistikgesetz)
VDEh	German Iron and Steel Institute (Verein Deutscher Eisenhüttenleute; in 2003, renamed "Stahlinstitut VDEh")
VDEW	Electricity Industry Association (Verband der Elektrizitätswirtschaft)
VDI	Association of German Engineers (Verein Deutscher Ingenieure e.V.)
VDN	Association of German network operators (Verband der Netzbetreiber e.V.)
VDZ	German Cement Works Association (Verein Deutscher Zementwerke e.V.)
VGB	Technical association of operators of large power stations (Technische Vereinigung der Großkraftwerksbetreiber e.V.)
VIK	Association of the Energy and Power Industry (Verband der Industriellen Energie- and Kraftwirtschaft e.V.)
VOC	Volatile Organic Compounds
VS	Volatile Solids
W	Fuel input for heat generation
WS	Portion of a specific wastewater treatment system (e.g. aerobic, anaerobic)
WZ	Economic activity listed in the National Classification of Economic Activities (NACE; Wirtschaftszweig)
XPS	Extruded polystyrene
ZSE	Central System of Emissions (CSE)
ZVEI	Zentralverband Elektrotechnik und Elektronikindustrie e.V.

Units and Sizes

Multiplication factors, abbreviations, prefixes and symbols

		Prefix/symbol	
Multiplication factor	Abbreviation	Name	Symbol
1,000,000,000,000,000	10^{15}	peta	P
1,000,000,000,000	10^{12}	tera	T
1,000,000,000	10^{9}	giga	G
1,000,000	10^{6}	mega	M
1,000	10^{3}	kilo	k
100	10^{2}	hecto	h
0.1	10^{-1}	deci	d
0.01	10^{-2}	centi	c
0.001	10^{-3}	milli	m
0.000001	10^{-6}	micro	µ

Units and abbreviations

Abbreviation	Units
°C	degrees Celsius
a	Year
cal	calorie
g	gram
h	hour
ha	hectare
J	joule
m^3	cubic metre
ppm	parts per million
t	tonne
W	watt

Standard conversions

Units			is equivalent to		
1	tonne (t)		1	megagram	(Mg)
1	kilotonne / thousand tonnes	(kt)	1	gigagram	(Gg)
1	megatonne / million tonnes	(Mt)	1	teragram	(Tg)

Reading the introductory information tables

The introductory information tables appear at the beginning of each source category chapter. Each such table provides an overview of the relevant source category's importance and of the methods used in connection with it.

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
L/T	**1A1c Manufacture of Solid Fuels and Other Energy Industries**	**All fuels**	**CO_2**	**65,289.06**	**5.34%**	**9,719.00**	**1.09%**	**-85.1%**
-/-	1A1c Manufacture of Solid Fuels and Other Energy Industries	All fuels	N_2O	659.23	0.05%	152.93	0.02%	-76.8%
-/-	1A1c Manufacture of Solid Fuels and Other Energy Industries	All fuels	CH_4	91.98	0.01%	180.61	0.02%	96.4%

Gas	Method used	Source for the activity data	Emission factors used
CO2	CS	NS	CS
CH4	Tier 2	NS	CS
N2O	Tier 2	NS	CS
NOX, CO, NMVOC, SO2			CS

Key category

The upper section of the table shows the key-category-analysis lines that are relevant for the source category in question; the emissions, as an absolute figure (kt CO_2 equivalent) and as a percentage of total emissions in 1990 and in the last reported year; and the pertinent emissions trend between the base year (1990 or 1995 for the F gases) and the last reported year. In the German-language version of the NIR, the term "Hauptkategorie" is used synonymously with the term "key category".

L = Key category in terms of emissions level
T = Key category in terms of emissions trend
2 = Key category pursuant to Tier-2 analysis

Gas

The lower section of the table provides information about the methods used, the source for the activity data and the emission factors (EF) used.

Method used

D = IPCC default
RA = Reference Approach
Tier 1 = IPCC tier 1
Tier 2 = IPCC tier 2
Tier 3 = IPCC tier 3
C = CORINAIR
CS = Country-specific
M = Model

Source for the activity data

M = Model
Q = Questionnaires, surveys
PS = Plant-specific data
AS = Associations, business organizations
RS = Regional statistics
NS = National statistics
IS = International statistics

Emission factor (EF)

D = IPCC default
C = CORINAIR
CS = Country-specific
PS = Plant-specific
M = Model

0 Summary (ES)

As a Party to the United Nations Framework on Climate Change (UNFCCC), since 1994 Germany has been obliged to prepare, publish and regularly update national emission inventories of greenhouse gases. In February 2005, the Kyoto Protocol entered into force. As a result, the international community of nations is required to implement binding action objectives and instruments for global climate protection. This leads to very extensive and detailed obligations vis-à-vis the preparation, reporting and review of emissions inventories. In keeping with Article 3 of the Kyoto Protocol, the EU countries have been making use of the option of jointly fulfilling obligations under the Kyoto Protocol and the UN Framework Convention on Climate Change. They have been doing so via European regulations, most recently EU Regulation 525/2013[1] and its Implementing Regulation 749/2014[2]. Current European implementation of the Kyoto Protocol, via regulations, has made the Protocol's provisions legally binding for Germany.

Pursuant to Decision 24/CP.19, all Parties listed in ANNEX I of the UNFCCC are required to prepare and submit annual National Inventory Reports (NIRs) containing detailed and complete information on the entire process of preparation of such greenhouse-gas inventories. The purpose of such reports is to ensure the transparency, consistency and comparability of inventories and support the independent review process.

Pursuant to to decision 15/CMP.1, as of 2010 all of the countries listed in ANNEX I of the UN Framework Convention on Climate Change that are also parties to the Kyoto Protocol must submit annual inventories in order to be able to make use of flexible mechanisms pursuant to Articles 6, 12 and 17 of the Kyoto Protocol.

Together with the inventory tables in the Common Reporting Format (CRF), Germany submits a National Inventory Report (NIR), which refers to the period covered by the inventory tables and describes the methods and data sources on which the pertinent calculations are based. The report and the inventory tables have been prepared pursuant to the UNFCCC guidelines on annual inventories (FCCC/CP/2013/10/Add.3) and in conformance with the 2006 IPCC Guidelines for national Greenhouse Gas Inventories (IPCC Guidelines, 2006) and the IPCC Good Practice Guidance (IPCC-GPG, 2000). The NIR contains a Part II, along with additional sub-chapters, that fulfill the expanded requirements under the Kyoto Protocol and the relevant obligations at the European level.

Part I of the NIR, comprising Chapters 1 to 10, contains all the information relevant to the annual greenhouse-gas inventory.

Chapter 1 provides background information about climate change and about greenhouse-gas inventories, as well as further information relative to the Kyoto Protocol. This section describes the National System pursuant to Article 5.1 of the Kyoto Protocol, which system is designed to aid and assure compliance with all reporting obligations with respect to atmospheric emissions and removals in sinks. In addition, this chapter describes the basic principles and methods with which the emissions and sinks of the IPCC categories are calculated, presents a short summary of key-category assessment and describes the Quality System for Emissions Inventories (QSE). The chapter concludes with sections on uncertainties analysis and completeness analysis.

[1] REGULATION (EU) No 525/2013 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 21 May 2013 on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change and repealing Decision No 280/2004/EC

[2] COMMISSION IMPLEMENTING REGULATION (EU) No 749/2014 of 30 June 2014 on structure, format, submission processes and review of information reported by Member States pursuant to Regulation (EU) No 525/2013 of the European Parliament and of the Council

Chapter 2 provides a general overview of development of emissions of direct and indirect greenhouse gases and of removals of carbon dioxide in sinks.

Chapters 3 through 9 present information about the individual source and sink groups. Along with general descriptions and information relative to the methods used, sub-chapters in this section also include information about pertinent uncertainties, quality assurance and quality control, recalculations carried out and planned improvements for relevant source and sink categories.

The inventories, the National System and the Quality System for Emissions Inventories have all been further improved in keeping with the results of the reviews that have taken place in recent years. More-detailed information about recalculations, and information relative to the improvements and changes made with regard to the last greenhouse-gas inventory, is presented in **Chapter 10** .

Part II of the NIR, comprising **Chapters 11 to 16**, presents the so-called "Kyoto-NIR", in fulfillment of the expanded requirements for Kyoto reporting, and in keeping with the required organisation (annotated NIR).

Chapter 11 contains all information relative to Kyoto reporting in the areas of land use, land-use changes and forestry (LULUCF), especially the definition of "forest" chosen, details on the land-classification technique used and all information relative to selected activities pursuant to Arts. 3.3 and 3.4 of the Kyoto Protocol.

Chapter 12 is devoted completely to accounting for Kyoto units, a process for which, in Germany, the German Emissions Trading Authority (DEHSt) is responsible.

Chapters 13 and 14 provide an overview of changes made in the National System, and at the German Emissions Trading Authority, with the aim of ruling out the possibility of any undue influences on Kyoto reporting.

Chapter 15 lists all the measures that Germany is taking to minimise negative impacts pursuant to Article 3 (14).

Chapter 16 presents any required further information relative to Kyoto reporting.

Annexes 1 through 7, comprising **Chapters 17-23**, contain more-detailed descriptions of key categories, of individual categories, of the CO_2-reference procedure, of completeness issues, of the National System and the Quality System, of the CSE emissions database and of uncertainties.

More-detailed information about specific relevant issues is presented in the literature listed in **Chapter 24**.

The Federal Environment Agency makes all calculations for the greenhouse-gas inventory and carries out all relevant compilation. Data on emissions and sinks in the land use, land-use changes and forestry sector have been provided by the Johann Heinrich von Thünen Institute (TI). The reporting is coordinated by the Federal Environment Agency (UBA).

0.1 Background information on greenhouse-gas inventories and climate change (ES.1)

0.1.1 Background information about climate change (ES1.1)

Ever since the start of industrialisation, significant trans-regional and global changes in the substance balance of the atmosphere have been observed as a consequence of human activities. Worldwide, concentrations of carbon dioxide (CO_2) have risen by approximately 43 % compared to their levels in pre-industrial times, whilst those of methane (CH_4) have increased by 150 % and those of nitrous oxide (N_2O) have risen by 20 %. Furthermore, a number of brand-new substances – i.e. substances that for all intents and purposes do not occur in nature and are produced almost exclusively by humans – such as chlorofluorocarbons (CFCs), halons, perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3) have entered the atmosphere. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)[3] shows that human impacts on climate are scientific fact.

0.1.2 Background information about greenhouse-gas inventories (ES1.2)

In February 2005, the Kyoto Protocol entered into force. As a result, the international community of nations is required to implement binding action objectives and instruments for global climate protection. In the first commitment period, which lasted from 2008 through 2012, the European Community (at the time, with 15 Member States) committed itself to reducing its greenhouse-gas emissions by 8 % with respect to the base year (1990 and 1995[4]). This commitment has been divided and fulfilled within the EU in the framework of a burden-sharing agreement between the participating Member States[5]. In that agreement, Germany agreed to reduce its emissions by 21 % in comparison to the base year and thus agreed to make a substantial contribution to fulfillment of the EU's commitment. With a reduction of over 26 % by 2012, Germany exceeded that goal.

In the framework of the second commitment period of the Kyoto Protocol, the European countries have committed themselves to reducing their greenhouse-gas emissions by 20 % by 2020. At the same time, they have announced that, under certain conditions, this European contribution could be increased to a 30 %[6] reduction with respect to 1990.

On 3 December 2014, Germany's federal cabinet adopted the Climate Action Programme 2020[7]. With this move, the Federal Government wishes to ensure that Germany will reduce its greenhouse-gas emissions by 40 %, with respect to 1990, by 2020.

0.1.3 Background information relative to supplementary information as required pursuant to Article 7 (1) of the Kyoto Protocol (ES.1.3)

The present report, in keeping with decision 15/CMP.1, presents, for the first time, supplementary information pursuant to Article 7 (1) of the Kyoto Protocol, for support of the review process under the Kyoto Protocol. This information includes:

- General information on inventory preparation in connection with reporting pursuant to Article 3 (3) Kyoto Protocol and for the selected additional activities pursuant to Article 3 (4) Kyoto Protocol; (cf. Chapter 11)
- Information regarding the certificates under the Kyoto Protocol in connection with decisions 13/CMP.1 and 5/CMP.1; (cf. Chapter 12)
- Information regarding changes in the National System of emissions reporting pursuant to Article 5 (1) of the Kyoto Protocol; (cf. Chapter 13)
- Information regarding changes in the National Registry; (cf. Chapter 14)

[3] IPCC Fifth Assessment Report: Climate Change 2007, available in the Internet at: http://www.ipcc.ch/ipccreports/assessments-reports.htm

[4] For HFC, PFC and SF_6

[5] Burden-sharing agreement, adopted with Council Decision 2002/358/EC of 25 April 2002 concerning the approval, on behalf of the European Community, of the Kyoto Protocol to the United Nations Framework Convention on Climate Change and the joint fulfilment of commitments thereunder [OJ L 130 of 15 May 2002]

[6] Information on the quantified emission limitation or reduction objectives (QELROs) for the second commitment period under the Kyoto Protocol; SUBMISSION BY DENMARK AND THE EUROPEAN COMMISSION ON BEHALF OF THE EUROPEAN UNION AND ITS MEMBER STATES, Copenhagen, 19 April 2012

[7] http://www.bmub.bund.de/themen/klima-energie/klimaschutz/nationale-klimapolitik/aktionsprogramm-klimaschutz/

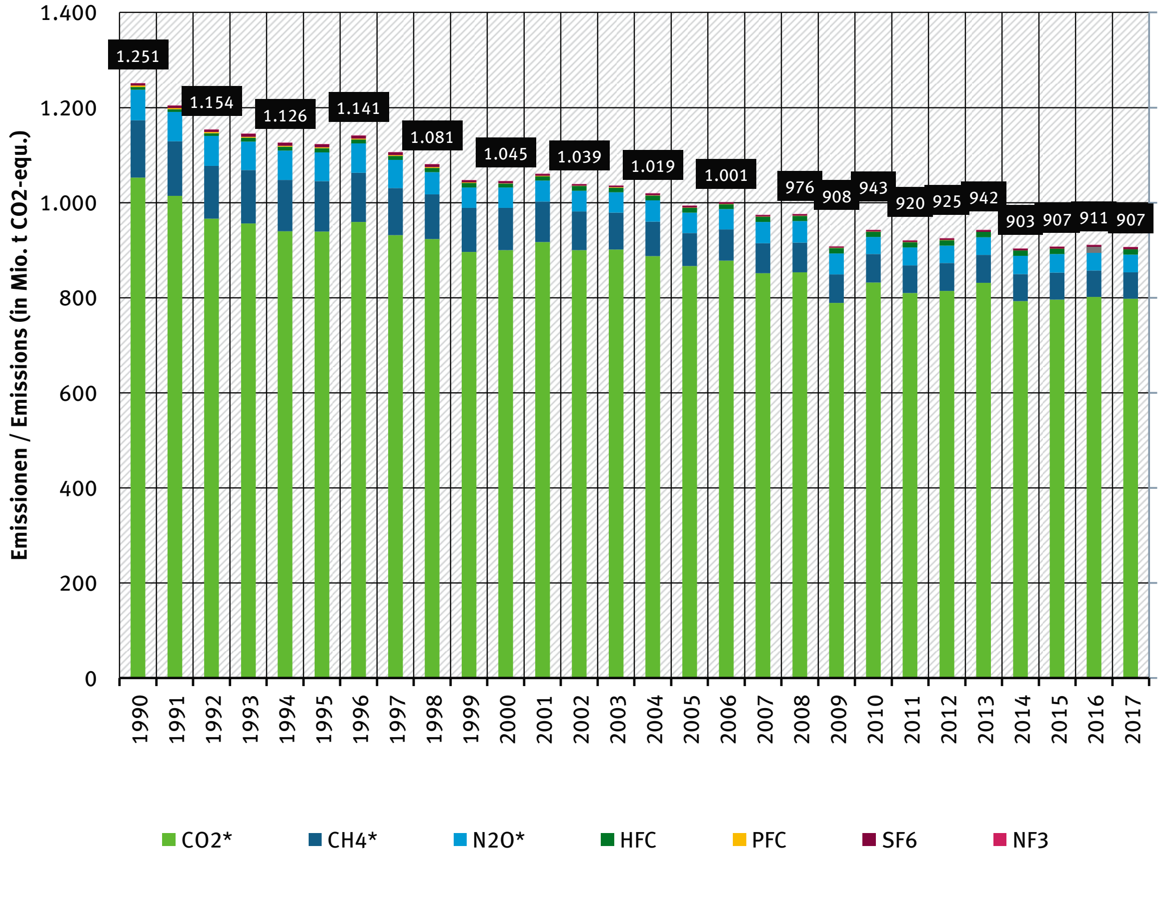
- Information regarding minimisation of negative impacts pursuant to Article 3 (14) of the Kyoto Protocol; (cf. Chapter 15)

0.2 Combined greenhouse-gas emissions, their removals in sinks, and emissions and removals from KP-LULUCF activities (ES.2)

0.2.1 Greenhouse-gas inventory (ES.2.1)

In the relevant interval, 2008 through 2012, Germany completely fulfilled its obligations within the framework of the aforementioned European obligation, with regard to the base-year emissions determined in 2007[8]. It did this by achieving a reduction of 1,232,429.543 Gg (CO_2 equivalent). In the following year, 2013, emissions increased considerably over their levels in 2012. Cold winter weather in 2013 was the primary factor for this increase. In the following years, emissions were again considerably lower than their level in 2013, and they largely stayed in step with economic trends and weather patterns (cf. Chapter 2.1).

Figure 1: Development of greenhouse gases in Germany since 1990, by greenhouse gases [9],



* not including LULUCF

The individual greenhouse gases contributed to this development to varying degrees (cf. Table 1). This is hardly surprising given that, in any given year the various greenhouse gases account for

[8] The reference figures for determining achievement of reduction obligations under the Kyoto Protocol have been defined in keeping with results of the review, carried out in 2007, of the initial report and of reporting for 2006 pursuant to Article 8 of the Kyoto Protocol. Pursuant to its obligations under the Kyoto Protocol and EU burden sharing (Council Decision 2002/358/EC), Germany's reduction obligations amount to 21 %.

[9] * Not including CO_2 emissions and removals from Land Use, Land Use Changes and Forestry (LULUCF).

varying proportions of total emissions (cf. Table 2). Detailed tables are provided in Annex Chapter 22.3.

In 2017, with an 88.0 % share, carbon dioxide emissions again accounted for the largest share of greenhouse-gas emissions. Most of the carbon dioxide is released via stationary and mobile combustion of fossil fuels. As a result of a disproportionately large reduction of other greenhouse-gas emissions, CO_2 emissions' share of total emissions has increased by about 4 percentage points since 1990. Methane (CH_4) emissions, caused predominantly by animal husbandry, fuel distribution and landfills, accounted for a 6.1 % share. Emissions of nitrous oxide (N_2O), caused primarily by agriculture, industrial processes and burning of fossil fuels, contributed 4.2 % of greenhouse-gas releases. The fluorinated greenhouse gases (the so-called F gases) contributed about 1.7 % to total emissions. The greenhouse gas NF_3, which is being reported for the first time, is of negligible importance. Furthermore, the low emissions of that substance are confidential in part, meaning that part of the emissions have to be reported elsewhere The distribution of greenhouse-gas emissions in Germany is typical for a highly developed and industrialised country.

Information about the relevant trends is provided in Chapter 0, while all detailed tables relative to discussion of trends are provided in Annex Chapter 22.3.

Table 1: Emissions trends in Germany, by greenhouse gas and category

Emissions Trends	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
						(kt)						
CO_2 emissions (without LULUCF)	**1,052,520**	**939,543**	**900,376**	**866,640**	**832,388**	**809,749**	**814,138**	**831,570**	**792,793**	**795,940**	**801,655**	**797,966**
Net CO_2 emissions/removals	1,019,502	904,802	860,743	852,967	814,342	792,327	797,960	815,575	776,190	779,843	786,020	781,052
CH_4 (without LULUCF)	**120,944**	**105,665**	**88,789**	**69,455**	**59,353**	**58,230**	**58,826**	**58,376**	**57,215**	**57,079**	**55,924**	**55,247**
CH_4 (including LULUCF)	121,820	106,537	89,660	70,321	60,221	59,097	59,693	59,242	58,080	57,946	56,789	56,111
N_2O (without LULUCF)	**64,134**	**60,747**	**42,745**	**43,016**	**36,362**	**37,707**	**36,899**	**37,447**	**38,106**	**38,698**	**37,858**	**37,666**
N_2O (including LULUCF)	64,964	61,561	43,546	43,765	37,171	38,529	37,734	38,288	38,953	39,553	38,718	38,531
HFCs (CO_2 equivalent, 1995 base year)	**5,898**	**8,513**	**8,230**	**10,059**	**10,840**	**11,029**	**11,230**	**11,237**	**11,352**	**11,574**	**11,479**	**11,258**
PFCs (CO_2 equivalent, 1995 base year)	**3,069**	**2,099**	**975**	**852**	**356**	**285**	**248**	**262**	**238**	**247**	**252**	**234**
SF_6 (CO_2 equivalent, 1995 base year)	**4,428**	**6,467**	**4,072**	**3,321**	**3,191**	**3,254**	**3,246**	**3,352**	**3,487**	**3,652**	**3,881**	**4,241**
NF3 (CO_2 equivalent, 1995 base year)	**C**	**C**	**C**	**C**	**54**	**52**	**25**	**6**	**6**	**C**	**C**	**C**
Total Emissions without LULUCF (CO_2 equi.)	**1,250,993**	**1,123,035**	**1,045,187**	**993,344**	**942,542**	**920,306**	**924,611**	**942,250**	**903,196**	**907,190**	**911,049**	**906,611**
Total Emissions/Removals with LULUCF (CO_2 equi.)	1,219,681	1,089,980	1,007,227	981,284	926,173	904,573	910,136	927,963	888,305	892,815	897,140	891,426
Emission source and sink categories	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
						(kt)						
1. Energy	**1,036,608**	**918,079**	**870,346**	**832,197**	**801,237**	**778,192**	**784,567**	**801,833**	**761,976**	**767,091**	**770,912**	**765,661**
2. Industry	**96,838**	**98,547**	**78,018**	**75,921**	**63,092**	**63,019**	**62,104**	**61,957**	**62,056**	**60,938**	**62,903**	**64,496**
3. Agriculture	**79,195**	**68,058**	**68,187**	**64,068**	**63,621**	**65,268**	**64,901**	**66,127**	**67,490**	**67,996**	**66,536**	**66,273**
4. Land-Use Change and Forestry	**-31,312**	**-33,055**	**-37,960**	**-12,060**	**-16,369**	**-15,733**	**-14,476**	**-14,288**	**-14,891**	**-14,375**	**-13,909**	**-15,185**
CO_2 (net emissions)	-33,018	-34,741	-39,633	-13,674	-18,045	-17,421	-16,178	-15,995	-16,603	-16,097	-15,634	-16,914
N_2O + CH_4	1,706	1,686	1,673	1,614	1,677	1,688	1,703	1,707	1,712	1,721	1,725	1,729
5. Waste	**38,352**	**38,350**	**28,637**	**21,158**	**14,591**	**13,828**	**13,039**	**12,333**	**11,674**	**11,165**	**10,697**	**10,182**

Table 2: Contributions to emissions trends in Germany, by greenhouse gas and category

GHG Emission Fractions	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
						(%)						
CO_2 emissions (without LULUCF)	**84.13**	**83.66**	**86.14**	**87.24**	**88.31**	**87.99**	**88.05**	**88.25**	**87.78**	**87.74**	**87.99**	**88.02**
CH_4 (without LULUCF)	**9.67**	**9.41**	**8.50**	**6.99**	**6.30**	**6.33**	**6.36**	**6.20**	**6.33**	**6.29**	**6.14**	**6.09**
N_2O (without LULUCF)	**5.13**	**5.41**	**4.09**	**4.33**	**3.86**	**4.10**	**3.99**	**3.97**	**4.22**	**4.27**	**4.16**	**4.15**
HFCs	**0.47**	**0.76**	**0.79**	**1.01**	**1.15**	**1.20**	**1.21**	**1.19**	**1.26**	**1.28**	**1.26**	**1.24**
PFCs	**0.25**	**0.19**	**0.09**	**0.09**	**0.04**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**
SF_6	**0.35**	**0.58**	**0.39**	**0.33**	**0.34**	**0.35**	**0.35**	**0.36**	**0.39**	**0.40**	**0.43**	**0.47**
NF_3	**C**	**C**	**C**	**C**	**0.006**	**0.006**	**0.003**	**0.001**	**0.001**	**C**	**C**	**C**
GHG Emission Fractions for Categories (without LULUCF)	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
						(%)						
1. Energy	**82.86**	**81.75**	**83.27**	**83.78**	**85.01**	**84.56**	**84.85**	**85.10**	**84.36**	**84.56**	**84.62**	**84.45**
2. Industry	**7.74**	**8.78**	**7.46**	**7.64**	**6.69**	**6.85**	**6.72**	**6.58**	**6.87**	**6.72**	**6.90**	**7.11**
3. Agriculture	**6.33**	**6.06**	**6.52**	**6.45**	**6.75**	**7.09**	**7.02**	**7.02**	**7.47**	**7.50**	**7.30**	**7.31**
5. Waste	**3.07**	**3.41**	**2.74**	**2.13**	**1.55**	**1.50**	**1.41**	**1.31**	**1.29**	**1.23**	**1.17**	**1.12**

* Information on the structure of the Common Reporting Format (CRF): http://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch1ri.pdf

0.2.2 KP-LULUCF activities (ES.2.2)

Removals of CO_2 pursuant to Article 3.3 (afforestation and deforestation) increased by 4.3 % with respect to 2016. That is equivalent to CO_2 removals of -5,010 kt CO_2-equivalent, for the year 2017, taking account of all GHG.

Activities in the areas of Forest, Cropland and Grazingland Management are reported under Article 3.4. The emissions and sinks for all three activity areas have hardly changed with respect to the previous year, 2016. They range from 0.4 % (grazing land management) to 1.2 % (cropland management). With regard to total emissions, a 4.4 % increase in sinks was determined with respect to the previous year, 2016. That is equivalent to CO_2-equivalent removals of -18,944 kt for the year 2017.

0.3 Combined emissions estimates, and trends for source and sink groups, including KP-LULUCF activities (ES.3)

0.3.1 Greenhouse-gas inventory (ES.3.1)

Figure 2 shows the contributions of the individual categories to total greenhouse-gas emissions. It highlights the considerable constancy of the relative shares of the various categories and the absolute predominance of energy-related emissions. On the other hand, absolute energy-related emissions have continuously decreased over time. The variations that are superimposed over this trend are largely temperature-related. Because temperatures – especially in winter – affect heating patterns, they also affect energy consumption for heating, and thus they have major impacts on annual trends in energy-related CO_2 emissions.

On the whole, greenhouse-gas emissions decreased by 27.3 % in 2017[10]. Considerations of the various components involved confirm this trend, to varying degrees. The relevant emissions changes for the most important greenhouse gases in terms of quantity were as follows: - 24.2 % for carbon dioxide (CO_2), - 54.3 % for methane (CH_4) and - 41.3 % for nitrous oxide (N_2O). The corresponding trends for the so-called "F" gases, which contribute about 1.7 % of greenhouse-gas emissions overall, have not been as clearly similar to each other, however. In keeping with the introduction of new technologies, and with use of these substances as substitutes, since base year 1995 SF_6 emissions decreased by 34.4 % and PFC emissions dropped by 88.9 %, while HFC emissions increased by 32.2 %. For the greenhouse gas NF_3, which is being reported for the first time, neither a trend nor an applicable fraction can be given, for reasons of confidentiality.

With respect to the previous year, 2016, total emissions decreased by 0.5 %. They remained at about the level seen in the previous years, however. The observed fluctuations are due largely to weather effects and economic trends.

In addition, CO_2 emissions from electricity generation decreased again in 2017. Use of hard coal and lignite also decreased again. In recent years, coal has been increasingly supplanted by natural gas, which has lower specific CO_2 emissions, in electricity generation. Renewable energies' share of electricity generation increased considerably.

[10] All figures do not include emissions from the category of Land Use, Land-Use Change & Forestry (LULUCF).

Figure 2: Emissions trends in Germany since 1990, by categories[11,]

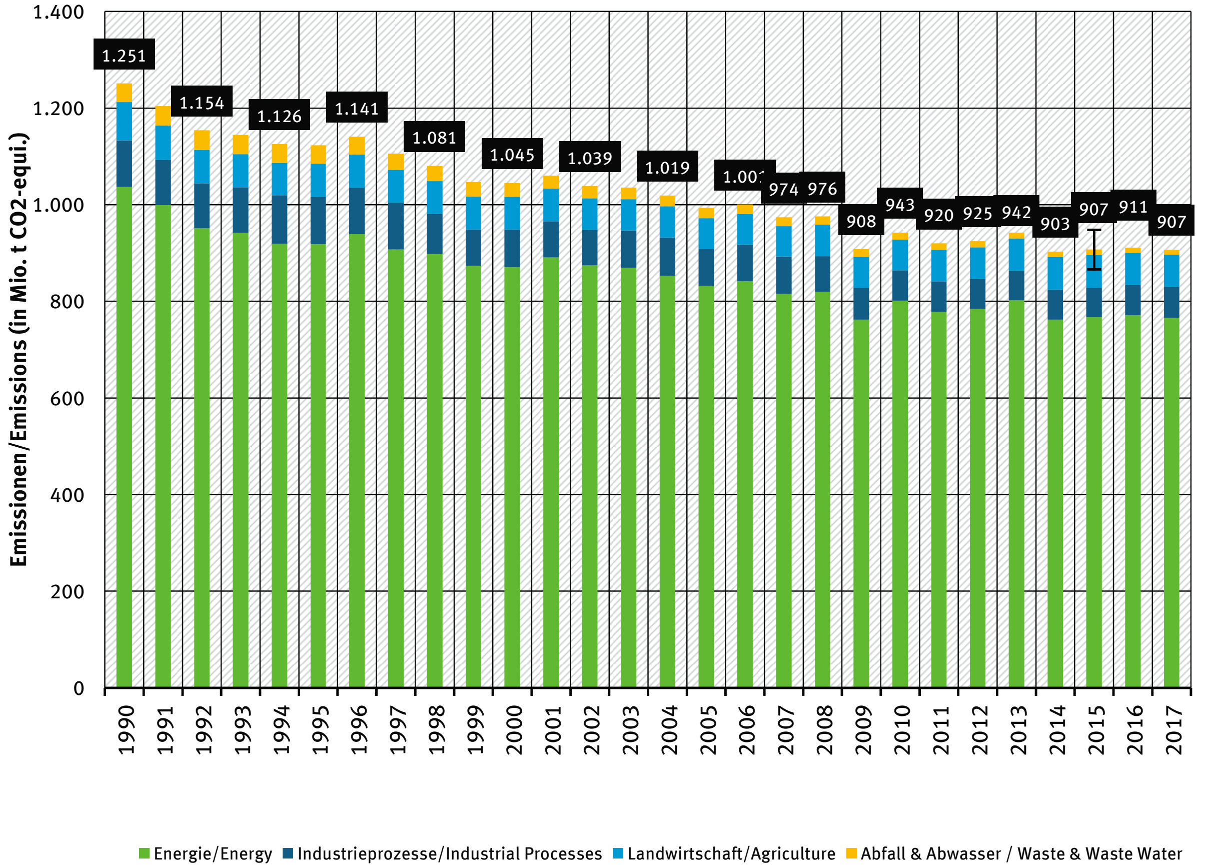
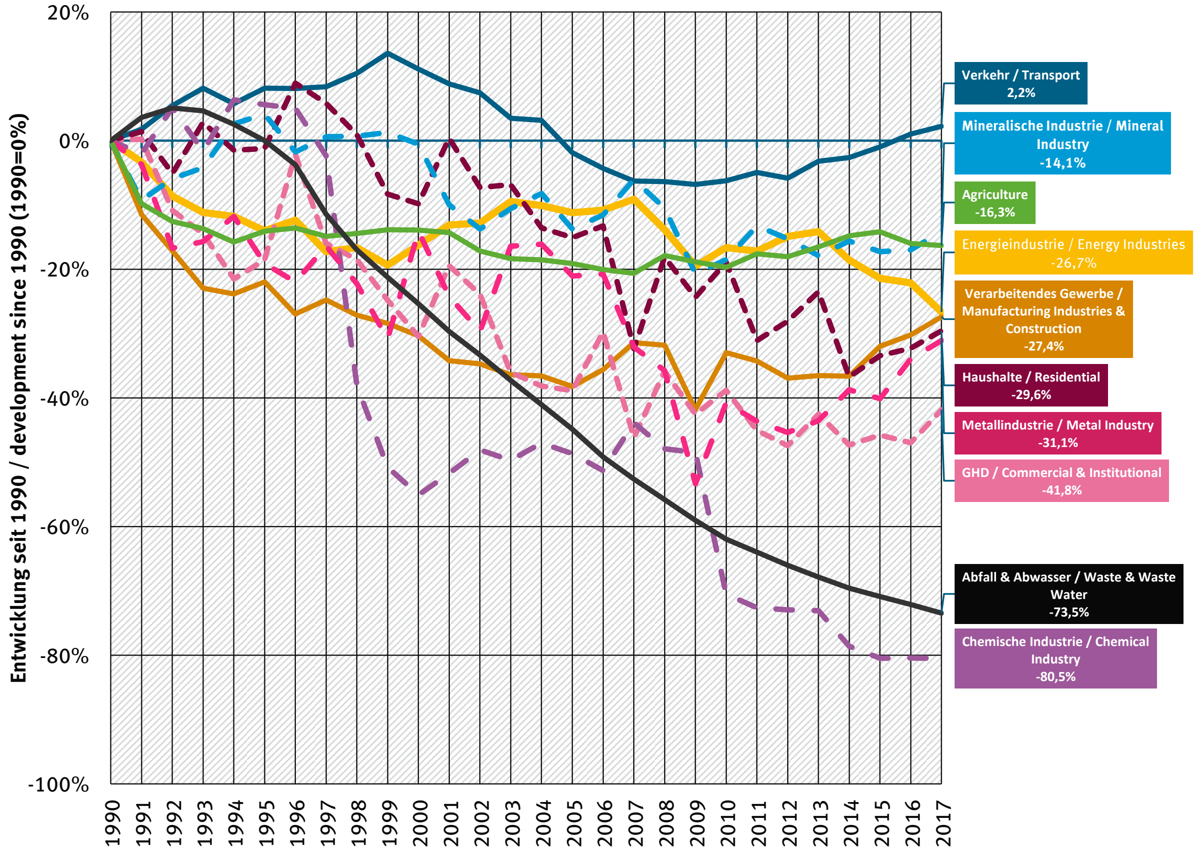


Figure3 shows the relative developments of emissions from the various categories since 1990. The most significant reduction occurred in the area of waste emissions. Increased recycling of recyclable materials (Packaging Ordinance), and reuse of materials as compost (Biowaste Ordinance), have led to a sharp reduction in the quantity of waste that is landfilled and hence to continuous reductions in landfill emissions. Emissions-reducing measures carried out in 1997 and 2009 in the sector of adipic-acid production had major impacts on emissions from industrial processes. Emissions from solvent and other product use decreased markedly, as a result of decreased narcotic use of N_2O. The development of emissions from agriculture essentially follows the development of livestock data. A detailed discussion of emissions trends is presented in Chapter 0, Trends in Greenhouse Gas Emissions.

[11] * Not including CO_2 emissions from Land Use, Land Use Changes and Forestry (LULUCF).

Figure3: Relative development of greenhouse-gas emissions since 1990, by categories[12,]



0.3.2 KP-LULUCF activities (ES.3.2)

Germany reports afforestation and deforestation pursuant to KP-LULUCF Article 3 (3). It reports forest management, cropland management and grazing-land management management pursuant to Article 3 (4) of the Kyoto Protocol. It reports emissions of the greenhouse gases carbon dioxide, methane and nitrous oxide.

Under Article 3.3, it is reporting removals of -5,010.45 kt CO_2 equivalent for the year 2017. The removals consist of -7,159.52 kt CO_2 equivalent of removals via afforestation and reforestation and 2,149.07 kt CO_2 equivalent of emissions from deforestation. In the category of afforestation and deforestation, it is reporting CO_2 emissions of -5,168.58 kt CO_2, CH_4 emissions of 15.31 kt CO_2 equivalent and N_2O emissions of 142.82 kt CO_2 equivalent.

Under Article 3.4, it is reporting removals of -18,944.38 kt CO_2 equivalent in the year 2017. The figure comprises removals of -55,694.91 kt CO_2 equivalent from forest management, emissions of 14,797.01 kt CO_2 equivalent from cropland management and of 21,953.52 kt CO_2 equivalent from grazing-land management. The emissions for the three activities break down as follows by gases: CO_2: -20,107.23 kt; CH_4: 746.30 kt CO_2 equivalent; and N_2O: 416.55 kt CO_2 equivalent.

12 Emissions from Land Use, Land Use Changes and Forestry are reported in detail in the relevant chapter.

1 Introduction

1.1 Background information regarding greenhouse-gas inventories and climate change, and supplementary information as required pursuant to Article 7 (1) of the Kyoto Protocol

1.1.1 Background information about climate change

Climate change consists of changes in average weather conditions, and in extreme events, over an extended period of time; it can occur in a particular area or be global.

Climate change may be attributable to the following causes:

- Changes in so-called "geo-astrophysical parameters" such as the solar constant, elements of the earth's orbit, etc.
- Changes in the earth's surface
- Changes in the energy balance in the "earth's surface and atmosphere" system
- Changes in the substance balance in the atmosphere (such as changes in the concentration of greenhouse gases).

Greenhouse gases, among which are carbon dioxide, nitrous oxide (laughing gas), methane, ozone and other gases (especially water vapour, the most important natural greenhouse gas), have a particular property: They allow the energy-rich radiation falling onto the earth from the sun (primarily in the visible, short-wave range) to pass almost unhindered, yet partially absorb the long-wave radiation emitted by the heated earth. This places them in an energetically excited state for a brief time, after which they return to their original basic state whilst emitting infrared radiation. Heat radiation occurs equally in all spatial directions – in other words, a substantial portion of this is returned to the earth's surface ("*thermal back radiation*"). So that this additional quantity of energy may nevertheless be irradiated (this must occur due to the dynamic, energetic equilibrium, at whose centre are the earth and the atmosphere), the earth must have a correspondingly higher temperature. This is a simplified description of the greenhouse effect.

Without the greenhouse gases occurring naturally, life on our planet would not be possible. Instead of having an average global temperature of approximately 15°C, the earth would have an average temperature of approximately –18°C. In other words, the natural greenhouse effect protects our life on earth.

Since the beginning of the industrial era, mankind has brought about marked changes in the atmosphere's substance cycles, however. These changes have been caused by humans' energy-intensive lifestyles and related emissions of greenhouse gases. From 1750 to 2017, the worldwide concentrations of carbon dioxide (CO_2) increased by about 46 %. The current CO_2 concentration in the atmosphere, at about 405.5 ppm, is the highest to have occurred over the past 800,000 years. In the same period, the concentration of methane (CH_4) in the atmosphere increased by a factor of 2.5, and the concentration of nitrous oxide (N_2O) increased by about 22 % (World Meteorological Organization, 2018a). Furthermore, a number of brand-new substances – i.e. substances that for all intents and purposes do not occur in nature and are produced almost exclusively by humans – such as chlorofluorocarbons (CFCs), halons, perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3) have entered the atmosphere.

In spite of being "trace gases", greenhouse gases have considerable impacts. Their increasing concentrations have led to the anthropogenic (human-caused) greenhouse effect, which supplements the natural greenhouse effect.

The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2015) has clearly confirmed that the earth's climate is currently changing: A wide range of changes have occurred throughout the entire climate system since the middle of the last century. The temperature of the lower atmosphere is rising, the oceans are warming, glaciers are melting, permafrost soils are thawing, icecaps are losing mass and sea levels are continuing to rise.

Extensive observations, expanded models and profound insights into the pertinent interrelationships indicate, with great reliability, that human activities are the main cause of the climate change currently taking place.

Significant examples of observed climate changes include the following:

- From 1880 to 2012, the global mean temperature near the ground rose by 0.85 °C. Each of the past three decades has been warmer than all previous decades since 1850. In the northern hemisphere, the last 30-year period (from 1983 to 2012) was the warmest such period in the past 1400 years.
- The year 2016 was the warmest to date since the beginning of record-keeping in the second half of the 19th century. 2017 and 2015 were the next-warmest, and almost as warm. Nine of the ten warmest years observed to date occurred after 2005, and the five warmest years occurred after 2010 ((World Meteorological Organization, 2018b)).
- In the period 1971 to 2010, the oceans have stored more than 90 % of the additional energy fed into the climate system. The **upper water layers** in the world's oceans (0 to 700 meters) warmed considerably in the period from 1971 to 2010. From 1971 to 2010, the temperature in the oceans' upper 75 meters rose by an average of 0.11°C per decade. In addition, data gained during the observation period 1957 through 2009 suggest a likelihood that the oceans have also warmed at **water depths between 700 and 2,000 meters**. Adequate measurement data for greater water depths are available only for the period 1992 through 2005. For depths below 3,000 meters, they show warming that is most pronounced in the southern oceans. Glaciers around the world have continued to retreat, apart from just a few exceptions, and the earth's polar icecaps have lost mass. In the entirely of the period 1971 through 2009, the average annual mass loss of **glaciers** (not including glaciers at the periphery of the large ice caps) worldwide amounted to about 226 gigatonnes per year. In a recent fraction of that period (1993 through 2009), the loss rate had increased to about 275 gigatonnes per year, however.
- Over the period 1979 through 2012, the area covered by **Arctic sea ice** decreased at a rate of 3.5 to 4.1 percent per decade. During the summer minimum (September), the decrease reached rates of 9.4 to 13.6 percent per decade. During the same period, the duration of the melting period increased by about 5.7 days per decade, and the thickness of the winter pack ice in the Northern Arctic Ocean decreased by about 1.3 to 2.3 meters.
- The spring **snow cover** in the Northern Hemisphere has been decreasing since the middle of the 20th century. From 1967 through 2012, snow cover during the months of March and April decreased by an average of 1.6 percent per decade, while the June snow cover decreased by 11.7 percent per decade.
- As a result of continuing melting of glaciers and icecaps, and of warming-related ocean-water expansion, the global mean sea level rose by about 19 cm from 1901 to 2010. **The average rise during that period amounted to about 1.7 millimeters per year. Over the last 20 years, the average rise, at about 3.2 millimeters per year, was nearly twice as large, however.**

The climate change will have extensive impacts on ecological and societal systems, with potentially serious consequences.

If dangerous impacts of climate change are to be prevented, global warming must be constrained to no more than 2 °C in comparison to pre-industrial levels. Of that increase, 1.0°C have already taken place World Meteorological Organization (2016). Successful limiting of warming to less than 2 °C can be expected only in a scenario with highly ambitious climate policies.

The latest research findings indicate that greenhouse-gas emissions must reach their final maximum no later than 2020 and that a trend reversal must then begin taking place. In subsequent years, global emissions then urgently need to be reduced by at least 50 % by the year 2050, with respect to the emission level of the year 2000 .

1.1.2 Background information about greenhouse-gas inventories

The world's nations were quick to recognize that the expected temperature changes would pose threats to ecosystems and to human civilisation, because the changes would take place relatively quickly, and existing systems would not be able to adapt to the new climate conditions without suffering damage.

The Framework Convention on Climate Change was adopted in 1992, in Rio de Janeiro, by nearly all nations of the world. Since 1994, the countries listed in ANNEX I of the Framework Convention on Climate are required to submit annual inventories of greenhouse gases, as of 15 April of each year, to the Secretariat of the Framework Convention. Such inventories must include data on emissions and sinks for the base year (1990 for CO_2, N_2O, CH_4; 1995 for HFCs, PFCs, SF_6 and NF_3) and for all years until two years prior to the year of the relevant report (UNFCCC, 2013b)).

At the third Conference of the Parties to the UN Framework Convention on Climate Change, held in Kyoto, legally binding obligations on emissions limitations and reductions were defined, for the first time, for the countries listed in ANNEX I. In the first commitment period under the Kyoto Protocol, industrialised nations were required to reduce their emissions of the six greenhouse gases carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) by an average of 5.2 percent in the period 2008 through 2012[13]. In the second commitment period of the Kyoto Protocol, the list of relevant gases was expanded to include nitrogen trifluoride (NF_3) and six hydrofluorocarbons (HFC-152, HFC-161, HFC-236cb, HFC-236ea, HFC-245fa, HFC-365mfc) and two fully fluorinated hydrocarbons (c-C_3F_6, $C_{10}F_{18}$).

For the first commitment period, the European Union adopted an obligation to reduce emissions by 8 %, with respect to the base year. For the second commitment period in the framework of the Kyoto Protocol, the European Union has adopted an obligation to reduce its GHG emissions by 20 %, with respect to the base year, by 2020. Via the European Effort Sharing Decision[14], that obligation has been divided among the 28 Member States and the European Union. While emissions reductions in those areas of inventories that are subject to emissions trading are implemented at the European level, the Member States are responsible at the national level for emissions reductions in inventory areas not subject to emissions trading. Germany is obligated to reduce its emissions to 451.33 million tonnes of CO_2-equivalents.

In the second commitment period of the Kyoto Protocol – as in the first – the effectiveness and success of the Kyoto Protocol vis-à-vis reduction of global greenhouse gas emissions depend on two key factors: Whether its Parties abide by the rules of the Protocol and meet their obligations, and whether the emissions data used for controlling compliance are reliable. As such, national reporting and the subsequent international review of emissions inventories play a key role.

[13] The average reduction, 5.2 %, was calculated from the emissions limitations and reductions that the various parties to the Kyoto Protocol entered in the Protocol's Annex B.

[14] Decision No 406/2009/EC of the European Parliament and of the Council of 23 April 2009

1.1.3 Background information relative to supplementary information, as required pursuant to Article 7 (1) of the Kyoto Protocol (KP NIR 1.1.3.)

Pursuant to decision 15/CMP.1 of the 1st COP of the Kyoto Protocol, as of 2010 all of the countries listed in ANNEX I of the UN Framework Convention on Climate Change that are also parties to the Kyoto Protocol must submit annual inventories in order to be able to make use of flexible mechanisms pursuant to Articles 6, 12 and 17 of the Kyoto Protocol.

In 2008 (with the NIR 2008), Germany began early, on a voluntary basis, to fulfill these reporting obligations. In the process, over the past two years it has begun preparing intensively for the binding reporting required pursuant to Art. 7 of the Kyoto Protocol.

The first binding report, that for 2010 (NIR 2010), was reviewed in detail in September 2010 in the framework of an In-Country Review. The recommendations made in the 2010 In Country Review were implemented in a resubmission of November 2010, and in subsequent reports in the period 2011 through 2014.

The first report within the second commitment period of the Kyoto Protocol (NIR 2016) was also reviewed in the framework of an In Country Review. Its recommendations were implemented via a resubmission in November 2016 and the following reports.

In submitting its seventeenth National Inventory Report (NIR 2019), Germany also submits its eleventh inventory report pursuant to the Kyoto Protocol (its fourth report within the second commitment period) that includes all of the information called for in Art. 7.

Information relative to Arts. 3.3 and 3.4 of the Kyoto Protocol (UNFCCC, 1998b) is provided in Chapter 11. Information on accounting of Kyoto units for the second commitment period is provided in Chapter 12. The relevant changes in the National System are described in Chapter 13, and the changes in the National Registers are described in Chapter 14. Information on minimisation of negative influences pursuant to Art. 3 (14) of the Kyoto Protocol is presented in Chapter 15.

1.2 Description of institutionalisation of inventory preparation, including the legal and procedural definitions relative to the planning, preparation and management of the inventory

Decision 24/CP.19 calls on all Annex I states to establish and describe national institutions for preparation of greenhouse-gas inventories. In addition, Article 5.1 of the *Kyoto Protocol* calls on the parties to the Kyoto Protocol to establish National Systems for preparation of GHG inventories. The requirements pertaining to such systems are set forth in the *Guidelines for National Systems* (UNFCCC Decision 19/CMP.1). The National System for Germany fulfills the requirements, as set forth by both decisions and by the European Regulation on a mechanism for monitoring and reporting greenhouse gas emissions in the European Union and its Member States.[15]

The National System provides for the preparation of inventories conforming to the principles of transparency, consistency, comparability, completeness and accuracy. Such conformance is achieved through use of the methodological regulations from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, through ongoing quality management and through continuous inventory improvement.

[15] Regulation (EU) No 525/2013 of the European Parliament and of the Council of 21 May 2013 on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change

The National System has been institutionalised in a process lasting from 2007 to 2011, and on the basis of a 2007 agreement between state secretaries of the involved ministries. Initially, this occurred via the establishment of a National Co-ordinating Committee and of pertinent in-house regulations for the Federal Environment Agency (UBA). Later, institutionalisation was completed primarily via signing of relevant agreements with other federal institutions, with industrial associations and with individual business enterprises. In 2013 and 2014, the National System was adapted to the requirements applying under the second commitment period of the Kyoto Protocol and expanded.

The requirements-conformal institutionalisation and function of the National System has been confirmed by all international reviews carried out to date, including the 2010 and 2016 In Country Reviews.

1.2.1 Overview of the institutional, legal and procedural definitions relative to preparation of greenhouse-gas inventories and of supplementary information as required pursuant to Article 7 (1) of the Kyoto Protocol

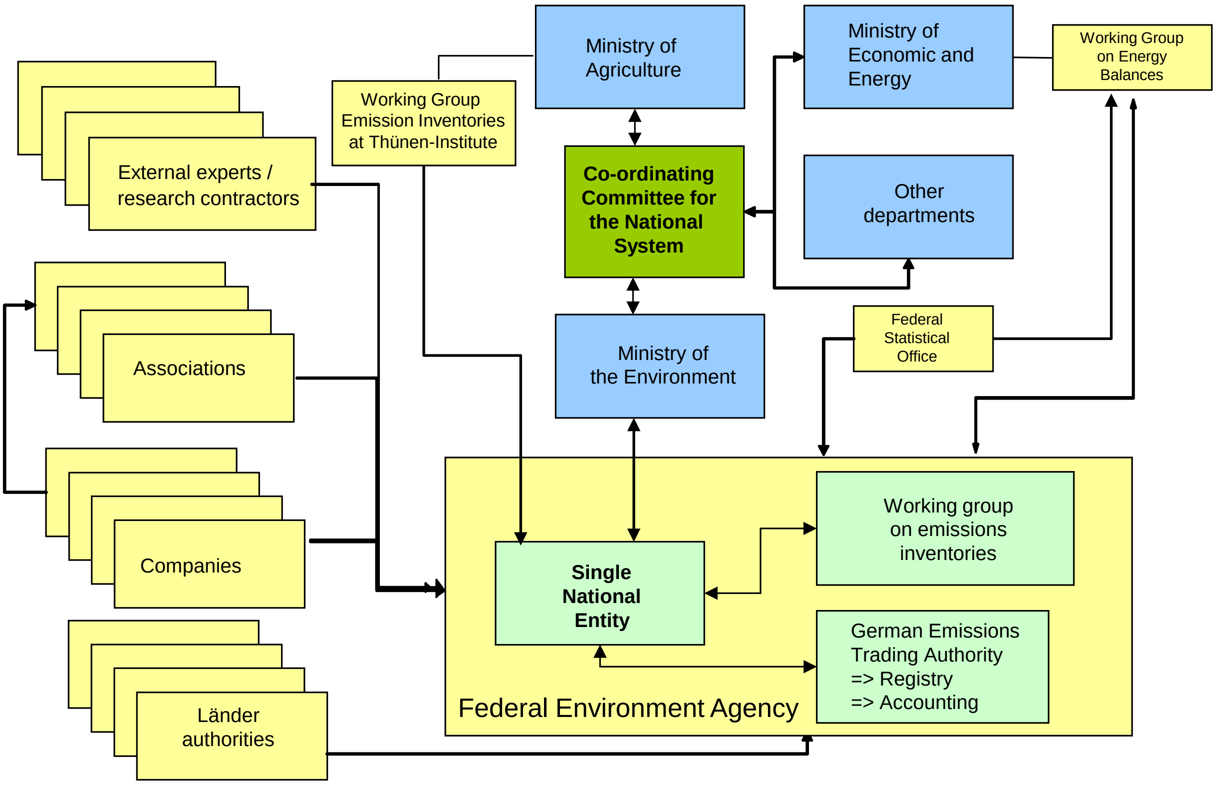
At the ministerial level, the National System has been established under the leadership of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), via an agreement 5 June 2007 signed by state secretaries of the participating ministries that serves as a pertinent policy paper and is entitled "National Emissions Reporting System" ("Nationales System zur Emissionsberichterstattung"). With the inclusion of the Federal Ministry of Food and Agriculture (BMEL), the Federal Ministry for Economic Affairs and Energy (BMWi), the Federal Ministry of Transport and Digital Infrastructure (BMVI), the Federal Ministry of the Interior, Building and Community (BMI), the Federal Ministry of Finance (BMF) and the Federal Ministry of Defence (BMVg), all key institutions and organisations are now involved in preparing emissions inventories that are in a position to provide high-quality specialised contributions (cf. Chapter 1.2.1.4). The policy paper on emissions reporting defines the relevant responsibilities of the various participating federal ministries, and it mandates that the National System is to be built on the basis of existing data streams. Where the data streams are incomplete, the pertinent gaps are to be closed by the responsible ministries, via suitable activities. In support of the reporting process, the participating ministries established a co-ordinating committee (cf. Chapter 1.2.1.1).

The "National Emissions Reporting System" policy paper also assigns the Federal Environment Agency the task of serving as the Single National Entity for Germany. Within the Federal Environment Agency, the Emissions Situation section has been entrusted with this task (cf. Chapter 0). At the level of the Federal Environment Agency, the Single National Entity integrates other specialised agencies within the National System and coordinates the contributions of the other institutions and organisations involved in emissions reporting. For co-ordination of pertinent work within the Federal Environment Agency, a working group on emissions inventories was established (cf. Chapter 1.2.1.3). For implementation, within the Federal Environment Agency, of the IPCC guidelines for quality control and assurance, a Quality System of Emissions was established in 2005, via an in-house directive (cf. Chapter 1.3.3.1.1).

The following Figure 4 provides an overview of the structure of the National System in Germany.

The "National Emissions Reporting System" policy paper of 5 June 2007 is presented in Annex Chapter 22.1.1.

Figure 4: Structure of the National System of Emissions (NaSE)



1.2.1.1 The National Co-ordinating Committee

In its Sec. 2, the state secretaries' resolution of 5 June 2007 provides for the establishment of a National Co-ordinating Committee that is to be headed by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and to include representatives of all federal ministries that participate in emissions reporting.

The National Co-ordinating Committee has the tasks of supporting the emissions-reporting process and clarifying open issues pertaining to the National System. In particular, the Committee carries out consultations with regard to gaps in data streams and settles issues pertaining to assigned responsibilities.

In addition, the National Co-ordinating Committee is responsible for approving inventories and the reports required pursuant to Arts. 5, 7 and 8 of the Kyoto Protocol.

The National Co-ordinating Committee met for the first time on 21 December 2007. It meets at least once per year, at the invitation of the BMU. Between meetings, the participating federal ministries carry out co-ordination via electronic communication.

In the second commitment period, the National Co-ordinating Committee continues to be an important, established component of the National System.

1.2.1.2 Single National Entity (co-ordination agency) for the National System

The state secretaries' policy paper of 5 June 2007 appointed the Federal Environment Agency (UBA) to carry out tasks of the **Single National Entity** for emissions reporting (**national co-ordination agency**). The Federal Environment Agency's in-house directive (Hausanordnung) 11/2005 gave Section V 1.6 Emissions Situation (FG V 1.6) responsibility for carrying out that function.

The Single National Entity's tasks include planning, preparing and archiving of inventories, describing inventories in the inventory reports and carrying out quality control and assurance for all important process steps. The Single National Entity serves as a central point of contact, and it co-ordinates and informs all participants in the National System. During the period 2003 to 2007, the Single National Entity has given priority to developing new data sources. Since 2008, its focus has been especially on a) improving existing data sources and safeguarding their availability for the long term, and b) maintaining the **institutionalisation of the National System**. Furthermore, institutions that need to be integrated within the *National System* have been identified and are now being successively integrated (cf. Chapter 1.2.1.4). In the years 2014 – 2016, its work focused especially on implementation of provisions under the second commitment periodof the Kyoto Protocol, and of the Revised UNFCCC Reporting Guidelines, in reporting and in the National System. Other important work has had to do with implementing the Quality System for Emissions Inventories (cf. Chapter 1.2.2).

The Single National Entity has developed two key **instruments** for carrying out those tasks:

The Federal Environment Agency's *Central System on Emissions* (CSE) database is the national, central database for emissions calculation and reporting. It is used for central storage of all information required for emissions calculation (methods, activity data, emission factors). The CSE is the main instrument for documentation and quality assurance at the data level.

Both within and outside of the Federal Environment Agency, the Quality System for Emissions Inventories (QSE) provides the necessary framework for good inventory practice and for routine quality assurance. Established within the Federal Environment Agency in 2005 via in-house directive 11/2005, it comprises the processes necessary for continually improving the quality of greenhouse-gas-emissions inventories. The framework it provides includes defined responsibilities and quality objectives relative to methods selection, data collection, calculation of emissions and relevant uncertainties and recording of completed quality checks and their results (confirmation that objectives were reached, or, where objectives were not reached, listing of the measures planned for future improvement). Ongoing quality improvement in the framework of the QSE is supported by a database that serves as the repository for all tabular documents emerging from the national QC/QA process (QC/QA plan, checklists, lists of responsibilities, etc.).

The quality control procedures have been developed with the help of external experts, taking special account of the Federal Environment Agency's work structures, general guidelines for quality assurance and the *IPCC Good Practice Guidance*. For the second commitment period, the quality control procedures have been brought into line with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Since 2008, the QSE has been expanded to cover the entire National System. This has occurred via integration of additional authorities, institutions and inventory experts in the quality-management process – via specification of minimum requirements for data documentation, QC/QA and archiving. In addition, the procedure is designed to enable other organisations to develop their own internal quality assurance systems on the basis of their existing structures. The QSE is described in detail in Chapter 1.3.3.

1.2.1.3 Working Group on Emissions Inventories, in the Federal Environment Agency

In its inventory work, and especially in work relative to emission factors, the Single National Entity receives significant support from other working units of the Federal Environment Agency, as well as from the Thünen institutes involved in preparation of the inventory. In addition, associations, companies and other independent organisations are integrated within the National System, for purposes of data provision, primarily via the Federal Environment Agency's specialised units that are responsible for the specific issues involved in each case.

In 2003, a *Working Group on Emissions Inventories* was set up to co-ordinate relevant work within the Federal Environment Agency; since then, it has liaised with all of the experts who are involved in inventory preparation.

The Single National Entity convenes meetings of the working group at least once a year. In addition, relevant members of the working group meet as necessary to discuss specific issues and to make any necessary in-house arrangements.

As necessary, information is provided via events of the working group, via the intranet of the Single National Entity for emissions reporting and via newsletters produced by the Single National Entity on the National System and on the Central System on Emissions (CSE) database (i.e. one for the National System and one for the database).

1.2.1.4 Co-operation by the Single National Entity with other federal institutions and with non-governmental organisations, in the framework of the National System

Via the "National Emissions Reporting System" policy paper of 05 June 2007, the involved ministries defined their responsibilities, relative to the various relevant source and sink categories, for the first commitment period of the Kyoto Protocol.

Furthermore, the relevant resolution sets forth that involved federal ministries are to undertake suitable activities to close data gaps that fall within their areas of responsibility. As necessary, data gaps are to be closed via provision of pertinent data, or via relevant calculations. In some cases, required data may be provided by reliable third parties.

The relevant arrangements are remaining in place during the second commitment period.

For some of the data streams moving to the Single National Entity from other federal institutions, special agreements have been concluded between a) the relevant institution in the case in question and b) the Single National Entity.

With regard to **data provision by the *Federal Statistical Office***, relative to emissions reporting, a legal arrangement was made in 2009, in the framework of the 3rd SME Relief Act (Mittelstandsentlastungsgesetz 3; MEG 3), that enables provision of data, from confidential energy, environmental and production statistics, for purposes of emissions reporting. On that basis, on 13 January 2010 an administrative agreement between the Federal Environment Agency and the *Federal Statistical Office* came into force that specifies data deliveries for emissions-reporting purposes. The agreement provides for annual reviews of the Federal Environment Agency's data requirements. In addition, a process of close direct exchanges between the Single National Entity and the Federal Statistical Office, regarding issues of emissions reporting, has been institutionalised.

The "National Emissions Reporting System" policy paper assigns responsibility for the areas of agriculture and LULUCF to the Federal Ministry of Food and Agriculture (BMEL). The BMEL has commissioned its subordinate departments to carry out the tasks necessary for emissions reporting. That commissioning took place via a directive of 29 July 2007 to the (then) Federal Agricultural Research Centre (FAL). As a result of a restructuring of the FAL as of 1 July 2008, the tasks are now carried out by the **Thünen Institute (TI)**. The relevant work includes all tasks in the agriculture and forestry sectors that are necessary for the preparation of the annual emissions inventories, including the writing of the relevant reports. The TI sends the pertinent data and report to the Single National Entity. With a concept (BMELV, 2016) that names and specifies all pertinent processes and actors, and the actors' roles, the BMEL and TI codified the procedures for preparation of emissions and carbon inventories for source and sink categories 3 and 4 (agriculture and forestry), and for KP-LULUCF (Art. 3.3. and 3.4 KP), and including a quality assurance concept.

In addition, on 13 February 2008, the TI concluded an agreement with the Federal Statistical Office on provision of emissions data on the basis of agricultural statistics. A research and development agreement between the TI and the *Association for Technology and Structures in Agriculture* (KTBL) has been in place since 7 July 2009. That agreement specifies the supporting work that the KTBL is to carry out for emissions reporting.

Furthermore, a working group on emissions reporting has been established within the TI, to serve as liaison to the Single National Entity within the Federal Environment Agency. That working group also has responsibility for planning and QC/QA for categories CRF 3 and CRF 4.

Responsibility for co-ordination of the Working Group on Emissions Reporting lies with the TI's Institute of Climate-Smart Agriculture (AK). Responsibility for reporting on agriculture and LULUC lies with the same institute, while responsibility for reporting on forests pursuant to the Convention and Kyoto Protocol Arts. 3.3 and 3.4 lies with the TI's Institute of Forest Ecosystems. As of the second commitment period of the Kyoto Protocol, the Thünen Institute of Wood Research (TI-HF) has responsibility for reporting on emissions from harvested wood products (HWP).

The working group on emissions reporting at the TI is integrated within the National System via direct (inter-departmental) participation within the Single National Entity's communications structures. The working group at the TI is also part of the working group ist on emissions inventories (Arbeitskreis Emissionsinventare – AKEI) within the Federal Environment Agency, and it is fully integrated within the Single National Entity's Quality System for Emission Inventories (QSE).

At least twice per year, additional co-ordinating meetings take place between the working group at the TI and the Single National Entity, for purposes of co-ordination and information provision – for example, with regard to inventory improvements and research projects.

Involvement of economic associations, companies and other independent organisations is achieved primarily via those departments of Federal Environment Agency divisions I and III that are responsible for pertinent concrete issues. The *Single National Entity* supports the departments in discussion of reporting requirements and in determination of requirements for data-sharing by associations. The data flows are continually reviewed by the Single National Entity and, where necessary, are safeguarded by suitable agreements between the Single National Entity and associations / business enterprises.

The **Working Group on Energy Balances** (AGEB) is contractually obligated, via the Federal Ministry for Economic Affairs and Energy (BMWi), to provide Energy Balances. Use of a co-ordinated schedule ensures that a provisional Energy Balance for the last reported year is prepared on time, and is transmitted to the Federal Environment Agency, by 31 July of each year, for purposes of inventory preparation. An effort is made to transmit the final Energy Balance by 28 February of year x+2. The current agreement ends in spring 2019, and thus a tendering procedure for the project "Preparation of energy balances for the years 2018 through 2020" is currently underway.

In 2008, a sample agreement was prepared for **inclusion of non-governmental agencies within the National System**. That agreement is used to involve stakeholders, under binding terms, within preparation of inventories. The sample agreement is adapted to the various data suppliers' own requirements and needs as is necessary. In July 2009, the Federal Ministry for Economic Affairs and Energy (BMWi) and the Federal Environment Agency concluded an agreement, with the German Chemical Industry Association (VCI) and German producers, on data provision in the categories Ammonia (2.B.1) and Nitric acid (2.B.2). In early summer 2014, that agreement was adapted to the requirements applying under the Revised UNFCCC Reporting Guidelines. In addition, in 2009 agreements on data provision were reached with producers of adipic acid (2.B.3) located in Germany. Furthermore, an association agreement was concluded with the VDD industry association for bitumen paper and bitumen roof sheeting relative to the category Bitumen for roof sheeting (2.D.3.c). Since 2009, data for the aforementioned categories for emissions reporting have been provided on the basis of these agreements. In June 2011, the Single National Entity, acting with the support of the responsible ministry, the Federal Ministry for Economic Affairs and Energy (BMWi), entered into a cooperation agreement with the Wirtschaftsvereinigung Stahl German steel industry association. That agreement had become necessary because the Federal Statistical Office had discontinued its data collection and publication activities for Fachserie 4 Reihe 8.1 (iron and steel statistics) as of 31 December 2009, due to the expiration of the pertinent legal basis (Raw-materials-statistics act (Gesetz zur Neuordnung der Statistiken der Rohstoff- und Produktionswirtschaft einzelner Wirtschaftszweige (Rohstoffstatistikgesetz – RohstoffStatG; Act for reordering of the statistics on raw materials and production in individual economic sectors)). That move had considerably reduced the availability of the bases for calculations in that area, and it created a significant gap in the pertinent data streams. The new cooperation agreement closed that gap. The agreement assures data provision by both member companies of the assocation and by non-member companies. On the other hand, the association did not supply any data for the 2019 inventory. The German Steel Federation (WV Stahl) has informed the UBA, on request, that the data on production and fuel inputs for 2017 cannot be provided until early 2019, since an antitrust-agency review is currently underway.

A relevant voluntary commitment of semiconductor manufacturers with production sites in Germany, a commitment that served as the basis for data provision for category 2.F.6, expired on 31 December 2010. In August 2012, the Single National Entity acted to close the resulting potential data gap by entering into a cooperation agreement, with the Electronic Components and Systems (ECS) division of the German Electrical and Electronic Manufacturers' Association (ZVEI), that is designed to assure long-term provision of data to the Federal Environment Agency for category 2.E.1.

These agreements provide a reliable long-term framework for data provision, and they have had the effect of considerably improving data quality in the relevant categories.

1.2.1.5 Binding schedule in the framework of the National System

The binding schedule for preparation of emissions inventories and of the NIR is announced to all relevant internal and external stakeholders via the Federal Environment Agency's intranet site and via publication within the NIR itself. The following dates can vary by 1-2 days, in keeping with annual calendar varations:

15 May	The Federal Environment Agency's national co-ordinating agency (Single National Entity) requests responsible experts to submit data and report texts
31 July	Delivery of energy data of the Working Group on Energy Balances (AGEB), of statistical data of the Federal Statistical Office and of data provided under agreements with associations and companies, where such data serve as the basis for further calculations
by 1 September	Deliveries of ready-to-use inventory data from the Federal Environment Agency and from external institutions of the NaSE
as of 2 September	Validation / discussion of deliveries by responsible experts and quality managers, taking account of review results
by 1 October	Preparation of CRF time series and of national trend tables; final editing by the Single National Entity within the Federal Environment Agency

6 November	In-house consultations at the Federal Environment Agency
as of 17 November	Final quality assurance by the QSE/CSE/NIR co-ordinator
25 November	Report of the Single National Entity to the BMUB, for commencement of inter-ministerial co-ordination relative to the CRF data and the National Inventory Report
by 20 December	Approval via departmental co-ordination (initiated by the BMUB)
as of 2 January	Final editing by the Federal Environment Agency's national co-ordinating agency (Single National Entity)
15 January	Report (CRF and certain parts of the NIR) goes to the European Commission (in the framework of the CO_2 Monitoring Mechanism) and to the European Environment Agency
15 March	Report (corrected CRF and complete NIR) goes to the European Commission (in the framework of the CO_2 Monitoring Mechanism) and to the European Environment Agency
15 April	Report goes to the FCCC Secretariat
May	Initial check by the FCCC Secretariat
June	Synthesis and assessment report I (by the UN FCCC Secretariat)
August	Synthesis and assessment report II (country-specific; by the UN FCCC Secretariat)
September - October	Inventory review by the UN FCCC Secretariat

1.2.2 Overview of inventory planning

Inventory preparation draws on the expertise of *research institutions*, via execution of research projects in the UFOPLAN (environmental research plan) framework. This takes place via consideration of specific questions and via overarching projects. In each of the UFOPLANs for the 2002-2009 period, the Single National Entity had a global project on *updating emissions-calculation methods*, a framework for initiating measures for continuous inventory improvement. In 2010 and 2011, measures for continuous inventory improvement were financed completely via the budget title for expert services. The Federal Environment Agency promised to provide the Single National Entity with funding, from the budget title for expert services (Title 526 02, Chapter 1605), for short-term contracting for purposes of inventory improvement under the responsibility of the Agency. The funding, provided as of 2005, in the interest of emissions reporting, comes in addition to the research funding available from the UFOPLAN. Since 2012, the Single National Entity has again been able to finance research in the framework of the "ReFoPlan" (new name; old name: UFOPLAN) departmental research plan. In addition, the budget title for expert services remains available for such financing.

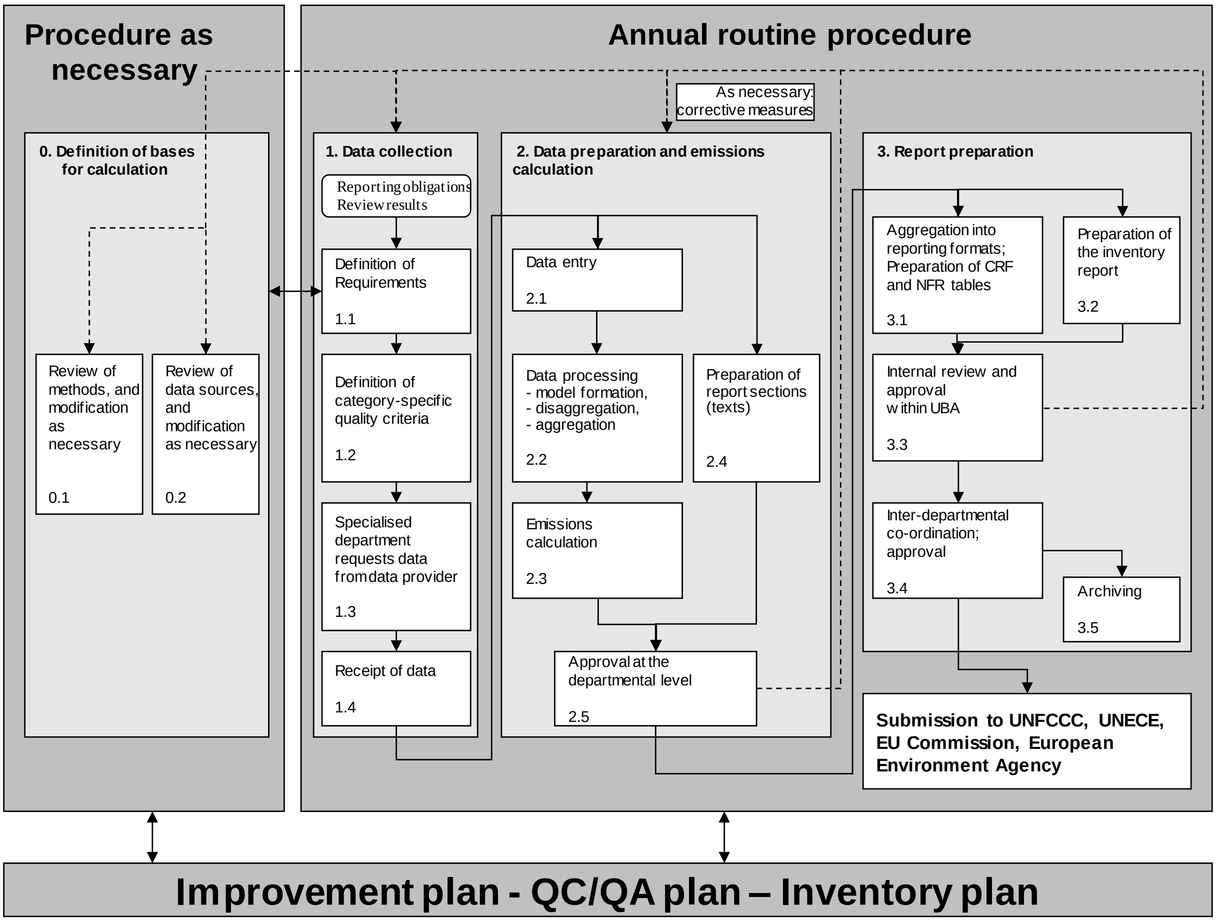
1.2.3 Overview of inventory preparation and management, including overview of supplementary information as required pursuant to Article 7 (1) of the Kyoto Protocol

The emissions-reporting process is a regular, annual process. Since it is a decentralised process, carried out by a range of different persons, it can differ for different parts of the inventory. Prior to the introduction of the QSE (in 2005), this process was intensively studied and analysed. As a result of that work, within the overall emissions-reporting process, the QSE differentiates the following main processes, which are described in detail in Chapter 1.3.2:

- Definition of the bases for calculation,
- Data collection,
- Data processing and emissions calculation, and
- Report preparation.

These main processes are broken down into sub-processes (cf. Figure 5).

Figure 5: Overview of the emissions-reporting process



It has proven to be the case that the workflow sequence chosen for inventory planning and preparation can influence the quality of the inventories. In other words, the sequence in which procedures are carried out is not irrelevant with regard to inventory quality. That is one of the reasons why the inventory-preparation process is closely tied to quality assurance and control measures. Suitable QC/QA measures have thus been assigned to each sub-process, to ensure that quality assurance not only safeguards the quality of inventory data in its final form, but also safeguards such quality on the pathways leading to that final form. This, in turn, makes it possible to carry out periodical internal evaluations of the inventory-preparation process pursuant to paragraph 26 of the *Reporting Guidelines (*24/CP.19).

The process, including QC/QA measures, fulfills the requirements of paragraph 21 (b) of the *Reporting* Guidelines (24/CP.19) with regard to inventory preparation.

The workflow for inventory preparation is described in detail in Chapter 1.3.

1.3 Inventory preparation

As the overview in Chapter 1.2.3 shows, inventory preparation functions in accordance with a regular, annual scheme. The processes for preparation of greenhouse-gas inventories, KP-LULUCF inventories and National Inventory Reports, and for execution of quality control and quality assurance measures, are very closely linked.

At the same time, the upstream processes for inventory preparation (cf. Chapter 1.3.1.1), including definition of bases for calculation (cf. Chapter 1.3.2.1), and data collection, processing and storage (cf. Chapter 1.3.2), remain distinct from those for quality control and quality assurance (cf. Chapter 1.3.3).

1.3.1 Greenhouse-gas and KP-LULUCF inventories

The upstream processes of inventory preparation and definition of the bases for calculation are identical for greenhouse-gas inventories and for KP-LULUCF inventories.

1.3.1.1 Preliminary/upstream processes

Apart from the sub-processes for emissions reporting, as outlined in Figure 5, certain upstream (preliminary) processes are carried out – in each case, between a pair of emissions-reporting cycles.

The following sub-processes are considered preliminary/upstream processes:

- Continuous review and assurance of data streams from data suppliers to the Federal Environment Agency, via improvement of institutionalisation of the National System;
- Implementation of improvements in inventory planning and inventory preparation;
- Identification of key categories (using Approach 1 pursuant to Chapter 4.3.1, Vol. 1 of the IPCC GL 2006);
- Calculation and aggregation of uncertainties relative to emissions, using Monte Carlo simulation (pursuant to Tier 1 or Tier 2, in keeping with the *IPCC Good Practice Guidance*);
- Expanded identification of key categories, via Monte Carlo simulation (using Approach 2 pursuant to Chapter 4.3.2, Vol. 1 of the IPCC GL 2006).

1.3.1.1.1 Improvement of the National System

The National System builds on existing data streams, and it provides for suitable measures to assure long-term data provision where such assurance is lacking (cf. Chapter 0). Consequently, data streams continually have to be reviewed between pairs of reporting cycles.

Where voluntary commitments expire, discussions have to be carried out with the relevant data suppliers in order to secure the commitments' renewal or their conversion into cooperation agreements. Where continued data provision is not assured, relevant commitments or co-operation agreements have to be obtained. In cases of any doubt, relevant legal provisions relative to data provision have to be reviewed and implemented.

Existing agreements have to be adapted as necessary to new circumstances and reporting requirements (for example, to changes in reporting procedures). Such efforts help assure the consistent high quality of the National System and the inventory preparation process.

Changes and improvements in the National System, during the current reporting cycle, are described in Chapter 13.

1.3.1.1.2 Implementation of improvements in inventory planning and inventory preparation

The quality system helps to assure the high quality of the inventory, and it supports the continual improvement of the inventory and of inventory planning.

Whenever possible, the following are implemented between reporting cycles: a) improvement requirements that have emerged from past quality control and quality assurance; b) results of past reviews; and c) planned improvements listed in the NIR.

A detailed description of the quality control and quality assurance procedures is provided in Chapter 1.6. The improvements achieved for the present report are described in the relevant category chapters.

1.3.1.1.3 Determination of key categories (pursuant to Tier 1)

In order to be able to focus the many and detailed activities and capacities required for inventory preparation and improvement on the principal categories of the inventory, the IPCC has introduced the definition of a "key category". Key categories are source/sink categories that play an especially prominent role in the national inventory because their emissions/removals have a significant influence on the total emissions of direct greenhouse gases – because of their absolute quantities, because of their contribution to the emissions trend over time, because of their uncertainties, or because they have been assessed by an expert as an important category.

The Single National Entity identifies key categories once per year, prior to the emissions-reporting process. Whereas in the reporting framework results are reported for year x, they cannot be taken specifically into account until inventory preparation for the year x+1. A category's designation as a key category helps decide what calculation method (Tier approach) must be used for the category and, as a result, how detailed emissions modelling for the category must be. In addition, the key-category selection process is used to identify any categories to which priority must be given in inventory improvement.

The *2000 IPCC Good Practice Guidance* (Vol. 1, Chapter 4) specifies the methods – "Approaches" – to be applied in identifying key categories. These methods identify the relevant key categories with the help of analysis of the inventory for one year with regard to emissions levels for individual categories (Tier 1 level assessment), time-series analysis of inventory data (Tier 1 trend assessment) and detailed analysis of inventory data with error evaluation (Tier 2 level and trend assessment with consideration of uncertainties).

The key categories have been defined by applying the two Approach 1 procedures, Level (for the base year and for the last year reported) and Trend (for the last year reported, as compared to the base year), to German greenhouse-gas emissions. In keeping with IPCC provisions, analyses have taken account of both emissions from sources and removals of greenhouse gases in sinks.

1.3.1.1.4 Calculation and aggregation of uncertainties relative to emissions

Uncertainties are a basic component of emissions inventories; an emissions inventory's uncertainties are determined in order to quantitatively assess the inventory's accuracy. While uncertainties are determined in connection with data gathering, and thus are part of the "data collection" section of the emissions-reporting process, they can be aggregated only after an inventory – or the pertinent emissions-reporting cycle – has been completed.

In calculation and aggregation of uncertainties, uncertainties for activity data and emission factors, which are normally estimated by experts at the lowest category level of the CSE, are converted into uncertainties for emissions and then aggregated. Uncertainties are aggregated once per year, at the end of the report-preparation cycle for the current report year.

For uncertainties determination, the individual uncertainties have been estimated, wherever possible to date, by data-supplying experts of the relevant Federal Environment Agency specialised sections and by external institutions.

1.3.1.1.5 Expanded determination of key categories

Aggregated uncertainties serve as a basis for expanded identification of key categories (Tier 2 key-categories determination).

1.3.2 Data collection, processing and storage, including data for KP-LULUCF inventories

1.3.2.1 Definition of bases for calculation

Selection and review of, and (where necessary) changes in, the calculation methods used to determine emissions affect the entire emissions-reporting process. For this reason, the main process "determination of the bases for calculation" must begin with review of the suitability of the methods to be used. The *2006 IPCC Guidelines* specify, via use of decision trees, what methods are to be used for the various categories. In each case, such methods selection depends on whether the group in question is a key category or not. Any use of different – country-specific – methods, instead of the prescribed methods, must be justified in the NIR. In each case, an outline of why the method in question is of equivalent or higher value is to be provided, along with clear documentation.

Another factor that is critical to the success of the overall process is **selection and review of, and (where necessary) changes in, data sources**, since the quality of results of all downstream processes (data preparation, calculation, reporting) cannot be better than that of the primary data used. Data sources may be oriented to the activity data, emission factors or emissions for/of a specific category. In many cases, the data sources used have been relied on for a number of years. It can become necessary to select new data sources – for example, as a result of required changes in methods, of the elimination of an existing data source, of a need for additional data or of findings from quality checks of previously used data sources.

The suitability of a given data source depends on various criteria. These include:

- Long-term availability,
- Institutionalisation of data provision,
- Good documentation,
- Execution of quality assurance and control measures, by the persons/organisations providing data,
- Identification of uncertainties,
- Representative nature of the data in question, and
- Completeness of the expected data.

In each case, it is vital that the reasons for choosing a particular data source be documented and, where the data source has significant deficits, that suitable measures for improving the data be planned.

Providers of data must always be given requirements relative to quality control, quality assurance and documentation; where research projects are commissioned, this requirement is particularly relevant, since the Federal Environment Agency, as the customer for such services, must be able to influence such projects.

1.3.2.2 Data collection

Data collection and documentation take place under the responsibility of the relevant experts. One way of collecting data is to evaluate official statistics, association statistics, studies, periodicals and third-party research projects. Other ways of obtaining data include carrying out own research projects, applying personally available information and exchanging data via relevant Federal/Länder channels. Often, work results obtained by other means are also reused for the purposes of emissions reporting.

Data collection comprises the following steps:

- Definition of requirements,
- Determination of the category-specific quality criteria for the data,

- Requesting of data from data providers (carried out by the relevant experts' group), and
- Receipt of data.

In each case, the National Single Entity (national co-ordinating agency) also requests inventory input from the experts responsible for the category in question, via the experts' superiors. A master file, specifying the structure for such input, is provided for NIR preparation. The requirements for later data input are provided by the relevant CSE (ZSE) specifications (direct entry or fill-in of the import format). Reporting requirements (including pertinent QC/QA measures), along with the results of all inventory reviews, the databases for the various specific categories and the current results of key-category identification, are all communicated to the responsible experts via informational events held by the *Federal Environment Agency's Working Group on Emissions Inventories*, via the Federal Environment Agency's intranet and share-point sites for emissions reporting and via an electronic inventory description (cf. Chapter 1.3.3.1.5). On this basis, responsible experts **define requirements** relative to data sources and to calculation methods.

Such requirements influence the upstream process of defining the bases for calculation (review and selection of methods and data sources) – a process which always takes place when requirements have not yet been fulfilled or have changed.

Before any third parties begin with data collection – after the requirements pertaining to data sources and methods have been defined – the **category-specific quality criteria for such third-party data should be defined**, in order to support the QC process on the data level.

When a responsible expert **requests data** from a third party able to supply data, the expert is expected to accompany his or her request with a description of the amount of data expected from the prospective data supplier, of the relevant data-quality requirements and of the relevant data-documentation requirements. Upon **receipt of data**, the data are checked for completeness, compliance with quality criteria and currentness. Data validation is carried out by the relevant expert.

1.3.2.3 Data preparation and emissions calculation

The process of data preparation and emissions calculation comprises the following steps:

- Data entry,
- Data preparation (model formation, disaggregation, aggregation)
- Calculation of emissions,
- Preparation of report sections (texts), and
- Approval by the relevant experts.

Report texts are prepared along with the time series for activity data, emission factors, uncertainties and emissions. As a result, the term "data" is understood in a broad sense. In addition to number data, time series, etc., it also includes contextual information such as the sources for time series, and descriptions of calculation methods, and it also refers to **preparation of report sections** for the NIR and documentation of recalculations.

Large shares of **data entry and processing** (processing of data, and emissions calculation) take place in the CSE. This considerably enhances transparency and consistency, and it opens up the possibility of automating required data-level quality-control measures in the CSE (such as checking of orders of magnitude and of completeness, and specification of checking parameters in CalQlator). In cases that lend themselves to such automation, certain QC measures then do not have to be carried out manually. At the same time, plausibility cross-checks, with simplified assumptions, should be applied to results of calculations with complex models.

After all checks have been carried out, and the relevant parties have been consulted where necessary, the **emissions are calculated** in the CSE by means of an automated procedure, based on the following principle:

activity data * emission factor = emission

If upstream calculation routes are also stored in the CSE, these calculations are initiated first, before the actual calculation of emissions takes place.

In each case, the relevant expert responsible for QC also has responsibility for **issuing expert-level approvals**, for written texts and for calculation results, prior to any further use of such texts and results by the Single National Entity. Such issuance normally takes place in connection with transmission to the Single National Entity, and it is carried out via approval of completed QC/QA checklists.

1.3.2.4 Report preparation

Report preparation includes the following steps:

- Aggregation of emissions data for the national trend tables and reporting formats, preparation of data tables for the NFR, export / import of XML files into the CRF reporter,
- Compilation of submitted report texts to form a report draft (NIR), and editing of the complete NIR,
- Internal review of the draft (national trend tables and NIR) by the Federal Environment Agency, followed by approval as appropriate,
- Handover to the BMUB, for interdepartmental co-ordination, leading to approval by the co-ordinating committee, followed by the final steps of
- Handover to the UNFCCC Secretariat, the EU Commission and the UNECE Secretariat, and
- archiving.

Following complete preparation of data, **report sections** and QC/QA checklists by the responsible experts, and transmission of those materials to the Single National Entity, the materials are reviewed by category-specific, specialised contact persons at the Single National Entity, on the basis of a QC checklist. The results of this review are then provided to the relevant responsible experts, to enable these experts to revise their contributions (if necessary, following suitable consultation) accordingly.

Before emissions data can be transferred into the report formats for the Framework Convention on Climate Change (CRF = Common Reporting Format), the Kyoto Protocol and the UN ECE Geneva Convention on Long-range Transboundary Air Pollution (NFR = New Format on Reporting), emissions data from CSE time series (in the data-collection format) **must be aggregated** into the CRF/NFR category **report formats**. This is accomplished via hierarchical allocation within the CSE, a process that, in Annex 3, is described in detail for the various key categories. Where no changes with respect to the previous year have occurred, the aggregations are carried out automatically.

Following calculatory aggregation, activity data and emissions are read, via export in XML-file form, into the CRF reporter, which automatically prepares the IPCC CRF reporting tables. Nonetheless, quality control still has to be carried out to ensure that the emissions inventory and the CRF-Reporter tables agree with respect to relevant values and to the implied emission factors calculated by the CRF Reporter. Furthermore, suitable explanatory remarks have to be provided for any recalculations and notation keys.

Calculation of greenhouse gases in CO_2 equivalents is carried out in keeping with Art. 2 of Decision 24/CP.19 and of Art. 31 of the Revised UNFCCC Reporting Guidelines (FCCC/CP/2013/10/Add. 3), on the basis of the relevant global warming potentials (GWP), as published in the *Fourth Assessment Report*. The GWP, which are oriented to greenhouse gases' impacts within a 100-year time frame, are listed in the following table.

Table 3: Global Warming Potential (GWP) of greenhouse gases

Greenhouse gas	Chemical formula	IPCC AR4 GWP
Carbon dioxide	CO_2	1
Methane	CH_4	25
Nitrous oxide	N_2O	298
Hydrofluorocarbons (HFC)		
HFC-23	CHF_3	14800
HFC-32	CH_2F_2	675
HFC-41	CH_3F	92
HFC-43-10mee	$CF_3CF_2CHFCHFCF_3$	1640
HFC-125	CHF_2CF_3	3500
HFC-134	CHF_2CHF_2	1100
HFC-134a	CH_2FCF_3	1430
HFC-143	CHF_2CH_2F	353
HFC-143a	CF_3CH_3	4470
HFC-152	CH_2FCH_2F	53
HFC-152a	CH_3CHF_2	124
HFC-161	CH_3CH_2F	12
HFC-227ea	CF_3CHFCF_3	3220
HFC-236cb	$CH_2FCF_2CF_3$	1340
HFC-236ea	CHF_2CHFCF_3	1370
HFC-236fa	$CF_3CH_2CF_3$	9810
HFC-245ca	$CHF_2CF_2CH_2F$	693
HFC-245fa	$CHF_2CH_2CF_3$	1030
HFC-365mfc	$CH_3CF_2CH_2CF_3$	794
Perfluorocarbons (PFC)		
Perfluoromethane	CF_4	7390
Perfluoroethane	C_2F_6	12200
Perfluoropropane	C_3F_8	8830
Perfluorocyclopropane	$c\text{-}C_3F_6$	17340
Perfluorobutane	C_4F_{10}	8860
Perfluorocyclobutane	$c\text{-}C_4F_8$	10300
Perfluoropentane	C_5F_{12}	9160
Perfluorohexane	C_6F_{14}	9300
Perfluorodecalin	$C_{10}F_{18}$	7500
Sulphur hexafluoride		
Sulphur hexafluoride	SF_6	22800
Nitrogen trifluoride		
Nitrogen trifluoride	NF_3	17200
Fluorinated ethers		
HFE-125	CHF_2OCF_3	*14900*
HFE-134	CHF_2OCHF_2	*6320*
HFE-143a	CH_3OCF_3	*756*
HFE-227ea	$CF_3CHFOCF_3$	*1540*
HCFE-235da2	$CHF_2OCHClCF_3$	*350*
HFE-236ca12	$CHF_2OCF_2OCHF_2$	*2800*
HFE-236ea2	$CHF_2OCHFCF_3$	*989*
HFE-236fa	$CF_3CH_2OCF_3$	*487*
HFE-245cb2	$CH_3OCF_2CF_3$	*708*
HFE-245fa1	$CHF_2CH_2OCF_3$	*286*

Greenhouse gas	Chemical formula	IPCC AR4 GWP
HFE-245fa2	*$CHF_2OCH_2CF_3$*	*659*
HFE-254cb2	*$CH_3OCF_2CHF_2$*	*359*
HFE-263fb2	*$CF_3CH_2OCH_3$*	*11*
HFE-329mcc2	*$CHF_2CF_2OCF_2CF_3$*	*919*
HFE-338mcf2	*$CF_3CH_2OCF_2CF_3$*	*552*
HFE-338mmz1	*$(CF_3)_2CHOCHF_2$*	*380*
HFE-338pcc13	*$CHF_2OCF_2CF_2OCHF_2$*	*1500*
HFE-347mcc3	*$CH_3OCF_2CF_2CF_3$*	*575*
HFE-347mcf2	*$CHF_2CH_2OCF_2CF_3$*	*374*
HFE-347mmy1	*$(CF_3)_2CFOCH_3$*	*343*
HFE-347pcf2	*$CHF_2CF_2OCH_2CF_3$*	*580*
HFE-356mec3	*$CH_3OCF_2CHFCF_3$*	*101*
HFE-356mmz1	*$(CF_3)_2CHOCH_3$*	*27*
HFE-356pcc3	*$CH_3OCF_2CF_2CHF_2$*	*110*
HFE-356pcf2	*$CHF_2CH_2OCF_2CHF_2$*	*265*
HFE-356pcf3	*$CHF_2OCH_2CF_2CHF_2$*	*502*
HFE-365mcf3	*$CF_3CF_2CH_2OCH_3$*	*11*
HFE-374pc2	*$CHF_2CF_2OCH_2CH_3$*	*557*
HFE-449sl	*$C_4F_9OCH_3$*	*297*
HFE-569sf2	*$C_4F_9OC_2H_5$*	*59*
HFE-43-10pccc124	*$CHF_2OCF_2OC_2F_4OCHF_2$*	*1870*
	$CF_3CF_2CH_2OH$	*42*
	$(CF_3)_2CHOH$	*195*
	$-(CF_2)_4CH(OH)-$	*73*
Perfluoropolyethers		
PFPMIE	*$CF_3OCF(CF_3)CF_2OCF_2OCF_3$*	*10300*

Source: FCCC/CP/2013/10/Add. 3, p.24

At the same time, the report co-ordinator **compiles the checked report texts to produce the draft** of the NIR.

Review and approval, **within the Federal Environment Agency**, of the completed report tables and the NIR, and of the inventory plan to be included in future, are certified via co-signing in the framework of the Federal Environment Agency's **internal co-ordination process**. Then, the materials are **forwarded** to the BMUB, for the second approval phase within the framework of **interdepartmental co-ordination**. In a concluding step, the co-ordinating committee approves the report tables and the NIR for submission to the UNFCCC Secretariat. The ministry arranges for translation of the NIR and for its **submission to the UNFCCC Secretariat**.

The data tables and the pertinent NIR are archived in secure form in the inventory description (cf. also Chapter 1.3.3.1.5). The content of the CSE database used for calculation purposes is also archived.

1.3.3 Procedures for quality assurance and quality control (QA/QC), and detailed review of greenhouse-gas and KP-LULUCF inventories

1.3.3.1 The Quality System for Emissions Inventories

The QSE takes account of provisions of the *2006 IPCC Guidelines (Vol. 1, Chapter 6)*, of national circumstances in Germany and of the internal structures and procedures of the Federal Environment Agency (UBA), the reporting institution. The QSE's procedures are flexible enough to be able to routinely incorporate future changes in requirements. The QSE's scope of application comprises the entire emissions-reporting process.

The QSE covers all participants of the NaSE. Within the Federal Environment Agency, the QSE has been made binding via the agency's in-house directive (UBA-Hausanordnung) 11/2005. Details regarding assurance of the QSE's binding nature for other NaSE participants are provided in Annex 22.1.1.

1.3.3.1.1 Directive 11/2005 of the Federal Environment Agency

In 2005, via its *in-house directive (Hausanordnung) 11/2005*, the Federal Environment Agency established a *Quality System for Emissions Inventories* (QSE), within the Agency. The QSE provides the necessary framework for compliance with good inventory practice and for execution of routine quality assurance. The QSE conforms to the provisions of the *2006 IPCC Guidelines (Vol. 1, Chapter 6)*, and it has been adapted to the national circumstances prevailing in Germany and to the internal structures and procedures of the Federal Environment Agency (UBA), the reporting institution. The in-house directive (Hausanordnung 11/2005) issues binding provisions on relevant competencies within the Agency, lists deadlines for the various inventory-preparation steps and describes the necessary relevant review actions for purposes of quality control / quality assurance.

The directive has fulfilled requirements, pursuant to Paragraph 20 of the *Reporting Guidelines* (24/CP.19), for specification of relevant procedures and, pursuant to Paragraph 23 (a), for definition of specific responsibilities at the Agency level.

1.3.3.1.2 Minimum requirements pertaining to a system for quality control and assurance

The requirements pertaining to the system for quality control and quality assurance (QC/QA system) and to measures for quality control and quality assurance are defined primarily by Chapter 6 of the *2006 IPCC Guidelines (Vol. 1)*.

In 2007, the Federal Environment Agency derived General minimum requirements pertaining to a quality control and quality assurance system for GHG-emissions reporting" ("Allgemeine Mindestanforderungen an die Qualitätskontrolle und Qualitätssicherung bei der Treibhausgasemissionsberichterstattung") from the previously applicable Good Practice Guidance (Chapter 8) (cf. Chapter 22.1.2.1). External National System participants then adopted the minimum requirements after representatives of the participating federal ministries approved them in the framework of the National Co-ordinating Committee for the National System of Emissions Inventories (cf. Annex Chapter 22.1.1).

Further information regarding the Federal Environment Agency's necessary organisational measures for implementing these requirements is provided in the following chapters and in a complementary section in the Annex, 22.1.2.1.11.

1.3.3.1.3 Start-up organisation for establishing the Quality System for Emissions Inventories

Within the QSE framework, a concept for a start-up organisation was developed that defines binding responsibilities, for the Federal Environment Agency, for implementation of the necessary QC and QA measures. The defined roles and responsibilities have the purpose of facilitating effective information exchange and directive-conformal execution of QC and QA (cf. Table 4).

Table 4: QSE – Roles and responsibilities

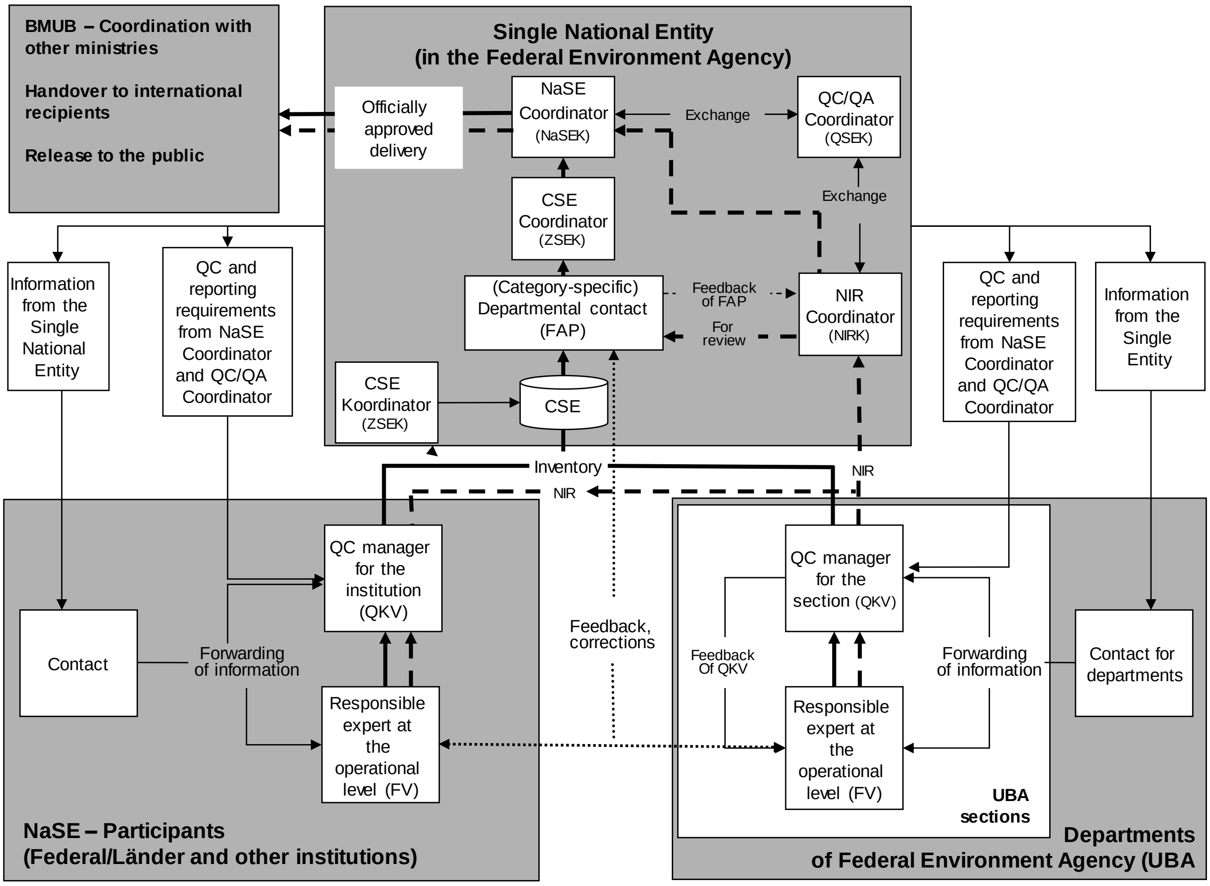
Role	Task	Responsible
Responsible expert at the operational level (FV)	Preparation of parts of the National Inventory Report (NIR) Data collection and data entry in the CSE, and calculation in keeping with the selected//prescribed methods Execution of systematic QC measures in the NIR, CSE and inventory description Execution of verification measures Archiving of all category-specific inventory information (inventory description and decentralised documentation) If necessary (for category-specific QC): Definition of category-specific quality targets and of the criteria for their achievement, in consultation with the QC section representative, the specialised contact person and the QC/QA co-ordinator (QSEK). Review, processing and answering of review results Active participation in review processes. This includes giving presentations, providing explanations and being available for questions (before and during the process, and in any follow-up). Initiating and developing (preparing specifications) R&D projects, and providing specialised support	All staff appointed by the head (FGL), on a category-specific basis
QC/QA section representative (QKV)	Execution of systematic measures for assuring the quality of the data and report sections delivered to the Single National Entity Checking and approving data and report sections Ensuring that the necessary inventory work, quality controls, documentation and archiving are carried out Defining responsibilities relative to emissions reporting in specialised fields, and provision of the necessary time resources Providing support for review processes, and participating in them	All responsible heads (Federal Government and the Länder)
Specialised contact person (category-specific) in the SNE (FAP)	Category-specific support for responsible experts (FV) and QC/QA section representatives (QKV); support/guidance of FV/QKV in: • Implementation of international requirements • Supporting work involving data and report texts • Quality control / quality assurance ○ Preparation of lacking parts of the National Inventory Report (NIR) ○ Collection of any data lacking in the CSE, entry of such data into the CSE and carrying out of calculations in keeping with the selected/prescribed methods ○ Ensuring that the necessary inventory work, quality controls, documentation and archiving are carried out ○ Execution of systematic QC/QA measures in the NIR, CSE and inventory description ○ Archiving of any lacking category-specific inventory information (inventory description and decentralised documentation) Initiating and supporting R&D projects Execution of all work using the CRF reporter, and execution of quality control Assumption of tasks of unavailable responsible experts (FV) and of positions that have not been filled Review, processing and answering (as necessary) of review results Support, participation in and execution of (as necessary) FV tasks in connection with review processes Execution of overarching work (affecting more than one category) If necessary (for category-specific QC): Definition of category-specific quality objectives and of the criteria for their achievement, in consultation with the QC section representative, the specialised contact person (FAP) and the QC/QA co-ordinator (QSEK).	Staff of the Single National Entity (SNE) that are appointed on a category-specific basis

Role	Task	Responsible
Report co-ordinator (NIRK)	Coordination of text contributions Compilation of the NIR, from the various contributions Overarching QC and QA for the NIR and, some cross-checking with the CRF	An appointed staff member of the Single National Entity (SNE)
CSE co-ordinator (ZSEK)	Overarching QC and QA in connection data entry and calculations for the inventory (data) Assuring the integrity of databases and report tables (Common Reporting Format (CRF)) Emissions reporting and data aggregation into report formats Supporting specialised departments in connection with questions relating to the Central System of Emissions (CSE) and to the report tables Determination of uncertainties (Tier 2), using Monte Carlo simulation	An appointed staff member of the Single National Entity (SNE)
QSE coordinator (QSEK)	Overarching QC and QA throughout the entire reporting process Maintenance and further development of the QSE Management and updating of the QC and QA plans, QC checklists and QSE manual Management for the administration and updating of the inventory plan and of the improvement plan If necessary (for category-specific QC): Definition of category-specific quality objectives and of the criteria for their achievement, in consultation with the responsible expert at the operational level (FV), the QC section representative and the specialised contact person (FAP)	An appointed staff member of the Single National Entity (SNE)
NaSE co-ordinator (NaSEK)	Ensuring of on-time, requirements-conformal reporting Initiation of overarching measures from the inventory plan Selection of institutions and collection of relevant informational materials and legal agreements Organisation of expert-peer reviews – for example, in the framework of NaSE workshops Ensuring that all relevant inventory information in addition to that archived in the inventory description is centrally archived Preparation of execution and post-processing of inventory reviews	An appointed staff member of the Single National Entity (SNE)

1.3.3.1.4 The process organisation of the Quality System for Emissions Inventories

Procedures for QC/QA measures in the QSE are oriented to the emissions-reporting process described in Chapter 1.2.3. At the same time, quality management is directly linked with the various steps in the inventory process. Suitable QC measures, assigned to the various process players, have been allocated to each step of the inventory-preparation process (cf. Figure 6).

Figure 6: QSE – Roles, responsibilities and workflow

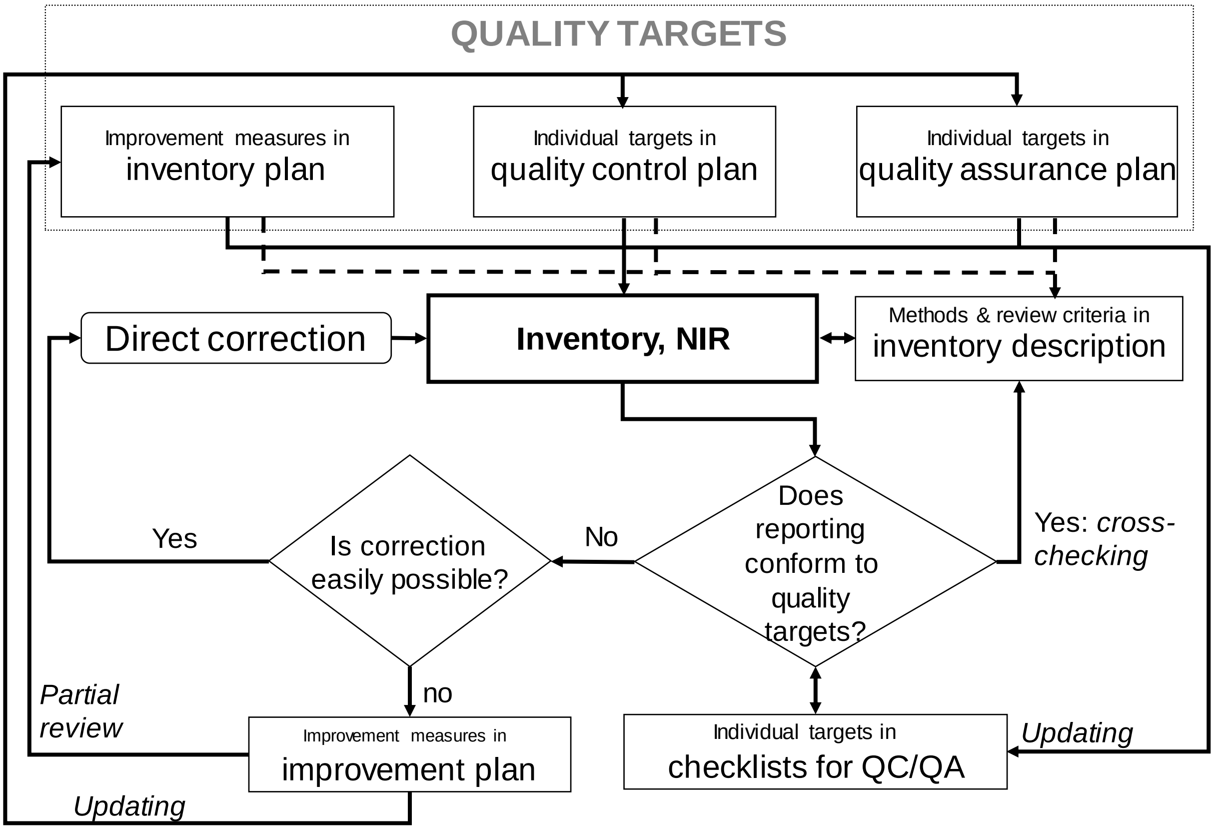


The required quality reviews pursuant to Paragraph 25 (f) of the *Reporting* Guidelines (24/CP.19) are provided, in the form of quality checklists and along with data requirements, to the FV, QKV, FAP and NIRK (cf. Table 4). They are completed in the course of the relevant supporting work.

1.3.3.1.5 Documentation in the Quality System for Emissions Inventories

The requirements pertaining to the execution, description and documentation of QC/QA measures, as formulated in connection with the minimum requirements for a QC/QA system (cf. Chapter 22.1.2.1), are largely fulfilled in conjunction with production of the pertinent inventory contributions. For the QSE, a documentation concept was developed that represents all such measures and related actions in an integrated form tailoured to the specific parties and tasks concerned. The various components of such documentation are shown in Figure 7.

Figure 7: Control and documentation



A general description of the **quality targets** is provided in the QSE handbook; the description is derived from the *2006 IPCC Guidelines (Vol. 1, Chapter 6)*. In addition, individual operational objectives, relative to quality control and quality assurance, have to be derived for the various categories from comparison of the requirements from the *2006 IPCC Guidelines*, the results of independent inventory review, the improvements required in the NIR framework and assessment of inventory realities.

Pursuant to the *2006 IPCC Guidelines (Vol. 1, Chapter 6)* and Paragraph 19 of the *Reporting* Guidelines (24/CP.19), the necessary QC/QA measures for emissions reporting should be summarised in a QC/QA plan. Such a QC/QA plan is to serve the primary purpose of organising, planning and monitoring such QC/QA measures. To permit transparent, effective control of execution and monitoring of measures for achieving these objectives, the measures are set forth in a **quality control plan (QC plan)** and a **quality assurance plan (QA plan)** with respect to specific roles and specific categories. Quality targets may be focused on the inventory, the reporting process or the QSE itself. In the framework of the quality assurance plan, scheduling of quality-assurance measures is also carried out. Such measures are executed partly by internal staff and mostly by independent, third parties (external). Both plans may be understood as sets of specifications.

As to their structure, the QC and QS plans are combined with the **checklists for quality control and quality assurance**, which are used to review and document successful execution of QC/QA. In this context, quality checks are actually defined not as checks but as quality objectives (data quality objectives pursuant to 2006 IPCC GL, Vol. 1, Chapter 6.5); in each case, either compliance with the objectives must be confirmed or non-compliance must be justified. The QC/QA checklists

have to be completed by the participants in the NaSE[16] in parallel with the inventory preparation process. They facilitate immediate improvements. Where improvements cannot be carried out immediately, they are still useful in providing important information about the quality of the inventory's underlying data, methods and texts. The first time the Federal Environment Agency carried out systematic QC/QA, in the form of checklists, and in co-operation with the NaSE participants, was for the 2006 report. Since then, the checklists for general quality control are filled out every report year, and for all reported categories – i.e. both for key categories and for categories that are not key categories. Since the 2007 report, the checklists have been used in electronic form. Also as of the 2007 report, the general QC checks (formerly, Tier 1 checks) have been expanded to include a number of category-specific QC checks (formerly, Tier 2 checks), for key categories. For the 2008, 2009 and 2010 reports, the checklists for the experts involved in the various specialised areas, and for specialised contact persons, have been comprehensively revised. Such revision has been aimed at further enhancing the clarity, practical usefulness and logical structure of the checklists. To ensure the success of the pertinent improvements, a number of persons from the affected group of persons were selected for inclusion in the revision process. No content-oriented requirements have been modifed as a result. The checklists are reviewed annually for any need for updating, and then they are revised or expanded as necessary. Like the checklists, the QC and QA plan is continually refined. As of the 2013 report, the checklists of the QC/QA section representatives (QKV), which were formerly category-specific, have been consolidated into single overarching checklists for each QKV (i.e. one checklist per QKV). This has been done in order to make the QC/QA process clearer for management personnel and to enhance resource efficiency.
As of the 2015 report, is has been assured that the general checklists meet the revised requirements applying under the 2006 *IPCC Guidelines (Vol.1, Kapitel 6)*. Lacking requirements have been added as necessary.

The two plans and the QC/QA checklists are instruments for reviewing fulfillment of the applicable international requirements, and they make it possible to control inventory quality via initiation of quality assurance measures pursuant to Paragraph 13 of the *Guidelines for National Systems*.

The **improvement plan** documents all potential improvements identified in the framework of the relevant last completed emissions-reporting cycle, as well as the findings that result from independent inventory review. In the plan, such improvements and findings are correlated with feasible corrective measures. The Single National Entity categorises the corrective measures, prioritises them and then, as a rule and via consultations with the relevant responsible experts, integrates them completely within the **inventory plan**. There, they are linked with deadlines and responsibilities. As an annex to the NIR, the inventory plan undergoes a co-ordination and release process. It is thus a binding set of specifications for improvements to be carried out in the coming reporting year.

The Single National Entity also maintains an **inventory description**, a central document record for the various categories. The description covers all key aspects of inventory preparation. It includes descriptions of all work that pertains to specific categories and that is relevant to preparation of category-specific inventories. The inventory description consists of a server-based folder (directory) system that is available both on mobile devices and on the desktops of the persons working in the framework of emissions reporting. The obligation to prepare defined documentation was introduced in the Federal Environment Agency via an in-house directive (cf.

[16] These include responsible experts (FV), specialised contact persons (Fachliche Ansprechpartner – FAP), QC/QA section representatives (QKV – quality control managers) and the coordinator for the national inventory report (Koordinator für den Nationalen Inventar Report – NIRK).

Chapter 1.3.3.1.1). It provides the key basis for archiving inventory information pursuant to the provisions of Paragraph 27 (a) of the *Reporting* Guidelines (24/CP.19).

- For a range of different reasons, the documentation concept calls for an archive that is predominantly, but not exclusively, centralised. The key reasons for this decision included the fact that the body of data that provides the basis for calculating the German inventory is extensive, and non-centralised.
- In addition, external parties hold some of the responsibility for the data,
- and confidentiality criteria preclude, for legal reasons, provision of certain data items, for archiving purposes, to a central agency.

The inventory description contains information as to the locations of documents that are not centrally stored.

1.3.3.1.6 The QSE handbook

The international requirements for quality assurance and quality control measures in emissions reporting have been set forth, for the National System of Emissions Inventories (NaSE) in Germany, in the "Handbook for quality control and quality assurance in preparation of emissions inventories and reporting under the UN Framework Convention on Climate and EU Decision 525/2013/EC" ("Handbuch zur Qualitätskontrolle und Qualitätssicherung bei der Erstellung von Emissionsinventaren und der Berichterstattung unter der Klimarahmenkonvention der Vereinten Nationen sowie der EU Entscheidung 280/2004/EG". That document, which is binding for the Federal Environment Agency, describes the Quality System for Emissions Inventories (QSE).

The QSE handbook has entered into force via an in-house directive of the Federal Environment Agency (cf. Chapter 1.3.3.1.1). It has been published, along with pertinent, co-applicable documents, in the Federal Environment Agency's intranet.

1.3.3.1.7 Support for the UNFCCC review

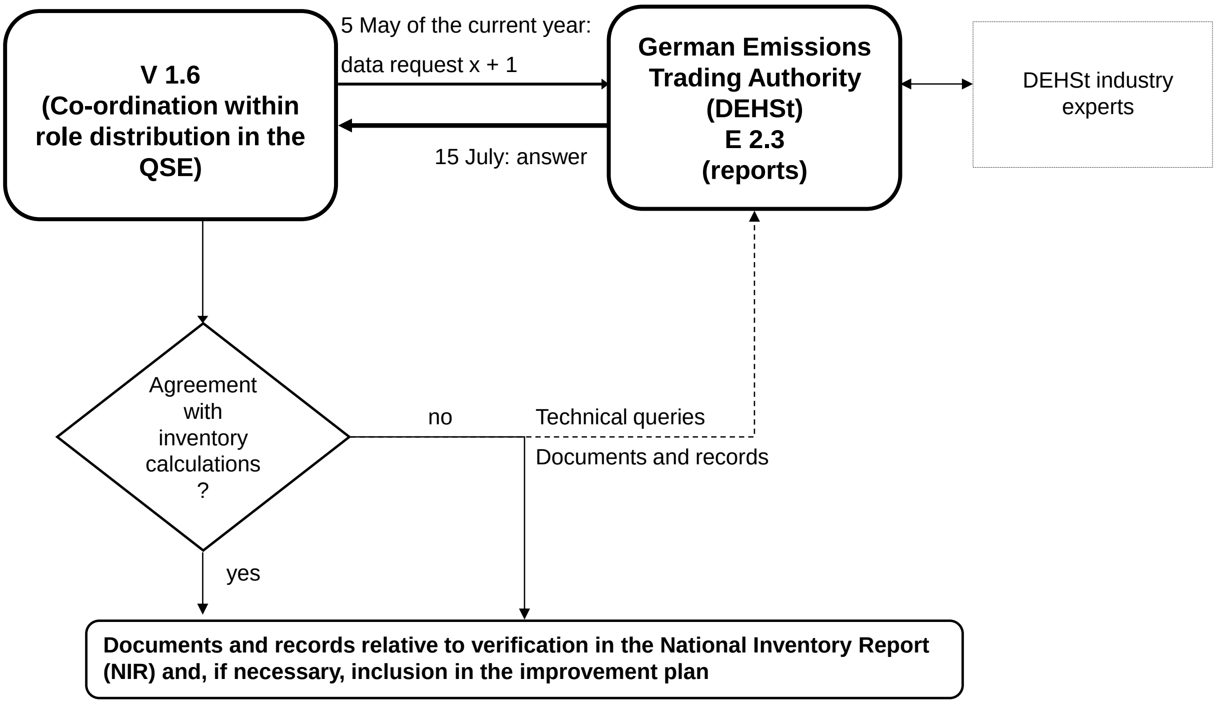
In addition to the Federal Environment Agency's own quality control and assurance measures, the UNFCCC review provides important impetus for inventory improvement. It is thus in the Single National Entity's own interest to fulfil the requirements for provision of archived inventory information for the review process and for responding to questions of expert review groups. This relationship has been given priority in the design of the QSE.

1.3.3.1.8 Use of EU ETS monitoring data for improvement of GHG-emissions inventories

Monitoring data from European emissions trading will be used to improve the quality of annual national emissions inventories with respect to categories that include installations subject to reporting obligations under the CO_2 Emissions Trading Scheme (ETS).

The comparisons have confirmed, in principle, the usefulness of such comparisons for verifying individual categories and identifying data gaps. A formalised procedure, with defined deadlines and workflow, has been agreed for their regular use and for the relevant annual required data exchanges.

Figure 8: Procedural flow for annual inventory verification using ETS monitoring data



Regarding the details of data use in QC/QA, cf. also Chapter 1.6.2.1.

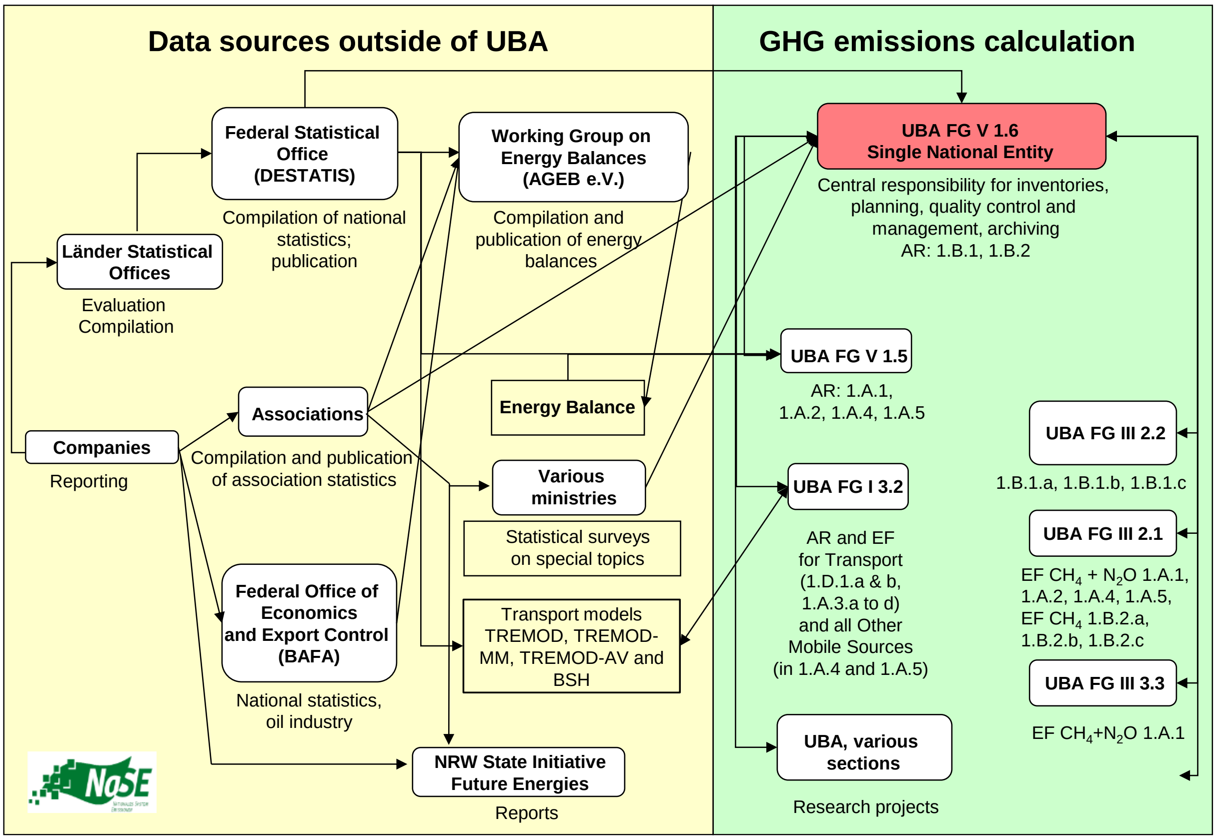
1.4 Short, general description of the methods and data sources used

1.4.1 Greenhouse-gas inventory

1.4.1.1 Data sources

1.4.1.1.1 Energy

Figure 9: Responsibilities and data flows for calculation of greenhouse-gas emissions in the energy sector



The central data sources for determination of activity data for category 1.A are the *"Energy Balances of the Federal Republic of Germany"* ("Energiebilanzen der Bundesrepublik Deutschland"; hereinafter referred to as: Energy Balance), which are published by the *Working Group on Energy Balances* (Arbeitsgemeinschaft Energiebilanzen - AGEB). An Energy Balance provides an overview of the links within Germany's energy sector, and it supports breakdowns in accordance with fuels and categories. The data for Energy Balances come from a wide range of other sources.

In commissioning the Working Group on Energy Balances (AGEB) to prepare the Energy Balances for the period 2007-2012 and then, subsequently, for 2013-17, the Federal Ministry for Economic Affairs and Energy (BMWi) imposed the requirement that the AGEB meet the National System's minimum quality assurance requirements. These requirements are also being imposed in the tendering process, which is currently underway, for a contract for preparation of the energy balances for the period 2018 – 2020. For the Energy Balances of the past few years, quality reports of the German Institute for Economic Research (DIW) and of Energy Environment Forecast Analysis GmbH Co. KG are available that describe relevant measures for quality assurance and quality control. As of 2012, the Working Group on Energy Balances (AGEB) provides a joint quality report for the Energy Balance (cf. Chapter 18.4.1). Also as of 2012, the AGEB prepares an "Energy-Data Action Plan for inventory improvement" ("Aktionsplan Energiedaten Inventarverbesserung"; cf. Chapter 18.4.1.1.1) that outlines actions to be taken to address the criticism that emerged from the inventory review. This action plan fulfills the action-plan requirement set forth in Paragraph 39 of the 2011 review report (FCCC/ARR/2011/DEU).

Along with the main Energy Balance, a *Satellite Balance of Renewable Energies* (Satellitenbilanz Erneuerbare Energieträger; hereinafter referred to as: Satellite Balance) also appears. This balance describes the growth and use of renewable energies in detail. The Satellite Balance appears together with the Energy Balance.

The *Federal Statistical Office (Statistisches Bundesamt) is the most important data source for determination of activity data and for the preparation of Energy Balances. The resources of that office that are used in inventory preparation include* the *Fachserien 4 (technical series 4) Reihe (sub-series) 4.1.1, Reihe 6.4,* and, for waste data, Fachserie 19. These data are published relatively promptly after collection (about one year), and they are broken down finely in accordance with various areas of the manufacturing sector. To support further data differentiation, and clarification of details, the Federal Statistical Office provides special evaluations.

For the iron and steel sector, as of the 2012 report, data of the Wirtschaftsvereinigung Stahl German steel industry association are being used. Inter alia, these data replace the so-called "BGS form" (Fuel, gas and electricity industries of blast furnaces, steelworks and rolling mills; and forging plants, press works and hammer mills, including the various other plants (without their own coking plants) locally connected to such operations), a section of the "Fachserie 4, Reihe 8.1", publication of which was discontinued as of 31 December 2009.

The series *Statistik der Kohlenwirtschaft* ("Coal industry statistics"), especially its annual publication "*Der Kohlenbergbau in der Energiewirtschaft der Bundesrepublik Deutschland*" ("Coal mining in the energy sector of the Federal Republic of Germany"), is used as an additional data source. In addition, the special evaluations provided by the Bundesverband Braunkohle (DEBRIV; federal German association of lignite-producing companies and their affiliated organisations) are used for differentiation of the different types of raw lignite coal that are burned. Furthermore, DEBRIV provides the necessary data for calculation of fuel inputs for lignite drying.

Another data source consists of the *"Petroleum Data" of the Association of the German Petroleum Industry (MWV)*, which include data on petroleum production and consumption in Germany, broken down by various production, transformation and utilisation sectors. These statistical data, which are a key basis for the National Energy Balance, are published within just a few months after the relevant survey and are thus a relatively current source.

The quantities of secondary fuels used for energy generation (listed under CRF 1.A.2) are taken from the annual report of the German Pulp and Paper Association (Verband der Papierindustrie) and from reports of the German Cement Works Association (Verband der Zementindustrie – VDZ).

Another important data source is the Emissions Trading System (ETS). It keeps highly detailed, plant-specific data that are also used for the inventory. Emissions trading data is used especially in areas that are not covered by national statistics:

- fuel-related CO_2 emission factors for stationary combustion systems,
- fuel inputs for natural gas compressors,
- emissions from coke burn-off in catalyst regeneration, and in calcining, in refineries, and
- fugitive emissions in coking plants.

For collection of transport emissions data (1.A.3), *Official Mineral-oil Data* (amtliche Mineralöldaten) of the *Federal Office of Economics and Export Control (BAFA)* and *Petroleum Data* (Mineralöl-Zahlen) of the *Mineralölwirtschaftsverband e.V. Association of the German Petroleum Industry (MWV)* e.V. are used, in addition to Energy Balance data.

For air transports, in addition to the aforementioned sources, the following sources for consumption data are used: The fuel consumption and emissions are broken down in accordance with national and international flights, on the basis of data on real aircraft movements. Those data are collected and made available by the Federal Statistical Office, and then they are processed in the TREMOD AV model, a separate module of the TREMOD ("Transport Emission Estimation Model") database. Fuel consumption and emissions are also broken down in accordance with the flight phases L/TO cycle (Landing and Take Off; movements below an elevation of 3,000 feet) and cruise (movements above 3,000 feet); this is also done on the basis of the aircraft-movement data collected by the Federal Statistical Office.

Country-specific consumption and emissions data provided by Eurocontrol are used solely for verification purposes.

Road-transport emissions are calculated primarily with the TREMOD model. For calculations carried out in TREMOD, extensive basic data from generally accessible statistics and special surveys are used, co-ordinated, and supplemented. A precise description of the data sources for emission factors is provided by the "Handbook of road-traffic emission factors" ("Handbuch Emissionsfaktoren des Straßenverkehrs") (HBEFA, Version 3.2).

TREMOD is also used for modelling emissions from fuel combustion in railway vehicles and inland waterway vessels. The emissions caused by historic steam railways, via combustion of coal and coke, are calculated outside of TREMOD, on the basis of operator information.

The specific consumption and emissions of ship transports departing from German seaports are calculated within a model developed by the Federal Maritime and Hydrographic Agency (BSH). For this area, the breakdown of fuel consumption and emissions in accordance with domestic and international transports is based on data derived, inter alia, from the ships' AIS messages.

Data on emissions of other mobile sources (in 1.A.4 and 1.A.5.b) are also collected from figures of the Working Group on Energy Balances (AGEB), of the Federal Office of Economics and Export Control (BAFA) and of the Association of the German Petroleum Industry (MWV). Military transports (1.A.5.b) have a special status in this regard; the consumption data for such transports, which as of 1995 are no longer listed in the Energy Balances, are obtained directly from BAFA statistics.

Due to a lack of reliable figures on consumption of biofuels by mobile sources in the construction, agricultural and forestry sectors, and by the residential and military sectors, the relevant annual quantities are calculated on the basis of the official admixture quotas.

Data for categories of category 1.B.1 are taken from publications of Statistik der Kohlenwirtschaft e.V. (coal-industry statistics), the Federal Ministry for Economic Affairs and Energy (BMWi), the DEBRIV Federal German association of lignite-producing companies and their affiliated organisations, Deutsche Montan Technologie GmbH (DMT), the German Society for Petroleum and Coal Science and Technology (DGMK) and Interessenverband Grubengas e.V. (IVG; association for the mine-gas sector).

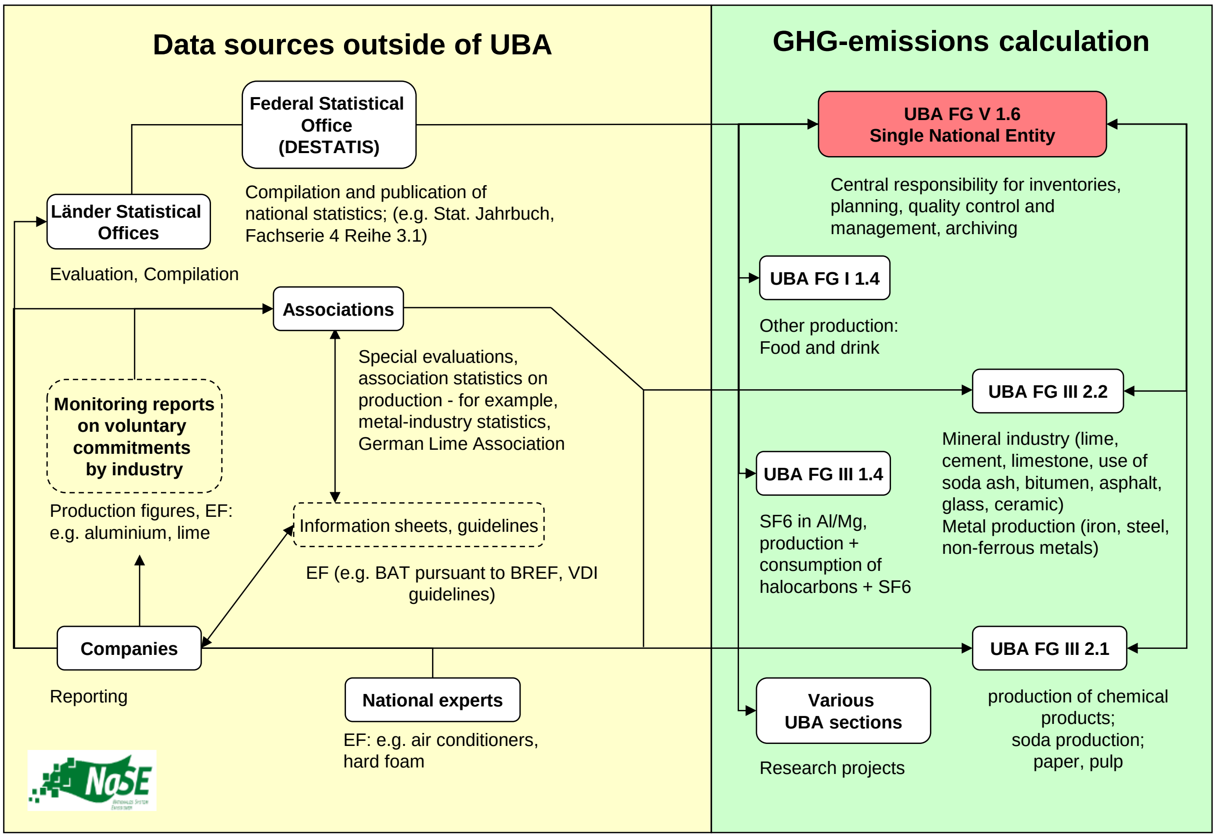
The publication "Statistik der Kohlenwirtschaft" (coal-industry statistics) is especially important in this context. It is processed with the help of federal and Land (state) ministries, including their authorities (such as supreme state mining authorities), and with use of reports and expert opinions of the "Landesinitiative Zukunftsenergien" NRW ("NRW State Initiative for Future Energies"; here, the AG Grubengas mine-gas working group). Inventory preparation is co-ordinated with the support of the Gesamtverband Steinkohle (Association of the German hard-coal mining industry).

Data for categories in category 1.B.2 are taken from publications of the *Federal Statistical Office*, the Association of the German Petroleum Industry (MWV), the German Society for Petroleum and Coal Science and Technology (DGMK), the Federal association of the natural gas, oil and geothermal energy industry (BVEG), the German Technical and Scientific Association for Gas and Water (DVGW), the Federal association of the German gas and water industry (Bundesverband der deutschen Gas- und Wasserwirtschaft – BDEW; gas statistics) and the German Emissions Trading Authority (DEHSt).

1.4.1.1.2 Industrial processes

Activity data for the mineral industry are obtained primarily from association statistics. The data for the cement industry (2.A.1) were provided by the German Cement Works Association (Verband der Zementindustrie – VDZ), especially by that association's research institute, as well as by the Federal association of the German cement industry (Bundesverband der Deutschen Zementindustrie e.V. – BDZ). For the most part, the data in question consist of data published in the framework of CO_2 monitoring under the industry's voluntary climate-protection commitment. The figures for lime and dolomite-lime production (2.A.2) are collected by the German Lime Association (BVK) on a per-plant basis and then provided annually in aggregated form. Glass-production figures (2.A.3) are taken from the regularly published annual reports of the Federal glass industry association (Bundesverband Glasindustrie), although relevant orientational figures on glass recycling are taken from other statistics. Production trends in the ceramics industry (2.A.4.a) are determined via official statistics and via conversion factors provided by experts, in the framework of a project. Figures for soda ash use (2.A.4.b) are obtained via expert assessment carried out by the Federal Environment Agency. .

Figure 10: Responsibilities and data flows for calculation of greenhouse-gas emissions in the area of industrial processes



A range of different sources are used to determine emission factors for the mineral industry. The emission factor used for calculation of emissions from cement-clinker production (2.A.1) is based on a calculation of the German Cement Works Association (VDZ) carried out by aggregating plant-specific data. CO_2 emissions from lime production (2.A.2) and from soda-ash use (2.A.4.b) are calculated with the help of stoichiometric factors. The CO_2-emission factors for various types of glass (2.A.3) have been derived, by responsible experts, from glass-composition data, while CO_2-emission factors for the ceramics industry (2.A.4.a) have been derived, by Federal Environment Agency experts, from analyses of ETS data.

The activity data for category 2.B Chemical industry are determined from data of the *Federal Statistical Office (FS 4, R 3.1)* and directly from figures of industry associations and producers. Some of these data are confidential. The relevant emission factors have been determined by experts in the Federal Environment Agency, via research projects or by the pertinent producers. Until 2008, activity data for 2.B.1 Ammonia production and 2.B.2 Nitric acid production were collected by the *Federal Statistical Office*. Since 2009, data for ammonia and nitric-acid production have been collected by producers themselves – plant-specifically, on the basis of an agreement with the chemical industry and for the entire time series as of 1990. These data are forwarded to the association, which aggregates them and forwards them, in anonymised form, to the Federal Environment Agency. For this purpose, in addition to determining the applicable activity data, the producers also determine the applicable emissions for 2.B.1 and the applicable emission factors for 2.B.2. Until the mid-1990s, plant-by-plant activity data were supplied for 2.B.3 Adipic acid production. The default emission factor for N_2O was applied to that data. Now, plant operators are supplying emissions data directly to the Federal Environment Agency, on a confidential basis. For the area of adipic-acid production, data delivery has also been assured for the long term, via an agreement from 2009. In 2.B.4, only N_2O emissions from caprolactam production play a significant role. Those emissions are below the applicable threshold value, however, and thus are not reported. Since there is only one calcium carbide (2.B.4) producer in Germany, the relevant data are confidential. The Federal Environment Agency obtains these data directly from the producer. The CO_2 emissions from titanium dioxide production are not reported, because they lie below the applicable threshold (2.B.6). The *Federal Statistical Office* determines the total amounts of soda ash (2.B.7) produced in Germany. The pertinent emission factors are derived from the ETS monitoring data of the German Emissions Trading Authority (DEHSt). The activity data for production of the products listed under 2.B.8 Petrochemicals and carbon black production are obtained from statistics of the *Federal Statistical Office*. Some of the data are subject to confidentiality. The emission factors are obtained from experts' estimates, research projects and default figures provided in the IPCC Guidelines. In the area of production of halocarbons and SF_6 (2.B.9), data are obtained from *producers' figures and surveys of producers*. For the most part, activity data are researched in the framework of research projects, directly in accordance with the inventory's requirements. In some cases, producers supply only emissions data. Only small numbers of companies are involved in the various sub- source categories, and thus data in these areas are confidential. Under 2.B.10 Other, emissions of precursor substances from production of sulphuric acid and fertilisers are reported. The activity data are obtained from information provided by producers and from data of the Federal Statistical Office. The emission factors are obtained from experts' estimates and research projects.

The activity data for the metal industry (2.C) are provided by the *Federal Statistical Office,* by the relevant associations (Steel Institute VDEh, Wirtschaftsvereinigung Metalle (metals industry association) and Gesamtverband der Aluminiumindustrie (aluminium industry association) and by sellers of industrial gases. The emission factors for the metals industry (2.C) are normally calculated by experts in the Federal Environment Agency; in some cases, emission factors are provided by industrial associations or IPCC default values are used.

One exception in this regard is the category Ferroalloys; for it, activity data from statistics of the UK Geological Survey are used, while the relevant emission factors are taken from the results of a research project (in some cases, IPCC default values are also used).

In category 2.D Non-energy-related products from fuels and solvents, the activity data have been taken from published surveys of the Federal Statistical Office and of other federal authorities (for production and foreign-trade statistics, and for petroleum statistics) and of relevant associations (the VDD industry association for bitumen paper and bitumen roof sheeting; the German asphalt industry association (Deutscher Asphaltverband – DAV)). The activity data are supplemented with industry statistics and information supplied by experts.

The emission factors have been taken from various sources. For example, those for lubricant and paraffin-wax use have been calculated by the relevant expert unit in the Federal Environment Agency, with the help of IPCC default values. NMVOC emissions from lubricant use have been given only as CO_2 emissions, however, in keeping with the 2006 IPCC Guidelines. The emission factors for production and laying of bitumen paper and bitumen roof sheeting (2.D.3), and for production of asphalt for road paving (2.D.3), refer only to NMVOC, and they have been taken from research reports.

Emission factors, along with other parameters that enter into calculation of emissions from solvent use, are taken from national studies, experts' opinions and research projects directly commissioned by the Federal Environment Agency; in some cases, they are also based on information provided by experts in the context of dialogues with industry.

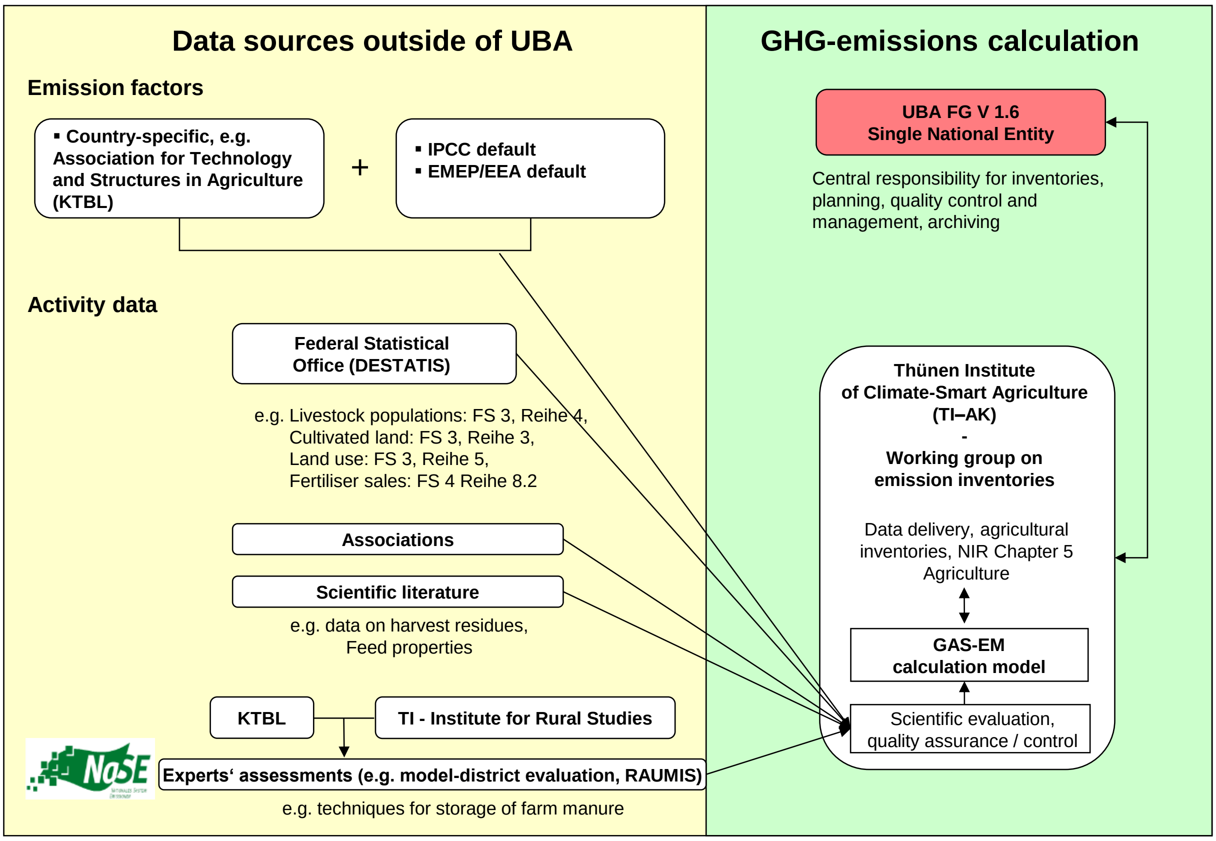
More-detailed pertinent information regarding emission factors is presented in the descriptions of methods for the various categories. The activity data for the electronics industry (2.E), for product use as substitutes for ODS (2.F) and for other product production and use (2.G), have been determined from information provided by producers and associations, from surveys of the Federal Statistical Office and of other federal authorities and with the help of calculation models. In individual cases, producers provide emissions data directly. The data are classified into several subcategories. Product use as ODS substitutes is also subdivided into production, use and disposal emissions. In these categories as well, the data in some areas are subject to confidentiality requirements.

Emission factors for fluorinated greenhouse gases are obtained in part from national and international fact sheets and directives or via surveys of experts; where necessary, IPCC default values are used.

In the area of 2.H.1 Other production: Pulp and paper production, data from the production report of the German Pulp and Paper Association (Verband Deutscher Papierfabriken – VDP) are used. In the area of 2.H.2 Other production: Food and beverages, data of the Federal Food Industry Association (Bundesvereinigung der Deutschen Ernährungsindustrie; BVE), of the Federal Statistical Office (Statistisches Bundesamt) and of the Federal Ministry of Food and Agriculture (BMEL) are used. The emission factors have been obtained from a research project that was completed in 2008.

1.4.1.1.3 Agriculture

Figure 11: Responsibilities and data flows for calculation of greenhouse-gas emissions in the area of agriculture



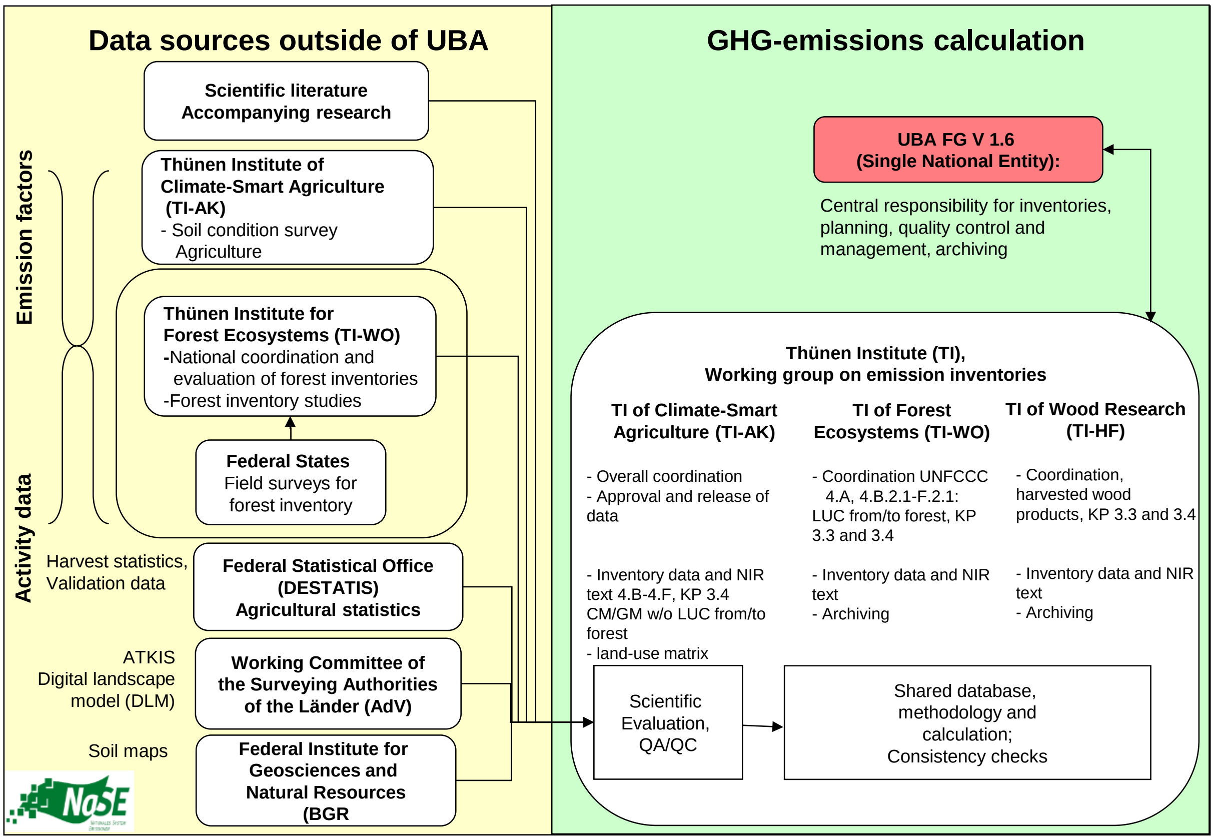
Emissions calculations for category 3 (Agriculture) are carried out by the Thünen Institute (TI). For calculation of agricultural emissions in Germany, the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) and the Federal Ministry of Food and Agriculture (BMEL) initiated a suitable joint project, in the framework of which the former Federal Agricultural Research Institute (FAL) developed a modular model for relevant spread-sheet calculation (GASeous EMissions, GAS-EM) ((Dämmgen et al., 2002) & Rösemann et al. (2019b)).

Agricultural statistics of the Federal Statistical Office are another important data source for calculation of agricultural emissions. Animal statistics have been obtained from Fachserie 3, Reihe 4 of the Federal Statistical Office *(STATISTISCHES BUNDESAMT, FS 3, R 4)*; other Fachserien (technical series) provide data on amounts of fertilizer sold and agricultural land under cultivation . In some areas, such data are supplemented by figures from the pertinent literature (for example, crop residues and fertilizer data). Additional data are available from experts' assessments (for example, an evaluation of model districts with regard to techniques for storing farm fertilisers).

In many areas, calculations for the agriculture sector are based on highly differentiated activity data obtained via national data sources. The activity data are combined, depending on the emission sources involved, either with national emission factors or with the standard emission factors of the 2006 IPCC Guidelines and of the EMEP/EEA guidebook of the United Nations Economic Commission for Europe (UNECE).

1.4.1.1.4 Land-use changes and forestry

Figure 12: Data flows for calculation of greenhouse-gas emissions from the areas of land-use changes and forestry (LULUCF) and KP-LULUCF



In the 2012 Submission, a consistent, unified method was introduced for taking account of land-use changes in the LULUC sector and the forestry sector. The method expands the existing sample-based system for determining forest-land areas, and land-use changes to and from forest land, for all land-use categories and change types.

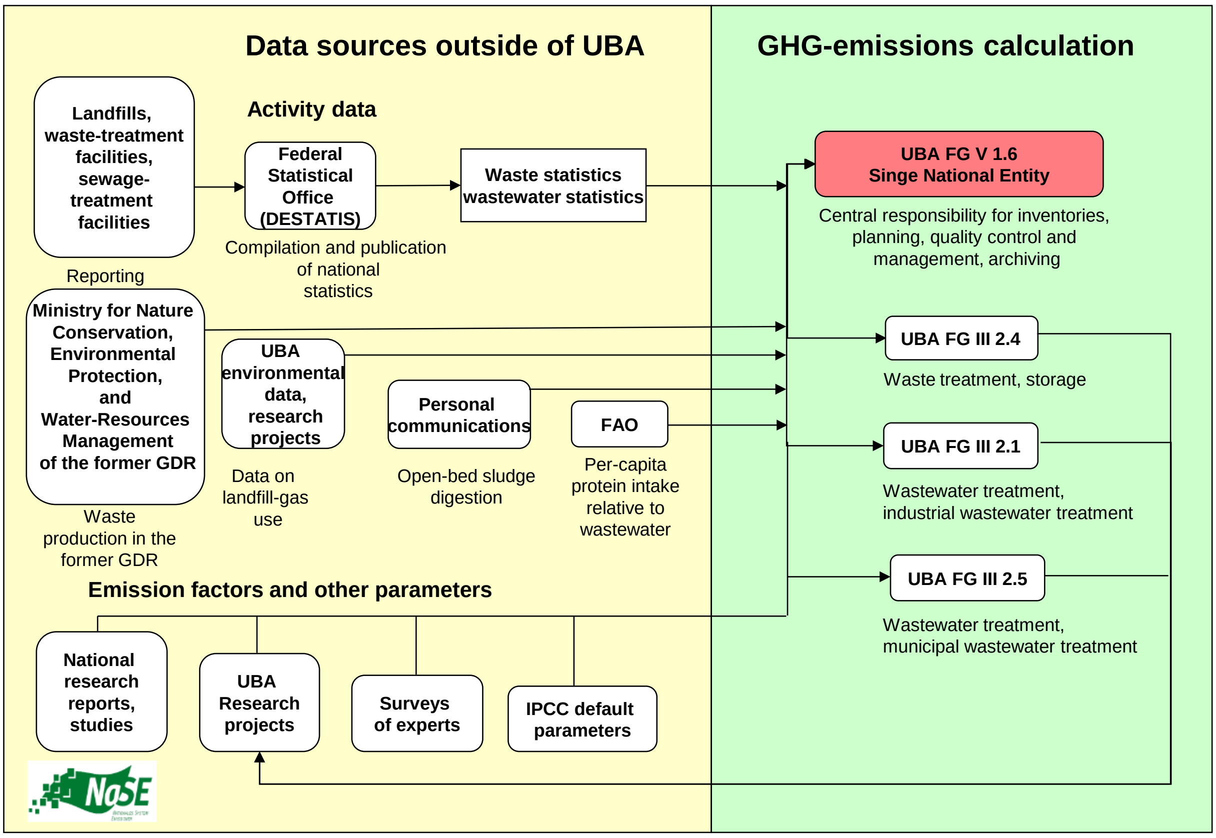
Soil carbon stocks are estimated with the help of soil maps and soil-profile data (both differentiated to show usages), and of data from the Forest Soil Inventory (BZE), while use-change-related changes in these stocks are estimated on the basis of changes in the mean stocks per land-use category.

Changes in biomass carbon stocks are estimated on the basis of harvest statistics, the main survey on soil use (Bodennutzungshaupterhebung), the National Forest Inventory (BWI) and specific factors given in the pertinent scientific literature (and used in conjunction with area data).

Projects for improvement of activity data, and especially for determination of country-specific emission factors for carbon and nitrogen, and for CO_2, CH_4 and N_2O – for example, the project "Organic Soils" (since 2009), the agricultural soil survey (Bodenzustandserhebung Landwirtschaft; since 2011) and others – will help validate and improve national estimates of emissions and removals.

1.4.1.1.5 Waste and wastewater

Figure 13: Data flows for calculation of greenhouse-gas emissions from the area of waste and wastewater



Federal Environment Agency Section FG III 2.4 *Waste technology, waste technology transfer* is responsible for selecting the methods, parameters and data for calculating emissions from the waste sector. In recalculation of landfill emissions in 2003 (development of the Tier 2 method for the Federal Republic of Germany), and in refinement of the Tier 2 method in 2006, the Federal Environment Agency was supported by a research project (ÖKO-INSTITUT, 2004b).

Activity data in the waste sector are drawn mainly from published data of the Federal Statistical Office, which provides detailed, disaggregated time series. The section on waste provides precise information as to what statistical series and sources were used. The Federal Statistical Office has not published any data on amounts of waste produced in the former GDR. In this area, an official source of the former GDR's ministry for nature conservation, environmental protection and water-resources management was used. The calculations relative to landfill-gas use are based on data from the Energy Balances and from Fachserie 19 of the Federal Statistical Office. The database for landfill-gas use was updated in the framework of the 2010 In-Country Review. Statistical data on gas collection at landfills in the follow-on care phase have been collected since 2012.

The emission factors and other parameters that enter into calculation of emissions from waste landfilling, from mechanical-biological waste treatment and from composting were taken from national studies and research reports conducted/prepared in research projects commissioned directly by the Federal Environment Agency. IPCC default parameters were also used for this purpose. Selected experts were also consulted regarding a few of the relevant parameters (for example, half-life selection). The relevant chapter presents the sources for the various parameters, in detail.

The Federal Environment Agency's Section for *General Aspects, Chemical Industry, Combustion Plants* (III 2.1) is responsible for selecting the methods, parameters and data for calculating emissions from the industrial wastewater / sewage sludge handling sector (5.D.2). The Federal Environment Agency's Section III 2.5 *Monitoring Methods, Waste Water Management* is responsible for selecting the methods, parameters and data for calculating emissions from the municipal wastewater handling sector (wastewater and sewage sludge) (5.D.1).

Activity data in the wastewater sector are drawn mainly from published data of the Federal Statistical Office, which provides detailed, disaggregated time series. The section on wastewater provides precise information as to what technical series and sources were used. The data on per-capita protein intake are taken from FAO data.

The emission factors and other parameters that enter into calculation of emissions from wastewater treatment were taken from national studies and research projects commissioned directly by the Federal Environment Agency. IPCC default parameters are also used. Various experts were consulted directly regarding a few parameters and methodological issues (for example, production of CH_4 emissions in aerobic wastewater-treatment processes).

1.4.1.2 Methods

The methods used for the individual categories are outlined in the overview tables for the various categories and in summary tables 3s1 and 3s2 of the CRF reporting tables. In addition, detailed descriptions are provided in the relevant category chapters.

A distinction is made between calculations made with country-specific ("CS") methods and calculations made, in the various categories, with IPCC calculation methods of varying degrees of detail (of varying "Tiers")[17]. The manner in which a calculation is assigned to the various IPCC methods depends on the pertinent category's share (expressed as equivalent emissions) of total emissions. Such assignment is carried out via an instrument known as "key-category analysis" (cf. Chapter 1.5 in this regard).

NMVOC emissions from solvent use, converted into indirect CO_2, are calculated on the basis of a product-consumption approach pursuant to the 2006 IPCC Guidelines. A similar procedure is used in the area of lubricant use.

1.4.2 KP LULUCF activities

The data sources and methods used for KP reporting do not differ from the data sources and methods used for reporting for categories with CRF categories 4.A, 4.B and 4.G in the UNFCCC framework. There are thus no differences with regard to the present purpose. Cf. also Chapter 1.4.1.1.4 and Chapter 5.2.

1.5 Brief description of key categories

1.5.1 Greenhouse-gas inventory (with and without LULUCF)

The key categories were identified by applying two Approach 1 procedures, Level (for the base year, 1990, and for the most current year) and Trend (for the most current year, as compared to the base year), to German greenhouse-gas emissions. In addition, the Approach 2 procedure was used. In keeping with the pertinent IPCC specifications for the Approach 1 procedure, analysis focussed both on emissions from sources and on removals of greenhouse gases in sinks. The analyses are first carried out solely for emissions from the sources listed in Annex 1 of the UN

17 Tier 1 refers to the simpler calculation methods that may be used with fewer input data, whereas Tier 2 and Tier 3 require more differentiated input data and hence generally lead to more accurate results.

Framework Convention on Climate Change and, then, in a second step, for storage of greenhouse gases in sinks. All specified key categories result either from level analysis, or from trend assessment, or from Approach-2 key-category analysis on the basis of current uncertainties determination. No new key categories have been added as a result of assessment of qualitative aspects (explanations regarding this aspect are provided in Annex Chapter 17.1.2).

For the current report, the Approach 1 procedure identified 44 categories, out of a total of 148 source and sink categories studied, as key categories. 31 of these were identified, by both trend and level analysis, as key categories. In addition, 9 categories were identified as key categories solely by trend analysis, and 4 categories were so identified solely by level analysis. Via the Approach 2 procedure, 5 additional key categories were identified (cf. Table 8).

Ultimately, 49 key categories were defined as a result. These are summarised in Table 5.

Table 5: Number of categories and key categories

Category	120		
			Key categories
by Level	Level & Trend	Trend	
4	31	9	**44 (Tier 1)** **+5 (Tier 2)** **49 (total)**

Table 6 provides an overview of the results of Tier-1 key-category analysis. Table 8 shows the additional key categories identified via Tier 2 analysis. Annex 1 (Chapter 17) of this report presents detailed explanations of the key-category analysis carried out.

Only few changes have occurred with respect to the results obtained in the previous year. The number of key categories pursuant to Tier 1 analysis, at 44, has remained the same. Three key categories have been added.:

- CH_4 emissions from road transport (1.A.3.b)
- N_2O emissions from road transport (1.A.3.b)
- CO_2 emissions from liming (3.G)

One category is no longer a key category.

- CH_4 emissions from manure management, swine (3.B.3)

Germany uses all recommended procedures for identifying and evaluating categories. The 2006 IPCC-Guidelines ((IPCC, 2006): Vol. 1, Chapter 4.3) mandate that 95% of emissions from sources / removals in sinks be classified in key categories. The key categories that Germany has identified comprise emission-causing activities that account for about 98 % of the total inventory. This high percentage results from Germany's practice of identifying key categories by combining the results of all analysis procedures and evaluations.

A comparison of the key-category analysis carried out within the CRF Reporter and Germany's key-category analysis has found that the two analyses differ only slightly. Small differences of approach are apparent; for example, Germany divides the energy sector into sub-categories, while the CRF Reporter differentiates it in accordance with fuel types. The resulting number of key categories is virtually the same in both analyses, however.

1.5.2 Inventory with KP-LULUCF reporting

As a result of the analysis of the UNFCCC inventory, as described in the previous chapter, CO_2 emissions / removals in the categories *Forest Land* (4.A), *Cropland* (4.B) *Grassland* (4.C) and

Wetlands (4.D) have been identified as key categories. For these categories, additional detailed analyses were carried out, in keeping with the methodological recommendations in Chapter "2.3.6 Choice of method" of the 2013 Revised Supplementary Methods and with the Good Practice Guidance Arising from the Kyoto Protocol. As a result, the sub-categories listed in Table 7 were identified as key categories for the KP-LULUCF inventory pursuant to Article 3.3. The key factors in such selections were the relevant emissions-contribution levels and emissions trends. With the help of Table 2.1.1, the activities selected in accordance with Article 3.4 were then correlated with these categories. Under this article of the Kyoto Protocol, Germany has selected the categories forest management, cropland management and grazing land management. These results, as well as the criteria used for the selection, are presented in CRF Table NIR.3 (Table 514 in Chapter 17.1.4).

Table 6: Key categories for Germany pursuant to the Tier 1 method

IPCC Categories	Activity	Emissions of	Level						Trend		KCA decision
			Base Year	Base Year + LULUCF	1990	1990 + LULUCF	2017	2017 + LULUCF	2017	2017 + LULUCF	
1.A.1.a Public electricity and heat production	All fuels	CO_2	●	●	●	●	●	●	●	●	L/T
1.A.1.a Public electricity and heat production	All fuels	CH4	-	-	-	-	●	●	●	●	L/T
1.A.1.b Petroleum refining	All fuels	CO_2	●	●	●	●	●	●	●	●	L/T
1.A.1.c Manufacture of solid fuels and other energy industries	All fuels	CO_2	●	●	●	●	●	●	●	●	L/T
1.A.2.a Manufacturing industries and construction: iron and steel	All fuels	CO_2	●	●	●	●	●	●	●	●	L/T
1.A.2.e Manufacturing industries and construction: Food processing	All fuels	CO_2	-	-	-	-	-	-	●	●	-/T
1.A.2.f Manufacturing industries and construction: Non-metallic minerals	All fuels	CO_2	●	●	●	●	●	●	●	●	L/T
1.A.2.g Manufacturing industries and construction: Other	All fuels	CO_2	●	●	●	●	●	●	●	●	L/T
1.A.3.b Transport: Road transportation	All fuels	CO_2	●	●	●	●	●	●	●	●	L/T
1.A.3.b Transport: Road transportation	All fuels	CH4	-	-	-	-	-	-	●	-	-/T
1.A.3.b Transport: Road transportation	All fuels	N2O	-	-	-	-	-	-	●	-	-/T
1.A.3.c Transport: Railways	All fuels	CO_2	●	●	●	-	-	-	●	●	L/T
1.A.3.d Transport: Navigation	All fuels	CO_2	●	●	●	●	-	-	●	●	L/T
1.A.4.a Other Sectors: Commercial/institutional	All fuels	CO_2	●	●	●	●	●	●	●	●	L/T
1.A.4.a Other Sectors: Commercial/institutional	All fuels	CH4	-	-	-	-	-	-	●	●	-/T
1.A.4.b Other Sectors: Residential	All fuels	CO_2	●	●	●	●	●	●	●	●	L/T
1.A.4.b Other Sectors: Residential	All fuels	CH4	-	-	-	-	-	-	●	●	-/T
1.A.4.c Other Sectors: Agriculture/Forestry/Fisheries	All fuels	CO_2	●	●	●	●	●	●	●	●	L/T
1.A.5 Other: Include Military fuel use under this category	All fuels	CO_2	●	●	●	●	-	-	●	●	L/T
1.B.1 Fugitive Emissions from Fuels	Solid fuels	CH4	●	●	●	●	-	-	●	●	L/T
1.B.2.b Fugitive Emissions from Fuels: Natural gas	Gaseous fuels	CH4	●	●	●	●	●	●	●	●	L/T
2.A.1 Mineral Products: Cement Production	Clinker Burning	CO2	●	●	●	●	●	●	●	●	L/T
2.A.2 Mineral Products: Lime Production	Burning of limestone and dolomite	CO2	●	●	●	●	●	●	-	-	L/-
2.B.1 Chemical Industry	Ammonia production	CO2	●	●	●	●	●	●	-	-	L/-
2.B.2 Chemical Industry	Nitric acid production	N2O	●	●	●	●	-	-	●	●	L/T
2.B.3 Chemical Industry	Adipic acid production	N2O	●	●	●	●	-	-	●	●	L/T
2.B.9 Fluorochemical production		HFCs	●	●	●	●	-	-	●	●	L/T
2.C.1 Metal Production: Iron and steel production	Steel (integrated production)	CO2	●	●	●	●	●	●	●	●	L/T
2.C.3 Aluminium production	Primary aluminium production	PFCs	-	-	-	-	-	-	●	●	-/T
2.F Product uses as substitutes for ODS	0	HFCs	-	-	-	-	●	●	●	●	L/T
2.G Other product manufacture and use	includes 2.B.10. Other N-dodecanedioic acid	N2O	-	-	-	-	-	-	●	●	-/T
2.G Other product manufacture and use	0	SF6	●	●	●	●	●	●	-	-	L/-

IPCC Categories	Activity	Emissions of	Level						Trend		KCA decision
			Base Year	Base Year + LULUCF	1990	1990 + LULUCF	2017	2017 + LULUCF	2017	2017 + LULUCF	
3.A.1 Enteric fermentation	Dairy cows	CH_4	●	●	●	●	●	●	-	-	L/-
3.A.1 Enteric fermentation	Other cattle	CH_4	●	●	●	●	●	●	●	-	L/T
3.D Agricultural soils	0	N2O	●	●	●	●	●	●	●	●	L/T
3.J Other	0	CH4	-	-	-	-	-	-	●	●	-/T
4.A Forest Land	0	CO2		●		●		●		●	L/T
4.B Cropland	0	CO2		●		●		●		●	L/T
4.C Grassland	0	CO2		●		●		●		●	L/T
4.D Wetlands	0	CO2		●		●		●		●	L/T
4.E Settlements	0	CO2		-		-		●		●	L/T
4.G Harvested wood products	0	CO2		-		-		●		●	L/T
5.A Solid Waste Disposal on Land	Managed Waste Disposal on Land	CH4	●	●	●	●	●	●	●	●	L/T
5.D.1 Wastewater handling	Domestic Wastewater	CH4	-	-	-	-	-	-	●	●	-/T

Table 7: Results of KP-LULUCF key-category assessment

Category	Selected KP activities (cf. KP supplement, Table 2.1.1)	matter	1990	2017	1990	2017
4.A.1 Forest Land remaining Forest Land	FM	CO2	70,327.1	53,701.6	●	●
4.A.1 Forest Land remaining Forest Land	FM	CH_4	0.6	0.6	-	-
4.A.1 Forest Land remaining Forest Land	FM	N2O	0.2	0.3	-	-
4.A.2 Land converted to Forest Land	AD	CO2	5,215.0	4,058.5	●	●
4.A.2 Land converted to Forest Land	AD	CH_4	0.2	0.2	-	-
4.A.2 Land converted to Forest Land	AD	N2O	0.7	0.2	-	-
4.B.1 Cropland remaining Cropland	CM	CO2	5,880.3	7,787.9	●	●
4.B.1 Cropland remaining Cropland	CM	CH_4	5.2	6.8	-	-
4.B.2 Land converted to Cropland	D, CM	CO_2	6,556.1	6,718.4	●	●
4.B.2 Land converted to Cropland	D, CM	CH_4	2.7	3.2	-	-
4.B.2 Land converted to Cropland	D, CM	N2O	1.0	1.2	-	-
4.C.1 Grassland remaining Grassland	GM	CO2	26,368.4	22,667.1	●	●
4.C.1 Grassland remaining Grassland	GM	CH_4	21.9	19.4	-	-
4.C.1 Grassland remaining Grassland	GM	N2O	0.3	0.3	-	-
4.C.2 Land converted to Grassland	D, CM, GM	CO2	824.8	732.1	-	-
4.C.2 Land converted to Grassland	D, CM, GM	CH4	1.9	0.9	-	-
4.C.2 Land converted to Grassland	D, CM, GM	N2O	0.0	0.0	-	-

Category	Selected KP activities (cf. KP supplement, Table 2.1.1)	matter	1990	2017	1990	2017
4.D.1 Wetlands remaining Wetlands	-	CO2	3,674.7	3,550.8	●	●
4.D.1 Wetlands remaining Wetlands	-	CH4	1.5	1.4	-	-
4.D.1 Wetlands remaining Wetlands	-	N2O	0.1	0.1	-	-
4.D.2 Land converted to Wetlands	D, CM, GM	CO2	389.3	417.9	-	-
4.D.2 Land converted to Wetlands	D, CM, GM	CH4	0.2	0.3	-	-
4.D.2 Land converted to Wetlands	D, CM, GM	N2O	0.0	0.0	-	-
4.E.1 Settlements remaining Settlements	-	CO2	636.6	1,045.4	-	-
4.E.1 Settlements remaining Settlements	-	CH4	0.5	0.9	-	-
4.E.1 Settlements remaining Settlements	-	N2O	0.1	0.2	-	-
4.E.2 Land converted to Settlements	D, CM, GM	CO2	1,174.1	2,427.0	-	-
4.E.2 Land converted to Settlements	D, CM, GM	CH4	0.4	0.9	-	-
4.E.2 Land converted to Settlements	D, CM, GM	N2O	0.4	0.6	-	-
4.F.1 Other Land remaining Other Land		CO2	0.0	0.0	-	-
4.F.2 Land converted to Other Land	D, CM, GM	CO2	0.0	0.0	-	-
4.G Harvested wood products	FM	CO2	1,330.4	3,036.7	-	-

Table 8: Key categories for Germany identified solely via the Tier 2 approach

IPCC Source Categories	Activity	Emissions of
3.B.1.a Manure Management	Dairy cows	N_2O
3.B.5 Indirect N_2O emissions	Atmospheric deposition	N_2O
4.C Grassland		CH_4
4.G Harvested Wood Products		CO_2
5.D.1 Wastewater handling	Domestic Wastewater	N_2O

1.6 Information regarding the quality assurance and quality control plan, the inventory plan (including verification) and management of confidential information

1.6.1 Quality assurance and quality control procedures

1.6.1.1 QC/QA plan

Pursuant to the 2006 IPCC Guidelines, the necessary QC/QA and verification measures for emissions reporting should be summarised in a QC/QA plan. Such a QC/QA plan is to serve the primary purpose of organising, planning and assuring the proper execution of such QC/QA measures. The QC section of the plan is relatively simply structured, and it remains unchanged from year to year. This is in keeping with the National System's basic purpose, which is to subject the entire inventory, each year, to a complete QC process in accordance with the Guidelines, and to cover all categories in the process, regardless of whether they are key categories or not. The QC section of the plan basically consists of the QC/QA checklists (cf. Chapter 1.6.1.2) and the inventory plan (cf. Chapter 1.6.1.3). A nearly identical approach is used with the QA section of the plan. This means that quality checks are carried out each year, as required by the Guidelines. At the same time, the required "peer reviews" are carried out periodically (see also below). The QA section of the plan thus basically consists of the QC/QA checklists (cf. Chapter 1.6.1.2) and of the schedule for emissions reporting (cf. Chapter 1.2.1.5), including the tasks that schedule entails. Those checklists and the schedule, along with the approval processes specified by the QSE, ensure that inventories annually undergo numerous checks, including internal checks and (especially) checks carried out by external checking authorities focussed on quality assurance. The external checks also include the "basic expert peer reviews" that are carried out annually by the participating ministries. The results of those reviews, including any required corrections, enter into inventories prior to completion of the reporting process, and in the framework of the established routines. These quality assurance activities are complemented and reinforced by periodic peer reviews (cf. Chapter 1.6.1.4).

Regular adaptation and revision of the aforementioned instruments, also taking country-specific requirements into account, ensure that the requirements of the 2006 Guidelines are met also in terms of proper consideration of specific national circumstances.

A general description of the manner in which the quality assurance and control process is organised – with regard to both establishment and workflow – is provided in Chapter 1.3.3.1. That section also describes the principles by which QC/QA measures are controlled and documented.

The requirements for quality assurance and quality control measures in emissions reporting are described in detail in the "Handbook for quality control and quality assurance in preparation of emissions inventories and reporting under the UN Framework Convention on Climate and EU Decision 525/2013/EC" ("Handbuch zur Qualitätskontrolle und Qualitätssicherung bei der Erstellung von Emissionsinventaren und der Berichterstattung unter der Klimarahmenkonvention der Vereinten Nationen sowie der EU Entscheidung 280/2004/EG" (Federal Environment Agency, 2015, unpublished). The most important specifications set forth in the handbook consist of quality reviews carried out primarily prior to the conclusion of inventory preparation.

1.6.1.2 Checklists

The quality checks are carried out with the help of checklists (for the relevant content, cf. Chapters 1.3.3.1.5 and 22.1.2.1.11). These lists currently comprise some 85 role-specific individual targets and some 50 optional targets.

Currently, some 50 Federal Environment Agency and external staff, in various functional roles, and in four layered, cumulative QC/QA review levels, are involved in emissions reporting. The review levels are represented, in each case, by the relevant expert (Fachverantwortlicher – FV); his superior, the QC/QA section representative (QKV); a specialised contact person, within the Single National Entity, for the relevant category (Fachlicher Ansprechpartner – FAP); and, finally, the co-ordinators responsible for achieving a consistent overall result comprising the NIR, the inventory, the QSE and uncertainties estimates.

In inventory preparation, role-specific QC/QA reviews are linked with general quality targets (cf. Chapter 22.1.2.1.10.3) and individual process steps (cf. Chapter 1.2.3), so that final evaluation can take account of such targets and steps. As a whole, the reviews cover the entire inventory-preparation process.

Subsequent evaluation of the checklists reveals, for specific categories, aspects that need to be reviewed – and, possibly, revised – with regard to fulfillment of specific inventory requirements. Such fulfillment is achieved via addition of pertinent further information. The great majority of all identified review requirements are added to the binding inventory plan. The inventory plan undergoes internal and interdepartmental approval processes and is then published in aggregated form.

1.6.1.3 Inventory plan

For the annual preparation of the inventory plan, the results of the QC/QA checklists for all categories are evaluated, and targets that have not been achieved are assigned improvement measures as necessary, as well as deadlines for their implementation (follow-up procedure). Those measures are then complemented by the improvement activities mentioned in the NIR (cf. Chapter 10.4.1), by the results of the various review procedures of the UNFCCC and the EU Commission, by audit results (cf. 1.6.1.4) and by any listings of further required improvements. The inventory plan comprises a range of individual measures that are to be implemented by the various roles within the QSE (cf. the role concept within QSE, Chapter 1.3.3.1.3) and by the Federal German ministries involved in emissions reporting (cf. Chapter 1.3.3.1.3), along with their subordinate authorities. The included measures are binding, i.e. have to be completed within the time periods defined within the inventory plan, although it must be noted that the relevant responsible NaSE participants have to provide the necessary personnel and financial resources for the measures.

During the preparation for each current IP, the QSE coordinator reviews whether the required actions defined in previous years have been completed. The IP is then updated with the information that results from such review. Required actions that could not be completed by the defined deadlines are flagged with an "overdue" status and given higher priority (in the "follow-follow-up procedure").

Because the individual measures included within the inventory plan are so numerous – they are too many to be listed here – they have been combined into overarching measures, as shown in Table 9. The inventory plan is updated at least once a year, via an ongoing process.

As measures within the inventory plan are implemented, large numbers of the included individual measures are processed to the point where they can be removed from the list. This occurs on a regular basis.

Table 9: Inventory plan– areas in which action is required

Main Category	Category (CRF-Code)	Data quality objective	Source	Source-Reference-Year of Reporting
Energy	1.A.3.d	Check whether requirements of IPCC-Guidelines pertaining to selection of	NIR	2017
Waste	5.B.1.+2.		CHKL	2019

Main Category	Category (CRF-Code)	Data quality objective	Source	Source-Reference-Year of Reporting
		calculation method and to procedures for applicable methods changes are fulfilled or if it´s necessary to adjust already existing calculation methods/modells.		
Waste	5.D.2	Check whether there are any gaps in time series.	CHKL	2018
Industrial Processes	2.C.2, 2.C.3.a	Check whether the source category is completely covered by the relevant data source and whether the defined data sets for EF and AR are consistently delimited.	Audit	2016
General	-	Check whether uncertainties have been determined, are complete and up to date.	Audit	2016
Energy	1.A.2.g.vii., 1.A.3.b+c+e, 1.A.4.a.ii+b.ii+c.ii, 1.B.2.a+b		Audit, CHKL	2012, 2014-16, 2019
Industrial Processes	2.B.10.(i), 2.C.3.a., 2.D.3.(b)		Audit, CHKL	2012, 2016+18
Waste	5.A.1, 5.D.1		Audit, CHKL	2016, 2019
General	-	Check whether obligations pertaining to keeping of records and documentation are fulfilled and whether the relevant documents are complete, meaningful and up to date.	Audit, CHKL	2015, 2016, 2018
Energy	1.A.2.e, 1.A.2.g.vii., 1.A.3.a+c+d.(a+b)+e., 1.A.4.a.ii+b.ii+c.ii+iii,, 1.A.5.b(iii)		CHKL	2013, 2016-2019
Industrial Processes	2.A.1+3+4a, 2.B.3+4.a+8+10(i), 2.C.3.a., 2.D.1.(b), 2.D.3.(a,d,e,f,g,h,i)		Audit, CHKL	2016-19
Agriculture	3.A+B+D+G		Audit	2016
LULUCF	4.LULUCF(Total area)		Audit	2016
Waste	5.A.1, 5.B.1+2, 5.D.1+2, 5.E.1.(a)		Audit, CHKL	2012, 2014-2016, 2018+19
General	-	Check whether data suppliers and contracted supporting entities are carrying out suitable routine quality controls, and whether the emissions-reporting requirements defined by the Single National Entity have been provided to such suppliers and entities and are being fulfilled.	Audit, Sonstige	2014, 2016
Energy	1.A.3.a-d, 1.A.4.c.iii, 1.A.5, 1.A.5.b		Audit, CHKL	2012, 2015-16, 2019
Industrial Processes	2.B.8.a., 2.B.9, 2.C.2, 2.D.3.(b)		Audit, CHKL	2012, 2016-17
Waste	5.B.1+2, 5.D.1		Audit, CHKL	2016, 2018+19
General	-	Check whether requirements for cross-checking and verification of data and their underlying assumptions have been fulfilled.	CHKL, Sonstige	2015+18
Energy	1.A.1, 1.A.2f, 1.A.3.d., 1.B.1, 1.D.1.a.		ARR, Audit, CHKL, Sonstige	2015, 2016, 2019
Industrial Processes	2.A.3., 2.A.4.b, 2.B.3+10.(i), 2.C.2+5+6		Audit, CHKL	2015-19
LULUCF	4, 4.G		CHKL, NIR	2012, 2014, 2018+19
Waste	5.A.1, 5.B.1+2, 5.D.1+2, 5.E.1.(a)		CHKL, Sonstige	2017-19
General	-	Check whether it was possible to take pointers from inventory reviews and inventory plan into account.	ARR	2010
Energy	1.A.3.d(b), 1.B.2.b.iv-vi		CHKL	2019
Industrial Processes	2.B.3		CHKL	2018
Energy	1.A.2.g.vii., 1.A.3.b-e., 1.A.4.a.ii.+b.ii+c.ii+iii, 1.A.5.b,	Check whether data-consistency requirements are fulfilled and whether the relevant documents are complete and meaningful.	CHKL	2016, 2018+19
Industrial Processes	2.B.3, 2.D.1.(b)		Audit, CHKL	2016+17, 2019
Waste	5.A.1, 5.D., 5.D.2, 5.E.1.(a)		CHKL, NIR, Sonstige	2013, 2016, 2019

Main Category	Category (CRF-Code)	Data quality objective	Source	Source-Reference-Year of Reporting
Energy	1.B.2.	Check whether the EF are plausible and complete (have no gaps and are completely documented) and up to date.	NIR	2019
Industrial Processes	2.A.3		Audit	2016
LULUCF	4.		NIR	2015
Waste	5.A.1		Audit	2016
Energy	1.A.3.a.	Check whether the AR are plausible and complete (have no gaps and are completely documented) and up to date.	NIR	2019
Industrial Processes	2.A.3, 2.A.4.a.		Audit, NIR	2016, 2019
Waste	5.D.2		ARR	2015, 2016
Industrial Processes	2.A.4.a.	Check whether data has been entered into the CSE correctly, including whether all numbers, units and conversion factors have been correctly entered and properly integrated.	CHKL	2019
Energy	1.,1.A.2.a+g.vii, 1.A.3.b+c., 1.B.1.	Check whether the NIR source category has been completely and logically described in terms of the required six sub-chapters for the NIR ("Source category description", "Methodological issues", etc.).	ARR, CHKL	2015, 2016, 2019
Industrial Processes	2.B.10.(i), 2.C.2+3.a+5-7.		ARR, CHKL	2015, 2016, 2019
LULUCF	4.A		ARR	2015, 2016
Waste	5.A.1, 5.B.1+2, .5.D.1+2, 5.E.1.(a)		ARR, CHKL	2015+16, 2018+19
KP	KP		ARR	2015, 2016
General	-	Various types of required action.	Sonstige	2014, 2016
Energy	1.A.2.e, 1.A.2.g.vii, 1.A.3.a+c+d, 1.A.4.a.ii+b.ii+c.ii+iii, 1.A.5.b., 1.D.1.a		Audit, CHKL, Sonstige	2013, 2015-19
Industrial Processes	2.B.3+4+8+10.(i), 2.C.3.a., 2.D.2		Audit, CHKL, NIR	2015+16, 2019
Agriculture	3.A+B+D		NIR	2011, 2012
Waste	5.A.1, 5.D.1+2		ARR, CHKL, Sonstige	2015+16, 2018+19
Other	-		ARR	2015+16
Energy	1.A.3.a+b, 1.C.2.	Initiated research projects for inventory improvement.	Audit, Sonstige	2016, 2018
Industrial Processes	2.B.4.b-d, 2.A.5.a.+b, 2.B.3., 2.B.4.a., 2.B.8.		CHKL, Sonstige	2016, 2019
Industrial Processes	2.D.3.(b)	Initiated research projects for inventory improvement.	NIR	2012
Waste	5.A.1, 5.D.1		ARR, NIR	2015+16

The first inventory plan was published together with the 2007 Submission. Since then, several thousand items for action or improvement have been addressed within the quality system. Since that total is too unwieldy to be presented in any clear manner, we simply provide an overview of the development of the IP since the 2010 Submission.

As of the end of the current reporting year, the inventory plan comprises some 2340 items for action or improvement. Of these, some 1860 have been successfully addressed. Those items span about 160 categories.

In the current round of reporting, about 140 additional required improvements have been identified, and about 190 required actions have been successfully completed. A total of 31 additional items related to review results (UNFCCC and ESD) from previous years have also been successfully addressed in the current round. The results of the UNFCCC's 2018 Inventory Review Report are not yet reflected in the inventory plan, since no officially published version of that report was available as of the editorial deadline for the present report. No required improvements for the inventory have emerged from the 2018 ESD Review. The focuses of all improvements completed to date include the areas of documentation, review results and verification. The focuses of the some 350 improvement items that are still open or are still undergoing processing include documentation, verification and other improvements. If one takes into account the number of repetitions that necessarily result via presentation of checklist and review results of past years, then the number of open improvement items decreases to an actual figure of about 480.

The overview in Table 10 presents more-detailed information on the improvement items that have been successfully addressed. Both tables (Table 9 & Table 10) include the review results from the years 2006 through 2016, the statements made in the NIR relative to planned improvements in the years as of 2011, the other improvement items for the years as of 2008 and the CHKL results from the years as of 2010.

Detailed information regarding individual improvements, with respect to categories, priorities, deadlines, responsibilities, gases, fuels, needs for action, etc., cannot be provided here, due to the sheer scope of the information involved. With regard to successfully addressed Review results, more-detailed excerpts from the inventory plan are provided in Table 479, while information relative to statements made in the NIR regarding planned improvements is provided in Table 480.

Table 10: Inventory plan – Items for action/improvement that have been successfully addressed

Main Category	Category (CRF-Code)	Data quality objective	Source	Source-Reference-Year of Reporting
Energy	1.A, 1.A.4.c.iii., 1.B.2.b., 1.D.1.b.	Check whether requirements of IPCC-Guidelines pertaining to selection of calculation method and to procedures for applicable methods changes are fulfilled or if it´s necessary to adjust already existing calculation methods/modells.	ARR, CHKL, ESD	2008, 2011-2014, 2016
Industrial Processes	2.A., 2.B.8, 2.C., 2.C.1, 2.E., 2.F.1+6		S&A I, NIR, CHKL	2006, 2010, 2012
Agiculture	3.A+B		NIR, ARR, Sonstige	2009, 2011-2013
LULUCF	4.D+E.2		ARR	2011, 2015, 2016
Waste	5.A, 5.D.1		ARR, CHKL	2011-2014
KP	KP		ARR	2015, 2016
Energy	1.A.1, 1.A.2.f, 1.A.2.g.viii, 1.A.3.e	Check whether the data source (s) used will be available throughout the long term.	CHKL	2011, 2014-2016
Agiculture	3.A.(a), 3.B.(a)		CHKL	2010
LULUCF	4		Sonstige	2008
Waste	5.D.2, 5.E.1		CHKL	2010, 2015
Energy	1.A.3.c	Check whether there are any gaps in time series.	CHKL	2010, 2013+2014
Industrial Processes	2.A.4.a, 2.C.2+3		CHKL	2010, 2011, 2013, 2016
Agiculture	3.A.(b), 3.B.(b), 3.D		CHKL	2010-2011
LULUCF	4. (total area), 4.A.(a), 4.G		ARR, CHKL, NIR	2012, 2015, 2016
Waste	5.D.2.		NIR	2013
Energy	1.A.1, 1.A.2.g.viii, 1.A.3.e.ii, 1.A.4.c.ii, 1.D.1.b.,	Check whether the source category is completely covered by the relevant data source and whether the defined data sets for EF and AR are consistently delimited.	CHKL	2011, 2014, 2015
Industrial Processes	2.B.2., 2.C.1, 2.D.3.(c)		Audit, CHKL, NIR	2012, 2016
Waste	5.A.1, 5.D.1+2		CHKL, NIR	2011, 2012, 2015
General	General	Check whether uncertainties have been determined, are complete and up to date.	ARR, CHKL	2011, 2013, 2015+2016
Energy	1.A.2, 1.A.3.a.ii, 1.A.3.b+c+d(a), 1.A.3.e.ii, 1.A.4.a-c, 1.A.5.b, 1.B.2.a.+b		Audit, CHKL	2010-2012, 2014-2016
Industrial Processes	2.A.4.a, 2.C.1-3, 2.D.3.a-c, 2.D.3.(a,d,e,f,g,h,i), 2.F.5, 2.G.4.(a)		Audit, CHKL, NIR	2010-2012, 2015-2017
LULUCF	4, 4(III+IV), 4.A, 4.B-F		Sonstige, CHKL, NIR, ARR	2008, 2010-2011
Waste	5.A.1, 5.D.1		CHKL	2010-2014

Main Category	Category (CRF-Code)	Data quality objective	Source	Source-Reference-Year of Reporting
Energy	1.A, 1.A.1+2, 1.A.1.c, 1.A.2.a+g.vii, 1.A.3.a-e, 1.A.4, 1.A.4.a.ii+b.ii+c.ii+iii, 1.A.5.a+b, 1.B.1+2, 1.D.1.a+b	Check whether obligations pertaining to keeping of records and documentation are fulfilled and whether the relevant documents are complete, meaningful and up to date.	Audit, CHKL, ARR	2010-2019
Industrial Processes	2.B.1.+2+9, 2.C.1-3, 2.D.3.(a,d,e,f,g,h,i), 2.F.1+5, 2.G.2.(c), 2.G.3.a.(i)+b, 2.H.1+2, 2.B.10.(i)		Audit, CHKL	2010-2011, 2014-2016, 2018
Agiculture	3.A.+B+D+G		Audit, CHKL	2010, 2016
LULUCF	4, 4(III+IV), 4.A-F, LULUCF - Total area		Audit, CHKL, Sonstige	2008, 2010, 2016
Waste	5.A.1, 5.B.1, 5.D.1+2, 5.E.1		Audit, CHKL	2010-2013, 2015+2016
General	General	Check whether data suppliers and contracted supporting entities are carrying out suitable routine quality controls, and whether the emissions-reporting requirements defined by the Single National Entity have been provided to such suppliers and entities and are being fulfilled.	CHKL	2014
Energy	1.A.1+2, 1.A.3.a.ii, 1.A.3.b-d, 1.A.3.e.ii, 1.A.4.c.ii, 1.A.5.b, 1.D.1.b		CHKL	2010-2011, 2014
Industrial Processes	2.C.2, 2.C.3.a., 2.D.3.(b), 2.F.5		Audit, CHKL	2011+2012, 2016
Agiculture	3, 3.A., 3.B., 3.D		CHKL, Sonstige	2008, 2010-2011
LULUCF	4, 4(III), 4.A.1, 4.B-F		CHKL, Sonstige	2008, 2010, 2012
Waste	5.D.1		CHKL	2010-2011
General	General	Check whether requirements for cross-checking and verification of data and their underlying assumptions have been fulfilled.	ARR , CHKL, Sonstige	2008, 2017
Energy	1, 1.A, 1.A.1+2, 1.A.3.a-e, 1.A.4, 1.A.4.a.ii+b.ii., 1.A.4.c.ii+iii, 1.A.5.a+b, 1.B.1+2, 1.D.1.a		ARR, Audit, Eu-Rev, S&A I, CHKL, NIR	2006-2008, 2010-2017
Industrial Processes	2.A.1-4, 2.B.1+3+4.a+7+8, 2.C.1-3, 2.D.1+2+3, 2.E.4., 2.G.3.a.(i), 2.G.4.(a+c), 2.H.2		Audit, ARR, CHKL, NIR	2010-2018
Agriculture	3.H+J		CHKL	2015
LULUCF	4., 4(II-V), 4.A-F, 4.LULUCF(Total area)		Audit, CHKL, NIR, Sonstige	2010, 2012, 2014- 2017
Waste	5.A.1, 5.B.1+2, 5.D, 5.D.2		Audit, CHKL	2010-2016, 2018
KP	KP		ARR	2015, 2016
General	General	Check whether it was possible to take pointers from inventory reviews and inventory plan into account.	ARR, ESD, IRR	2006, 2008-2013, 2015
Energy	1, 1.A, 1.A.1.a+b, 1.A.2, 1.A.2.a+f, 1.A.3.a-d, 1.A.4.c.iii., 1.A.5.b.(iii), 1.B.1+2, 1.B.2.a.iii,1.B.2.b.iv, 1.D.1		ARR, CHKL, ESD, IRR, SL	2006, 2008-2013, 2015, 2018
Industrial Processes	2, 2.A.1-3, 2.A.4.b+d., 2.B.1-3+4.b+8+9+10.(i), 2.C.1-4, 2.D.1+3.(a), 2.D.3.(a,d,e,f,g,h,i), 2.F+G		ARR, ESD, IRR, CHKL	2006, 2008-2010, 2012-2015, 2017+2018
Agiculture	3, 3.A-D+G		ARR, ESD, IRR, NIR	2006, 2008-2010, 2012-2015
LULUCF	4, 4.A-D		ARR, IRR, SL	2006, 2008-2010, 2012-2013
Waste	5, 5.A, 5.A.1., 5.B.1+2, 5.C.1, 5.D, 5.D.1+2, 5.E		ARR, ESD, IRR, CHKL	2006, 2008-2010-2015, 2018
KP	Kyoto Protocol		ARR	2010-2013
General	General	Check whether data-consistency requirements are fulfilled and whether the relevant documents are complete and meaningful.	ARR	2011
Energy	1, 1.A, 1.A.1+2, 1.A.2.a+f+g, 1.A.3.a.ii+b-d, 1.A.4, 1.A.5.b, 1.B.1.a, 1.B.2		ARR, EU-Rev, S&A I, CHKL, NIR	2006-2008, 2010-2016, 2017
Industrial Processes	2, 2.A.4.d, 2.B.2+4.a+8, 2.B.10.(i), 2.C.1, 2.D.1+3.(b+c), 2.F.1, 2.G.4.(a), 2.H.1.(b)		ARR, EU-Rev, CHKL	2007, 2010-2013, 2016, 2018
Agiculture	3, 3.D		ARR	2008
LULUCF	4, 4.A.2, 4.B.1, 4.C.1		EU-Rev, NIR	2007, 2013
Waste	5.A, 5.D, 5.E.1		ARR, EU-Rev, CHKL, NIR	2007, 2011-2014, 2016+2017

Main Category	Category (CRF-Code)	Data quality objective	Source	Source-Reference-Year of Reporting
Energy	1.A.1, 1.A.2, 1.A.2.f.(d), 1.A.3.d(b)+e.ii, 1.A.4, 1.A.5.a	Check whether the EF are plausible and complete (have no gaps and are completely documented) and up to date.	ARR, Audit, CHKL, EU-Rev, S&A I, NIR	2006, 2007, 2011-2014, 2016
Industrial Processes	2.A.3, 2.a.4.a, 2.B.1, 2.B.9., 2.C.4+6, 2.F, 2.F.5		Audit, EU-Rev, NIR	2007, 2011, 2016
Agriculture	3.B, 3.B.(b)		EU-Rev, NIR	2007, 2012
LULUCF	4, 4.C.2		EU-Rev, NIR	2007, 2016
Waste	5.B., 5.D.1		Audit, CHKL, NIR	2013+2014, 2016
General	General	Check whether the AR are plausible and complete (have no gaps and are completely documented) and up to date.	Sonstige	2008
Energy	1.A.1; 1.A.2; 1.A.3.a+b+d, 1.A.4+a.i+c.i; 1.A.5.a, 1.B.1.c, 1.D.1.a+b		EU-Rev, S&A I, NIR, CHKL	2006, 2007, 2011-2013, 2015, 2016
Industrial Processes	2.A.3, 2.B.4.a., 2.B.10.(i), 2.D.3.(a)		CHKL, NIR	2011-2012, 2015-2017
Agiculture	3.A(b)+B+D, 3.G		ESD, NIR	2011-2012, 2016
LULUCF	4.A-C		NIR	2011-2012
Waste	5.A.1, 5.B.2, 5.D, 5.D.2, 5.E.1		ARR, NIR, Sonstige	2011-2013, 2015, 2016
General	General	Check whether data has been entered into the CSE correctly, including whether all numbers, units and conversion factors have been correctly entered and properly integrated.	CHKL	2015
Industrial Processes	2.B.4.a.		CHKL	2018
Waste	5.D.1		CHKL, Sonstige	2011, 2013-2015
General	General	Check whether the NIR source category has been completely and logically described in terms of the required six sub-chapters for the NIR ("Source category description", "Methodological issues", etc.).	ARR	2011
Energy	1, 1.A., 1.A.1, 1.A.2, 1.A.2.f.(a-d), 1.A.3.e., 1.B.1, 1.B.2., 1.B.2.a+b		ARR, CHKL, ESD	2008, 2011-2013, 2015, 2016, 2018
Industrial Processes	2.A.1+2, 2.B.1+6+8, 2.A.4(a), 2.B.3+4, 2.B.1+9, 2.C, 2.C.2+3, 2.D.3.(a+b), 2.G.2, 2.G.3.a.(i), 2.G.4.(a), 2.H.1.(a)		ARR, EU-Rev, NIR, CHKL	2007, 2010-2011-2017
Agriculture	3.A., 3.A.2, 3.(II).D.B, 3.B, 3.D.a.6., 3.D.b.2., 3.G		ARR	205, 2016
LULUCF	4, 4 (II), 4.A.(b)+1, 4.B.+1, 4.G		ARR, CHKL	2011, 2015-2017
Waste	5.B.2., 5.C.1, 5.D, 5.D.1		ARR, CHKL	2011-2013, 2015, 2016
KP	KP		ARR	2015, 2016
General	General	Check whether any recalculations are required. If they are they must be documented in a logical manner.	ARR	2011
Energy	1, 1.A.1+2+4		EU-Rev, S&A I	2006, 2007
Industrial Processes	2		ARR, EU-Rev, S&A I	2006, 2007, 2011-2013
Agiculture	3		S&A I	2006
LULUCF	4.A		ARR	2011
Waste	5, 5.E		S&A I, EU-Rev	2006, 2007
General	General	Various types of required action.	ARR, CHKL, Sonstige	2010+2011, 2013-2016
Energy	1.A., 1.A.2.f.(a-d), 1.A.2.g.vii., 1.A.3.a-e, 1.A.4.+a.ii+bii+c.ii+iii, 1.A.5.b, 1.B.1+2a+b+d, 1.D		ARR, Audit, NIR, Sonstige, CHKL	2009-2016, 2018
Industrial Processes	2.A.2+4.a+d., 2.B.4.a+8.f.+9+10.(i), 2.C.1+6, 2.D.1-3.(a+c), 2.F.5, 2.G.2, 2.G.3.a.(i), 2.G.3.b., 2.G.4, 2.H.1.		ARR, Audit, CHKL, NIR, Sonstige	2010-2013, 2015-2017
Agiculture	3, 3.B+I+J		NIR, CHKL	2011, 2017
LULUCF	4, 4.A-E, 4.LULUCF(Total area)		ARR, CHKL, NIR	2008, 2011, 2013, 2015-2016
Waste	5, 5.D		ARR, CHKL, Sonstige	2013, 2015-2017
KP	KP		ARR	2013, 2014

Main Category	Category (CRF-Code)	Data quality objective	Source	Source-Reference-Year of Reporting
Energy	1.A.2.a+b+d+e+f.(d), 1.A.3.a+b+d.(a)+e., 1.A.4.c.iii., 1.B.1, 1.B.2.a+b, 1.B.2.c.iii.-Flaring, 1.D.1.a.	Check whether pertinent responsibilities need to be updated.	Audit, CHKL	2010, 2013-2016, 2018
Industrial Processes	2.A.3+4.(b), 2.B.3+8.a-e+g.(i)+10(i), 2.C.1-3(a), 2.D.3.(b+c), 2.G.3.a.(i), 2.G.3.b, 2.H.1.		Audit, CHKL	2010-2014, 2016
Agriculture	3.A.+B.+D.+G.		Audit	2016
LULUCF	4.A., 4.LULUCF(Total area)		Audit	2016
Waste	5.D.1.		Audit, CHKL	2010, 2013, 2016
Energy	1.A.1, 1.A.2.f, 1.A.3.c-e, 1.A.4.c.iii., 1.B.1.c, 1.B.2, 1.D.1.b.	Initiated research projects for inventory improvement.	CHKL, NIR	2011-2014
Industrial Processes	2.A.2+4.a, 2.G.2		Audit, NIR	2011+2012, 2016
Agiculture	3.B		NIR	2012
LULUCF	4.A-C+E		NIR	2011-2012
Waste	5.A.1, 5.B.1		CHKL, NIR	2011-2012, 2014

1.6.1.4 Audits

In April 2016, the Federal Environment Agency's Quality System for Emission Inventories (QSE) was externally audited for the first time. The aims of the audit were to:

- Check whether the QSE is conformal with the quality requirements of the 2006 IPCC Guidelines,
- Identify any potential for improvement,
- Identify any possible risks for the continuing maintenance of data quality.

An audit program was developed that covers more than simply a representative cross-section of all emissions categories, since the audited staff, in most cases, also handle additional, "related" categories, and do so with procedures that differ little from those used in the directly considered cases.

In February 2016, the so-developed audit plan was used as a basis for carrying out a pre-audit for two categories, and for the coordinators of the Quality System for Emission Inventories (QSE), the Central System of Emissions (CSE) (the database) and the National System (NaSE), with a view to testing the audit's suitability and time requirements and to determining whether the audit plan needed to be adjusted in any way. In parallel with the revision of the audit plan, a schedule for the execution of the audit, with 5 auditors, was prepared. During the audit, the following procedure was normally carried out on three successive days: the responsible experts (Fachverantwortlicher; FV) and their specialised contact persons (Fachlicher Ansprechpartner; FAP) were audited in pairs. This work covered a total of 44 of 148 categories. The reviewed procedures and workflows in the audited categories represent more than 80 % of the total emissions covered by the German greenhouse-gas inventory. In addition, all coordinators who had not already been covered in the pre-audit were included in the audit program, in the framework of individual audits.

The audit plan covered the following topic areas:

- Roles and responsibilities
- The use of general quality control procedures
- Implementation of requirements set forth in the QSE manual (IB, IP, NIR)
- Category-specific quality controls for
    - Emission factors
    - measurements
    - Activity data

- calculation procedures and determination of uncertainties

The key findings of the audit include:

1. The minimum requirements pertaining to quality control / quality assurance (QC/QA), as specified by the 2006 IPCC Guidelines, are being met, without exception. All target requirements are being met via the design and the implementation of the QSE.
2. The QSE's prescribed QC/QA procedures function effectively in assuring data quality, in conformance with the requirements of the IPCC Guidelines, and in ensuring that a continual improvement process takes place. The success of the system depends on consistent fulfillment of the QSE requirements via the involved staff and areas.
3. The QSE accomplishes much more than its goal of fulfilling the minimum requirements; for many aspects of the inventory process, it provides best-practice examples modelled after the 2006 IPCC Guidelines. The structure and the scope of the inventory description are worthy of particular mention. In nearly all categories studied, the description serves as a comprehensive, transparent tool for documentation of data, the processing status and the procedures applied. Only in the area of category-specific quality control – in a small number of aspects – is some room for improvement seen, and the relevant improvements could well be carried out in the longer term (such as preparation of standardised spread-sheet templates)
4. The risk that data quality could decrease is seen as very low, in light of the QSE's structure and design, as well as of the extensive, detailed information contained in the inventory descriptions. Risks might apply with regard to temporary gaps in the continual, consistent use of survey and calculation procedures, since extrapolation calculations, for reporting purposes, sometimes have to be carried out in cases in which experienced staff suddenly become unavailable. By no means does such unavailability lead to a loss of information, however – it would always be possible to subsequently restore the database, at the customary data quality levels.
5. In some categories, data quality could be improved still further via more-frequent review of the currentness of the data used. It thus could be useful to review, at mandatory intervals, whether emission factors are still current, or whether in the meantime data that would support use of higher-Tier approach (such as national factors, instead of the IPCC defaults) have become available or could be obtained. Where factors prove to require updating, the necessary studies could be included in the research budget.
6. Individual potential improvements for the categories studied, and for general areas, could also be determined. Such aspects would be included in the existing instruments for improvement (the inventory plan).

An external audit has proven to be a useful element in the process of providing quality assurance for the national reports. Current plans call for such audits to be repeated at regular intervals (of about 5 years). Such audits could be complemented by internal audits – carried out by internal auditors – that would monitor the implementation of improvement processes and that, via annually changing focuses throughout a multi-year repeating schedule, would cover all procedural steps for quality control and reporting.

1.6.1.5 Workshops on the National System (Peer Review)

In November 2004, the Federal Environment Agency held a first workshop on the National System of Emissions Inventories. This created a forum that significantly promoted inclusion of associations and other independent organisations, as well as supporting implementation of Paragraph 15 (b) of the *Guidelines for National Systems*, which requires that inventories be reviewed by third parties (peer review).

Subsequently, several workshops were held with the purpose of facilitating review of the inventories by independent third parties, pursuant to Paragraph 15 (b) of the *Guidelines for National Systems*. In 2009, a second workshop focussed on selected specific categories of the inventory, such as "N_2O from product use," "emissions from non-energy-related use of fossil fuels" and "SF_6 emissions from the photovoltaics industry". The extensive and intensive discussions conducted during the workshop contributed significantly to overall improvement of the data – and, thus, to the quality of the reporting.

In 2011, an international experts' workshop on the German LULUCF-reporting system was carried out that reviewed the methodological changes made as a result of the In-Country Review of September 2010. All of the recommendations made by experts in that framework have been fully implemented.

Technical discussions on the topic of natural gas statistics were conducted with the Federal Statistical Office in 2012 and in summer 2015 (one discussion at each time). The participants in the technical discussion in 2012 included representatives of the Federal Statistical Office, the Federal Environment Agency (UBA) and the German Association of Energy and Water Industries (BDEW), as well as representatives of various gas companies and the German Institute for Economic Research (DIW; Working Group on Energy Balances (AGEB)). In preparation for revision of the national Energy Balance, the discussion focussed on the available natural gas statistics. In the process, measures were approved that will directly improve the Energy Balance and, thus, will improve the emissions inventory. In addition, agreement was reached on additional study that will be carried out in order to verify the available statistical data. The technical discussion in 2015 served the purpose of coordinating data exchange between the Federal Statistical Office and the Federal Environment Agency, also with regard to the new reporting requirements set forth in the 2006 IPCC Guidelines and the European Greenhouse gas Monitoring Mechanism Regulation (MMR).

In March 2014, a workshop was held with European inventory experts on the topic of implementation of the 2006 IPCC Guidelines in German greenhouse-gas reporting. That workshop, which had about 60 participants, focussed especially on the sectors of energy (CRF 1) and industrial processes and product use (CRF 2). With the help of the findings from experience that were shared during that event, it proved possible to significantly improve implementation of the new methods in German greenhouse-gas inventories.

1.6.1.6 Cross-Country Review on fluorinated gases

In February 2011, a group of experts met in Vienna for a cross-country review focussing on reporting on F gases. The participating countries included the UK, Austria and Germany. After basic presentations of data collection in the three countries, the various individual areas of application concerned were considered in detail and compared in terms of data sources, precision, emission factors and other criteria. In the process, it emerged that, of the three countries, Germany has the most extensive specialised knowledge resources and presumably is thus best able to assess the completeness and plausibility of the available data.

One of the key results that emerged from the cross-country review is that all three countries have to commit high levels of manpower to reporting on F gases. Any reduction in such resources commitments would mean that reporting would no longer be IPCC-conformal.

As a result of the meeting, a report was prepared that has entered into German reporting regarding F gases.

1.6.2 Activities for verification

1.6.2.1 Verification in selected categories

In the 2015/2016 reporting year, a verification project was carried out, in keeping with the 2006 IPCC Guidelines (Vol.1, Chapter 6). In the project, all of the inventory's categories were reviewed for any need for verification. The following categories were identified:

- 1.A.2.a Iron & Steel
- 1.A.3.e Other Transportation
- 1.B.1.a.ii Surface Mining
- 1.B.2.b.v.i Natural Gas: Other
- 2.A Mineral Industry
- 2.B.1 Ammonia Production
- 2.B.2 Nitric Acid Production
- 2.B.3 Adipic Acid Production
- 3 Agriculture
- 4 Land Use Matrix
- 4 Consistency between the descriptions in the NIR and the CRF tables
- 4.A Forest Land
- 5.A.1 Managed Waste Disposal

For each of the listed categories, verification has been carried out by the project holder. Upon completion of this work, the results will be listed in the relevant categories' verification chapters (i.e. the results for a given category will be listed in that category's verification chapter).

1.6.2.2 Procedure for using monitoring data from European emissions trading

In efforts to fulfil mandatory quality criteria, a need has been seen – especially within the EU – to use data from the EU Emissions Trading Scheme (EU ETS) to improve greenhouse-gas emissions inventories. All Member States are now called upon to use ETS data to improve the quality of their annual national emissions inventories.

A reliable database from emissions trading, showing relevant annual emissions, is available for the period since ETS monitoring commenced. Those data can be used, in aggregated form, to draw category-specific conclusions regarding the completeness and consistency of certain parts of emissions inventories. In addition, they provide a basis for reviewing emission factors used and for verifying activity data. Since emissions calculations for all components are all based on the same activity data, such verification is of significance for all reported emissions inventories.

Emissions-trading data required for improvement of inventory data subject to reporting are available in electronic form, in the installations database of the German Emissions Trading Authority (DEHSt). In 2005, agreement was reached regarding a general procedure for individual data queries related to inventory preparation. In the main, this procedure involves direct communication between the Single National Entity and the German Emissions Trading Authority's section E 2.3, which is responsible for reports (cf. Chapter 1.3.3.1.8). To make it possible to use this "resource" on a regular basis, this formalised procedure for the pertinent required annual data exchanges, including deadlines and defined workflows, has been agreed.

Monitoring data from European emissions trading will be used to improve the quality of annual national emissions inventories with respect to categories that include installations subject to reporting obligations under the CO_2 Emissions Trading Scheme (ETS). Relevant information is provided in the category chapters on verification, although the detailed comparisons involved are presented only in some cases. For reasons of confidentiality, especially regarding certain inventory details, the results of the comparisons are usually simply described in text form. Tables with the data used can be made available only in connection with inventory reviews. The comparison of fuel-related CO_2 emission factors in the Annex, Chapter 18.8, provides a sample overview of a successful verification.

The process of data provision, from the German Emissions Trading Authority (DEHSt) to the responsible experts for the inventories, called for several instances of project-based support. In a research project (ÖKO-INSTITUT, 2006b), allocation rules were developed that make it possible to compare data from verified emissions reports with data from the inventories' database, on a year-by-year basis. The comparisons, which have been carried out only once to date, have confirmed, in principle, the usefulness of such comparisons for verifying individual categories and identifying data gaps. A follow-on project begun in 2011, "D.E.N.K.", studied whether the allocation rules can be improved and the relevant procedure can be further automated. In the process, it became clear that the data quantities the ETS provides for inventory calculations present challenges in terms of available resources and time. When discrepancies occur in existing aggregates that fulfill requirements for confidentiality of business and operational secrets, the underlying data sets for individual operational steps have to be checked. This obstacle was confirmed for the German situation, by experts of other countries, in the framework of an international workshop within the project. In another project, the situation relative to adjustment of the ETS requirements for the third trading period was studied (Herold et al., 2016). Its report analysed the technical provisions for monitoring of and reporting on greenhouse-gas emissions in the EU-ETS framework, in comparison to monitoring and reporting in the framework of the 2006 IPCC Guidelines. Differences between the two sets of requirements can lead to differences in CO_2-emissions data, especially for reported years as of 2014, the year in which the ETS provisions were adjusted. This can hinder then hinder use of verified ETS emissions data, by inventory preparers, for verification purposes.

1.6.3 Handling of confidential information

Following the entry into force of the 3rd SME Relief Act (MEG – Mittelstandsentlastungsgesetz), with its article for amendment of the Act on Energy Statistics of 26 July 2002, the Federal Environment Agency (UBA) was granted access, for purposes of inventory preparation, to data of the Federal Statistical Office that are subject to statistical confidentiality. Such access was then assured via the amendment of the Act on Energy Statistics of 6 March 2017 (Federal Law Gazette (BGBl) I p. 392), in Section 13 of that amended version.

In addition, from associations and companies, the Single National Entity receives activity data, emission factors and emissions data that reflect operational and business secrets and that are otherwise confidential.

In storing and using such data, therefore, the Single National Entity must take special precautions, and apply special procedures, to protect the confidentiality of the data.

In particular, it must provide for strict separation (both spatial and in terms of staff assignments) of statistical work / analysis and any enforcement of legal provisions pertaining to the installations for which data are collected.

The Single National Entity and the affected sections of the Federal Environment Agency have taken various measures for the purpose of fulfilling these requirements. For example, as a basic rule, persons charged with enforcement of laws in a specific area are never permitted to carry out specialised tasks relative to emissions reporting in the same area.

In 2008, the Single National Entity commissioned a legal study with the aim of precisely assessing the requirements and possibilities pertaining to use and management of data for emissions reporting. The results entered into revision and refinement of the Single National Entity's concept for handling confidential data.

Previously, access to the Central System on Emissions (CSE) database was already limited to a specified group of authorised persons. That measure represents the key precaution for dealing with confidential data. In particular, it makes it practicable to separate – in terms of the persons involved – the tasks of data analysis and legal control. In addition, in 2009 a special access-restricted area was set up, on a central server of the Federal Environment Agency, for confidential electronic data that are not centrally stored in the CSE (for example, energy data subject to statistical confidentiality, emissions-control declarations, data relative to large combustion plants, information about production processes, etc.).

Furthermore, data of the *Federal Statistical Office* are provided on a password-/access- protected server (i.e. available only for specifically authorised persons) of the *Federal Statistical Office*. In the Federal Environment Agency, such data are processed in a database protected by personalised access control (i.e. a database available only for specifically authorised persons).

1.7 General estimation of uncertainties

1.7.1 Greenhouse-gas inventory

The 2006 IPCC Guidelines characterise determination of uncertainties as a key element of any complete inventory. As a result of the need to continually improve the inventories, uncertainties in the inventories play an important role. Uncertainties information is used primarily as an aid for improving the precision of inventories, as well as for selecting methods and carrying out recalculations for inventories. The declared aim is to minimise uncertainties to the greatest possible degree, in order to maximise the inventories' accuracy. In a first step, the uncertainties for all categories and sinks have to be quantified, in order to enhance assessment of inventory quality – which assessment, in turn, is the key to effective inventory planning.

In general, two methods for determining uncertainties are differentiated. The Tier 1 method combines, in a simple way, the uncertainties in activity data and emission factors, for each category and greenhouse gas, and then aggregates these uncertainties, for all categories and greenhouse-gas components, to obtain the total uncertainty for the inventory. The Tier 2 method for uncertainties determination is the same, in principle, but it also considers the distribution function for uncertainties and carries out aggregation using Monte Carlo simulation. In the Tier 2 method, this process also necessarily includes determining a probability density function for both parameters. Ideally, these functions can be determined via statistical evaluation of individual data items (such as measurements for a large number of facilities). In many cases, few relevant values are available, however, and thus the uncertainty must be determined on the basis of experts' assessments.

Research project 42 266 2004 (Handke et al., 2004) determined uncertainties, for the first time, in keeping with the Tier 1 and Tier 2 methods, pursuant to Chapter 6 of the 2000 Good Practice Guidance (IPCC, 2000). Following that project, and for the 2016 report, the resulting database was continually improved, and additional uncertainties data for the greenhouse-gas inventory were added. In addition, the provisions of the 2006 Guidelines (IPCC, 2006) were adopted. In Germany, uncertainties are determined, on an annual basis, pursuant to both the Tier 1 and Tier 2 methods. The uncertainties for the activity data, emission factors and emissions data used were taken from the CSE database. They are based on estimates of experts in relevant departments of the Federal Environment Agency and at external institutions. In cases in which uncertainties information is not yet available in complete form, as an expert's estimate, pertinent figures are added from other sources (such as relevant technical literature).

1.7.1.1 Procedures for uncertainties determination

In uncertainties determination pursuant to Chapter 3 of the 2006 IPCC Guidelines (IPCC, 2006), the determination proceeds on the basis of the uncertainties for AR (activity data), EF and EM, as determined on the lowest sub-category level (primarily by responsible experts of the Federal Environment Agency), and as listed in the CSE. In the Tier 1 method, where asymmetric uncertainties figures are yielded, the larger of the two relevant values is used, under the assumption of a normal distribution, as both the upper boundary and the lower boundary. The Tier 2 method, on the other hand, uses the complete data set in each case. In each sector, the uncertainties for the individual time series are aggregated to form a total uncertainty for the sector pursuant to the IPCC Good Practice Guidance (IPCC, 2000). The uncertainty of the inventory as a whole is obtained from aggregation of the sector uncertainties. In general, as a result of technical limitations, and in a departure from the Guidelines, the year 1995 is used as the base year for calculation of uncertainties.

In general, in calculation of uncertainties, uncertainties for activity data can be assumed to be smaller than those for emission factors. In particular, the uncertainties are smaller for activity data derived from fuel use and based on the Federal Energy Balance. On the other hand, uncertainties for activity data derived from disaggregated fuel use normally increase as the relevant disaggregation increases.

The following list presents a number of sector-specific details that underlie calculation of uncertainties:

- Pursuant to the results of an R&D project (Rentz et al., 2002), the uncertainties in emission factors for indirect greenhouse gases in stationary combustion systems (CRF 1.A.1) are relatively small, as a result of regular monitoring of such emissions. Higher uncertainties are listed for N_2O emission factors, since N_2O emissions are not normally monitored. The same applies to the emission factors for CH_4.
- In the category for the iron and steel industry (CRF 1.A.2.a), the uncertainties for the year 2017 have increased. The occurred because the steel industry association was unable to supply fuel input data via the BGS form, with the result that the trends had to be calculated on the basis of the development of production data from emissions trading. The association's inability to supply the BGS data occurred as a result of provisions of antitrust law.
- The uncertainties in the Transport category (primarily CRF 1.A.3) can generally be considered to be small, since precise relevant data on fuel use and vehicle fleets are available, due to taxation obligations, and since that category's emission factors have been very finely modelled and are normally determined via measurements. Some uncertainties may arise via systematic measuring errors or wrong disaggregation.
- In the category Fugitive emissions from fuels (CRF 1.B), the uncertainties for the activity data for oil and natural gas (CRF 1.B.2) are low, as a result of the fuels' being subject to taxation. Flaring of gases represents the only exception. The activity data for Coal mining (CRF 1.B.1) are also well-represented by production volumes. By contrast, the uncertainties for emission factors for fugitive emissions are likely to be higher. This results from the great number and diversity of the technical factors that affect fugitive emissions in transport, storage and processing of oil and natural gas.

- Considerable uncertainties are seen in many areas in the category of industrial processes (CRF 2). Activity rates based on production figures that must be reported to the Federal Statistical Office can be subject to uncertainties, especially as a result of discrepancies between reporting structures and relevant industry definitions. Activity rates determined from association information are subject to uncertainties that correlate, in each case, with the degree to which the relevant industrial sector is represented in the association in question. For emission factors, uncertainties – which can be considerable, depending on the greenhouse gas in question – result, understandably, from the factors' strong dependence on technology, in combination with extensive technological diversification. Furthermore, equipment-specific emission factors often are tied to business secrets, particularly in sectors with few market players (for example, manufacturing of chemical products (CRF 2.B)), and this tends to make operators hesitant to publish such data or leads them to provide information in consolidated form. In addition, uncertainties can be higher for complex processes in which non-combustion-related activities generate emissions, if relevant emissions-generating processes are inadequately understood and the relevant contributions of pertinent individual activities are not known.
- In the area of production of alcoholic beverages, within the area of Food and drink production (CRF 2.H.2), the activity-rate uncertainties must be considered very small, since production of such beverages is subject to taxation regulations that require very precise determination of production volumes. On the other hand, statistics for sectors with large numbers of small and medium-sized enterprises (such as baked-goods production) tend to be significantly less precise, and thus the activity data for such sectors are subject to higher uncertainties. The uncertainties for the relevant emission factors are also larger, due to the sectors' extensive technological diversification.
- The uncertainties for emissions parameters for the categories Managed waste disposal in landfills (CRF 5.A.1, 5.B and 5.E) and Industrial wastewater treatment (CRF 5.D) are presumed to be high. This applies especially to the areas of composting, MBT and waste landfilling, which have high waste-type diversity that tends to reduce the reliability of data for the relevant emissions parameters. The reasons for the higher uncertainties seen for activity data include the fact that the underlying statistical data make use of non-standardised waste and recycling definitions. The general assumptions relative to the uncertainties of activity data also apply to thermal treatment of waste.

1.7.1.2 Results of uncertainties assessment

The total uncertainty of the inventory for the year 2017, pursuant to Tier 1, is 4.4 %; pursuant to Tier 2, it is -4.3/+4.5%. The following table provides a concise overview of the uncertainties of the inventory as a whole:

Table 11: Overview of the uncertainties for the inventory as a whole

	Base Year	2017	Trend	Method	Base year uncertainty		2017 uncertainty		Trend uncertainty	
	kt	kt	%		%		%		%	
National total incl. LULUCF	1,223,366	891,426	-27.13	Tier 1	5.61		4.47		5.36	
				Tier 2	-4.36	+4.54	-4.28	+4.53	-28.57	+30.10
National total w/o LULUCF	1,254,677	906,611	-27.74	Tier 1	5.39		4.07		4.65	
				Tier 2	-2.69	+2.89	-2.69	+3.12	-17.15	+18.13

The overview shows the uncertainties for the German inventory as whole, in each case both with and without CRF 4. For both cases, uncertainties are listed for the base year, for 2017 and for the trend. In each case, the uncertainties have been determined both pursuant to Tier 1 method and via use of Monte Carlo simulation (Tier 2). The latter method yields considerably better insights.

For example, only Tier 2 uncertainties properly highlight the difference between the two lines (with and without LULUCF).

Detailed information about the applicable sector-specific uncertainties is provided in Annex 7 (cf. Chapter 0). The following section describes, in greater detail, several sectors that have a great influence on the uncertainty of the inventory as a whole:

- The CO_2 emissions of the sector Combustion of fuels (1.A) contribute another important share of the total uncertainty. The predominating components of that share include solid fuels in the sector Public electricity and heat production (1.A.1.a) and mobile sources (1.A.3), especially road transports (1.A.3.b) and combustion in the residential and commercial/institutional sectors (1.A.4.a/b/c).
- Nitrous oxide emissions overall also contribute significantly to the total uncertainty. This effect is shaped especially by nitrous oxide emissions from agricultural soils (3.D) and from municipal wastewater treatment (5 D.1).
- The CO_2 sinks and sources in Sector 4 LULUCF also account for an important share of the total uncertainty.

Significant contributions to the total uncertainty also come from the areas of methane emissions from waste storage (5.A) and animal husbandry (enteric fermentation, 3.A).

1.7.2 KP LULUCF inventory

Since the same data and methods are used, under both UNFCCC and KP, for reporting for categories 4.A-4.G, the uncertainties for the two reporting areas are comparable. The information provided in the previous chapter and in the relevant category chapters (cf. also Chapter 11.3.1.5) applies.

1.8 General checking of completeness

1.8.1 Greenhouse-gas inventory

Completeness information for the various individual categories is presented in CRF Table 9(a), which is summarised in NIR Chapter 21 (Table 554 and Table 555). The following are differentiated in Germany:

- Source-specific emissions and sinks that do not occur (NO – not occurring), and
  source-specific emissions and sinks that are not reported, either because they are not quantitatively relevant or because the necessary data for calculation are lacking (NE – not estimated), and

The following section touches on a few category-specific approaches for improving the completeness of the inventory.

All combustion-related activities (1 A) from the area of energy are recorded in full. At certain points, the Energy Balance of the Federal Republic of Germany is supplemented if it is evident that complete coverage is not achieved in selected sub-sections (such as the non-commercial use of wood, secondary fuels). In some categories, separation of combustion-related and non-combustion-related emissions from industry requires further verification. In general, avoidance of duplicate counting is an important part of quality assurance for such categories, however.

In the area of industrial processes, some use is made of production data from association statistics and of manufacturers' information. In the interest of the inventory's completeness and reliability, where emissions reporting is based on such sources, checking of category definitions and data-collection methods will continue to receive priority.

The emissions that are reported as "not estimated" (NE) consist of emissions that, pursuant to 24/CP.19 Annex I (cf. FCCC/CP/2013/10/Add.3), would be of secondary importance relative to the overall level and development of national emissions. An emission may be considered insignificant only if the emission is likely to account for less than 0.05 percent of the total national GHG emissions and if it does not exceed 500 kt CO_2 equivalent.

Some of the emissions data available to the Federal Environment Agency are confidential, due to data-protection requirements, and thus are reported only in aggregated form – although they are reported completely.

1.8.2 KP LULUCF inventory

Since, for reporting for categories 5.A-5.G, the data and methods used for reporting under UNFCCC do not differ from those used for reporting under KP, the information provided in the previous chapter applies.

2 Trends in Greenhouse Gas Emissions

Table 12 below shows the total emissions, as determined for this inventory, of direct and indirect greenhouse gases and of the acid precursor SO_2. Table 13 shows the annual progress achieved, with respect to 1990, for each pertinent year. With the exception of HFC, and the rather minimal emissions of NF_3, considerable emissions reductions were achieved for all substances. In total, greenhouse-gas emissions, calculated as CO_2 equivalents, decreased by 27.5 %, with respect to 1990[18].

All detailed tables relative to discussion of trends are presented in Annex Chapter 22.3.

Trends, taking account of changes with respect to the previous year of the reporting period

With regard to the previous year, 2016, total emissions decreased by 0.5 %. The reduction is due to yet another decrease in the energy industry; the industry consumed smaller quantities of coal and greater quantities of natural gas. At the same time, renewable energies' share of the energy mix increased considerably.

[18] All figures do not include emissions from the category of Land Use, Land-Use Change & Forestry (LULUCF).

Table 12: Emissions of direct and indirect greenhouse gases and SO_2 in Germany since 1990

Emissions Trends	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
						(kt)						
CO_2 emissions (without LULUCF)	**1,052,520**	**939,543**	**900,376**	**866,640**	**832,388**	**809,749**	**814,138**	**831,570**	**792,793**	**795,940**	**801,655**	**797,966**
Net CO_2 emissions/removals	1,019,502	904,802	860,743	852,967	814,342	792,327	797,960	815,575	776,190	779,843	786,020	781,052
CH_4 (without LULUCF)	**4,838**	**4,227**	**3,552**	**2,778**	**2,374**	**2,329**	**2,353**	**2,335**	**2,289**	**2,283**	**2,237**	**2,210**
CH_4 (including LULUCF)	4,873	4,261	3,586	2,813	2,409	2,364	2,388	2,370	2,323	2,318	2,272	2,244
N_2O (without LULUCF)	**215**	**204**	**143**	**144**	**122**	**127**	**124**	**126**	**128**	**130**	**127**	**126**
N_2O (including LULUCF)	218	207	146	147	125	129	127	128	131	133	130	129
HFCs (CO_2 equivalent, 1995 base year)	**5,898**	**8,513**	**8,230**	**10,059**	**10,840**	**11,029**	**11,230**	**11,237**	**11,352**	**11,574**	**11,479**	**11,258**
PFCs (CO_2 equivalent, 1995 base year)	**3,069**	**2,099**	**975**	**852**	**356**	**285**	**248**	**262**	**238**	**247**	**252**	**234**
SF_6 (CO_2 equivalent, 1995 base year)	**4,428**	**6,467**	**4,072**	**3,321**	**3,191**	**3,254**	**3,246**	**3,352**	**3,487**	**3,652**	**3,881**	**4,241**
NF_3 (CO_2 equivalent, 1995 base year)	**C**	**C**	**C**	**C**	**54**	**52**	**25**	**6**	**6**	**C**	**C**	**C**
Total Emissions (without LULUCF) (CO_2 equi.)	**1,250,993**	**1,123,035**	**1,045,187**	**993,344**	**942,542**	**920,306**	**924,611**	**942,250**	**903,196**	**907,190**	**911,049**	**906,611**
Total Emissions/Removals with LULUCF (CO_2 equi.)	1,219,681	1,089,980	1,007,227	981,284	926,173	904,573	910,136	927,963	888,305	892,815	897,140	891,426
NO_x	**2,892**	**2,184**	**1,947**	**1,584**	**1,355**	**1,338**	**1,305**	**1,307**	**1,271**	**1,247**	**1,221**	**1,184**
SO_2	**5,486**	**1,747**	**646**	**472**	**409**	**395**	**375**	**366**	**346**	**343**	**319**	**315**
NMVOC	**3,439**	**2,066**	**1,638**	**1,349**	**1,257**	**1,147**	**1,146**	**1,102**	**1,068**	**1,042**	**1,043**	**1,068**
CO	**12,544**	**6,482**	**4,831**	**3,753**	**3,347**	**3,259**	**2,887**	**2,859**	**2,757**	**2,864**	**2,802**	**2,828**

Table 13: Changes in emissions of direct and indirect GHG and SO_2 in Germany, since the relevant reference year (1990/1995)

Emissions Trends Changes compared to base year / prev. year (%)	Base Year	Base Year to 2016	Base Year to 2017	compared to prev. year (2016 – 2017)
CO2 emissions (without LULUCF)	***1990***	-23.8	-24.2	-0.5
Net CO2 emissions/removals	1990	-22.9	-23.4	-0.6
CH_4 (without LULUCF)	*1990*	-53.8	-54.3	-1.2
N_2O (without LULUCF)	*1990*	-41.0	-41.3	-0.5
HFC	*1995*	+34.8	+32.2	-1.9
PFC	*1995*	-88.0	-88.9	-7.4
SF_6	*1995*	-40.0	-34.4	+9.3
NF_3	*1995*	C	C	C
Total emissions (without LULUCF)	**Base Year**	**-27.4**	**-27.7**	**-0.5**
Total emissons (without LULUCF)	***1990***	**-27.2**	**-27.5**	**-0.5**
NO_x	*1990*	-57.8	-59.0	-3.0
SO_2	*1990*	-94.2	-94.3	-1.3
NMVOC	*1990*	-69.7	-68.9	+2.5
CO	*1990*	-77.7	-77.5	+0.9

2.1 Description and interpretation of trends in aggregated greenhouse-gas emissions

From 1990 through 2017, greenhouse-gas emissions were reduced considerably, by 27.5 %[19]. The individual greenhouse gases contributed to this development to varying degrees (cf. Table 1). Among the direct greenhouse gases, emissions of those gases that predominate in terms of quantity were markedly reduced, with the strongest reductions occurring for methane. The main reasons for these developments are found in the following areas:

- Transition from use of solid fuels to use of liquid and gaseous fuels, which have lower emissions, in the period since 1990;
- Growing use of renewable energies, and growing, related, use of substitutes for fossil fuels;
- Increased plant (installation) efficiencies;
- Changes in animal-housing methods, and reductions of livestock populations;
- Fulfillment of legal regulations in the waste-management sector;

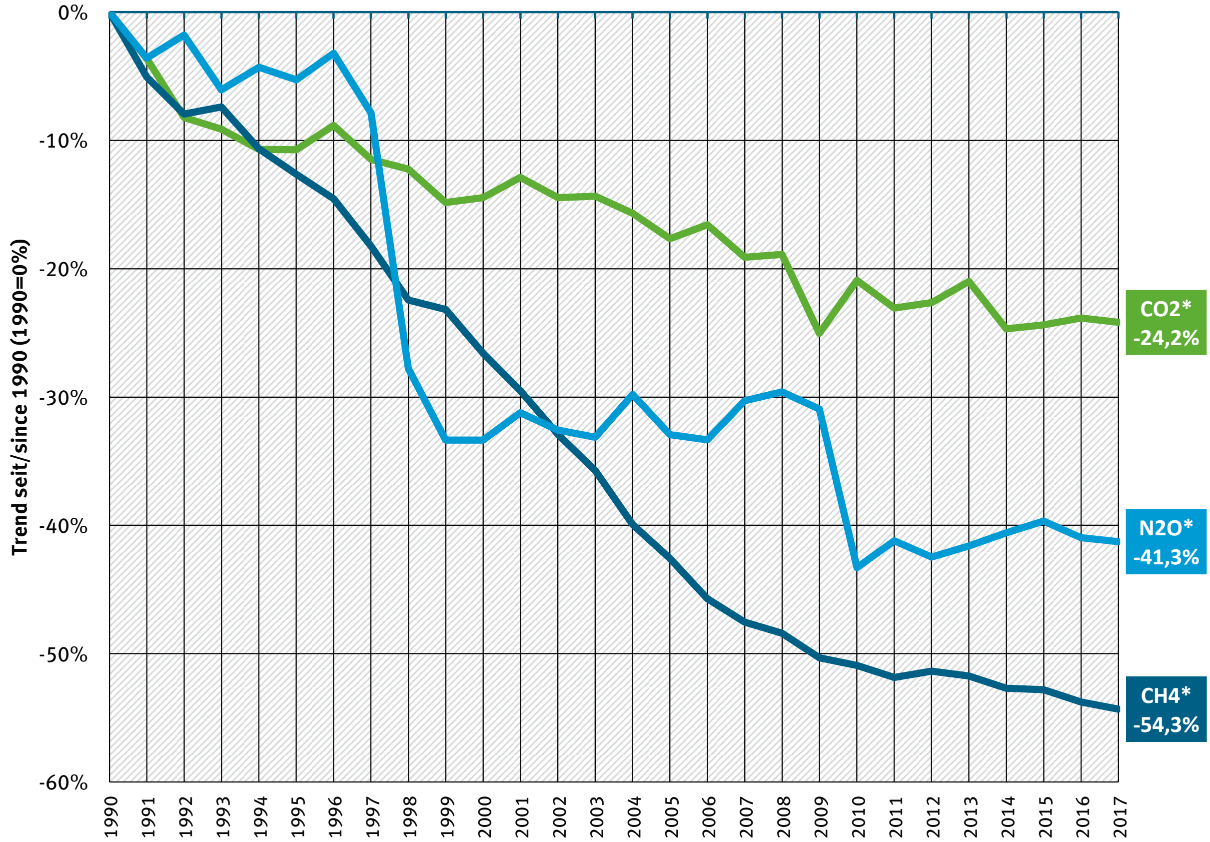
Such areas are considered in greater detail in the discussion below of trends for the various individual greenhouse gases.

Releases of carbon dioxide – the great majority of which are caused by stationary and mobile combustion processes – predominate in the overall picture of greenhouse-gas emissions. Due to a disproportionately large decrease in emissions of the other greenhouse gases, the proportion of total greenhouse gases attributable to CO_2 emissions has increased since 1990 (cf. Table 2). All other greenhouse gases together account for only slightly more than one-tenth of greenhouse-gas emissions. Germany's range of GHG emissions is typical for a highly industrialised country.

[19] All figures do not include emissions from the category of Land Use, Land-Use Change & Forestry (LULUCF).

2.2 Description and interpretation of emission trends, by greenhouse gases

Figure14: Relative development of carbon dioxide, methane and nitrous oxide with respect to 1990



* Carbon dioxide emissions apart from LULUCF

Figure14 and Figure 15 show the relative development of emissions of the various greenhouse gases since 1990. In the discussion, it must be remembered that the development of each of these greenhouse gases as shown here is largely dominated by specific developments in a single category.

2.2.1 Carbon dioxide (CO_2)

The reduction in CO_2 emissions is closely linked to trends in the energy sector. The sharp emissions reduction in this area seen in the early 1990s was primarily the result of restructuring in the new German Länder, including related conversions to cleaner fuels and decommissioning of obsolete facilities. The changes in the fuel mix have continued, to a somewhat lesser degree, through the current report year.

Use of gases, primarily natural gas, as substitutes for solid and liquid fuels is also reflected in emissions trends for stationary combustion systems. While CO_2 emissions from liquid fuels decreased by about 41 %, with respect to their levels in 1990, and emissions from solid fuels decreased by about 47 percent, emissions from gaseous fuels increased by nearly 51 percent.

When these emissions trends are viewed at the level of individual categories, a highly consistent picture emerges. In comparison to 1990 levels, emissions in all sub-categories of stationary combustion systems decreased by a total of nearly 239 million t CO_2.

The situation is somewhat different only in the transport sector, which is dominated by road transports: CO_2 emissions in this area increased through 1999, to over 184 million t, and then decreased slightly as a result of reductions in consumption, shifting of refueling to other countries[20], substitution of diesel fuel for gasoline[21] and use of admixtures with biodiesel. In about 2007, the trend began stagnating, in part as a result of ongoing increases in average engine power. In the years as of 2013, that stagnation ended, in an upwardly direction, as a result of further increases in transport densities and mileage travelled, and as a result of decreased use of biofuels (between 2012 and 2017, a constant increase amounting to a total of 13 million t). The transport sector's CO_2 emissions, at about 166 million t in 2017, are now again above their outset level in 1990 of about 162 million t.

Trends, taking account of changes with respect to the previous year of the reporting period

CO_2 emissions decreased slightly with respect to the previous year. Considerable reductions in the energy sector were offset by economically related higher emissions in manufacturing, industrial processes and transport, as well as by weather-related higher heating requirements in the residential sector.

2.2.2 Nitrous oxide N_2O

Since 1990, N_2O emissions have decreased by about 41 %. The main emissions areas/sources include agricultural use of nitrogen-containing fertilisers, animal husbandry and fuel use. Smaller amounts of emissions are caused by wastewater treatment, by the chemical industry and by product use of N_2O (for example, as an anaesthetic). Industry has had the greatest influence on emissions reductions, especially in the area of adipic acid production – via installation of waste-gas-treatment systems in 1997 and 2009. Via technological reduction measures, the chemical industry's emissions have been reduced by 97 %, with respect to 1990. Since 1999, trends in the remaining emissions have been strongly influenced by economic trends in the chemical industry sector.

Trends, taking account of changes with respect to the previous year of the reporting period

The total emissions increased slightly (-0.5%) with respect to the previous year, primarily as a result of slight emissions decreases (-0.6%) in the agricultural sector.

2.2.3 Methane (CH_4)

Methane emissions are caused mainly by animal husbandry in agriculture, waste landfilling and distribution of liquid and gaseous fuels; energy-related and process-related emissions, and emissions from wastewater treatment, play an almost negligible role. Methane emissions have been reduced by 54.3 % since 1990. This trend has been primarily the result of environmental-policy measures (waste separation, with intensified recycling and increasing energy recovery from waste) that have decreased landfilling of organic waste. A second important factor is that use of pit gas from coal mining, for energy recovery, has increased, while overall production of such gas has decreased (via closure of hard-coal mines). Emissions in this area have decreased by 78 % since 1990. Yet another reason for the emissions reductions is that livestock populations in the new Federal Länder have been reduced, with reductions occurring especially in the first half of the 1990s. Repairs and modernisations of outdated gas-distribution networks in that part of Germany,

[20] The emissions are calculated on the basis of domestic fuel sales. Fuel quantities not purchased in Germany thus do not enter into the German emissions inventory.

[21] Diesel fuel's share of total fuel consumption in road transports has increased sharply throughout the entire time period. In 1990, nearly two-thirds of road transport emissions were the result of gasoline consumption. Now, this ratio has nearly reversed itself.

along with improvements in fuel distribution, have brought about further reductions of total emissions.

Trends, taking account of changes with respect to the previous year of the reporting period

In comparison to the previous year, emissions decreased by 1.2 %. The largest reductions have occurred in the areas of emissions from landfills (-5.8 %) and from agriculture (-0.7 %). The latter area accounts for the largest absolute quantities involved.

2.2.4 F gases

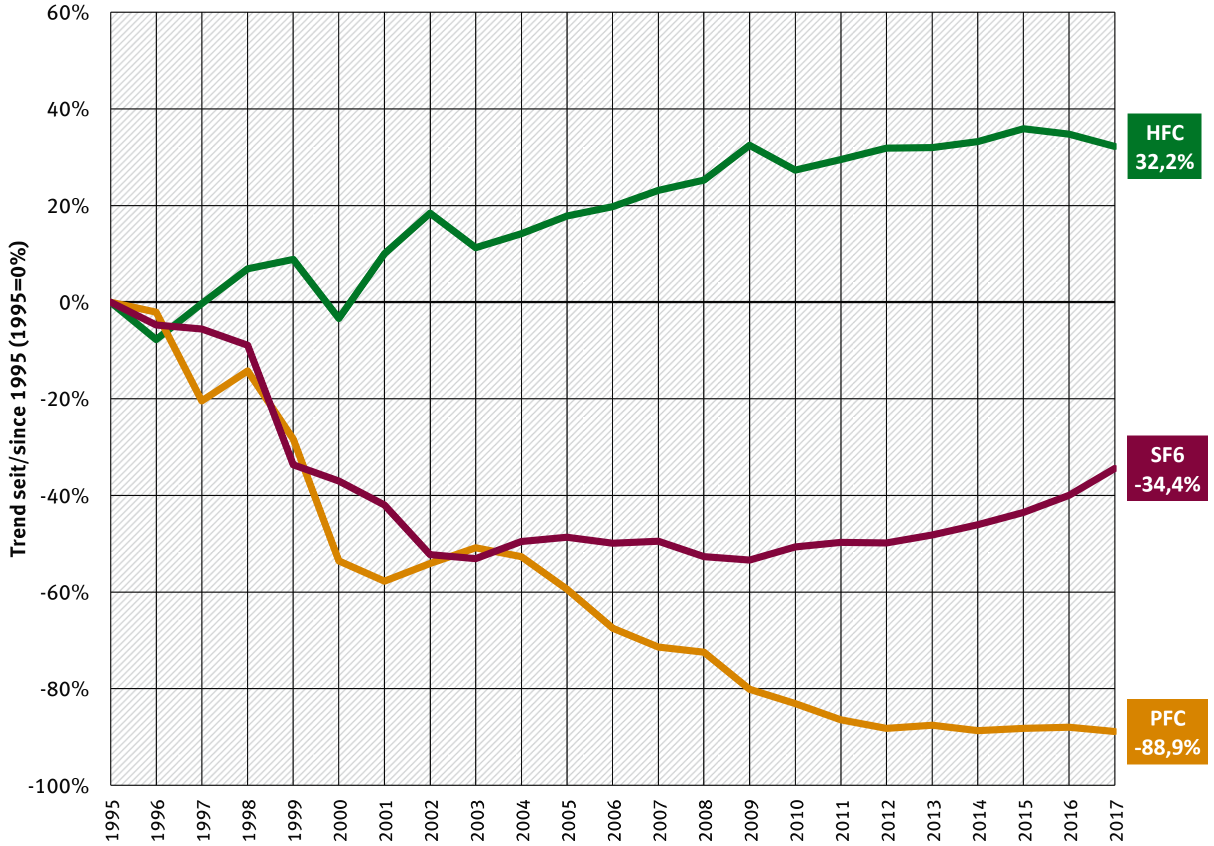
Figure 15 shows emissions trends for so-called "F" gases for the period 1995 through 2017. **HFC** emissions increased primarily as a result of intensified use of HFCs as refrigerants in refrigeration and air-conditioning systems and of increasing disposal of such systems. This more than offset emissions reductions resulting from their reduced use in PUR installation foams.

The emissions reductions for **PFCs** were achieved primarily through efforts of primary aluminium producers and semiconductor manufacturers.

The **SF_6** emissions reduction until 2003 is due primarily to decreasing use of the gas in automobile tyres since the mid-1990s. In this area, efforts to increase environmental awareness have been successful, resulting in emissions reductions of over 100 t and greenhouse-gas reductions of 2.5 million t of CO_2 equivalents. Similar success has been achieved with soundproof windows, for which production use of SF_6 has been reduced to nearly zero since 1995. And a large share of current and future SF_6 emissions (will) result from open disposal of old windows. Emissions from electricity-transmission facilities have also decreased considerably. Important remaining emissions sources include welding and production of optical glass fibre.

Since 2015, **NF_3** has been used in Germany only in semiconductor production. A large portion of the data is classified as confidential (C). For this reason, this category is reported elsewhere. Because those emissions are of such minor importance with regard to total GHG emissions, we have not carried out a separate trend analysis for them.

Figure 15: Relative development of F gases in comparison to relevant 1995 levels



2.3 Description and interpretation of emission trends, by greenhouse gases

Energy

The emissions reduction in the energy sector results primarily from a sharp decrease in combustion-related CO_2 emissions (cf. in this regard also the results of the key-category analysis). On the other hand, emissions of other greenhouse gases are negligible in this sector. The situation is different solely for emissions that are not combustion-related (category 1.B.). In this area, CO_2 emissions are very low, while emissions trends are clearly shaped by CH_4 emissions caused by distribution of liquid and gaseous fuels.

On the whole, energy-related emissions of all greenhouse gases have decreased by 26.1 % since 1990. The transport emissions included in this figure increased slightly – by about 2.2 % – over the same period In the area of emissions from stationary combustion systems, the reductions have been achieved through fuel changeovers and higher energy and technical efficiencies. In addition, increasing use of renewable energy sources is having an effect, because such energy sources are primarily supplanting fossil-fuel-based electricity generation. That said, it should be noted that carbon dioxide from use of biomass is not reflected in the emissions trends. For distribution emissions, it has resulted from increased use of pit gas, modernisation of gas-distribution networks and introduction of vapour-recovery systems in fuel distribution.

Table 562 in the Annex shows the relevant emissions changes, in comparison to the previous year in each case, for the period since 1990. For CO_2 from the energy sector, for example, it is clear that largely temperature-related fluctuations over time – especially variations in winter temperatures – influence heating patterns. Such fluctuations thus affect energy consumption for space heating, thereby having a major impact on annual trends in energy-related emissions. Consequently, any trend analysis should always cover periods of several years.

Industrial processes (including product use)

In the area of emissions from industrial processes, carbon dioxide and nitrous oxide are the predominant greenhouse gases. Relatively noticeable changes in emissions of F gases, on the other hand, have no major impacts on overall trends, because such emissions account for only a small share of total emissions.

Emissions from industrial processes are closely tied to production levels. CO_2 emissions trends, in particular, reflect economic trends in the mineral, chemical and metal-producing industries.

The trend for N_2O emissions has been decoupled from production ever since adipic acid producers' emissions-reducing measures began taking effect. In 1997 and 2010 in particular, those measures yielded considerable reductions in this sector's N_2O emissions. Overall since 1990, the sector's N_2O emissions have decreased to about one-twentieth of their outset level.

For greenhouse gases since 1990, and for all industrial processes and product use together, a reduction of 33.4 % GHG equivalents results, along with growing emissions in comparison to the previous years, 2015 and 2016.

Agriculture

The decrease in agricultural emissions since 1990, amounting to over 16.3 %, is due primarily to reductions in livestock populations, although it is also due to reductions in emissions from agricultural soils and from fertiliser use.

Land use, land-use changes and forestry

The reduction in greenhouse-gas removals via land-use changes and forestry is due primarily to a change of the sink function in the category "Forest Land remaining Forest Land". In the period 2002 through 2007, the decrease in forests' sink function was due to increasing harvesting of wood, for a range of different types of uses. In 2008, the sink function began increasing again, although it did not reach the level seen in the period 1990 through 2001. This was also due to wood use.

Waste and wastewater

The most significant emissions reduction, at 73.5 %, occurred in the area of waste & wastewater. In that area, intensified recycling of recyclable materials ("yellow sack" for recyclable materials, Ordinance on Packaging, etc.), and the ban, in effect since June 2005, on landfilling of biodegradable waste (achieved for the most part via mechanical-biological waste treatment), have reduced annual quantities of landfilled waste. All in all, these factors have reduced landfill emissions by 76.4 %. Emissions from wastewater treatment, which also belong to this category, are produced in considerably lower quantities than landfill emissions are. Nonetheless, they also decreased very sharply.

The relevant detailed data are presented in Table 563 in Annex Chapter 22.3.

Table 14: Changes in greenhouse-gas emissions in Germany, by categories, since 1990 / since the relevant previous year

Emissions change with respect to 1990; change in %	1990	1995	2000	2005	2010	2011	2012	2013	2014	2105	2016	2017
1. Energy	0.0%	-11.4%	-16.0%	-19.7%	-22.7%	-24.9%	-24.3%	-22.6%	-26.5%	-26.0%	-25.6%	-26.1%
2. Industrial processes	0.0%	1.8%	-19.4%	-21.6%	-34.8%	-34.9%	-35.9%	-36.0%	-35.9%	-37.1%	-35.0%	-33.4%
3. Agriculture	0.0%	-14.1%	-13.9%	-19.1%	-19.7%	-17.6%	-18.0%	-16.5%	-14.8%	-14.1%	-16.0%	-16.3%
4. Land Use, Land Use Change and Forestry (CO_2, CH_4 & N_2O)	*0.0%*	*5.6%*	*21.2%*	*-61.5%*	*-47.7%*	*-49.8%*	*-53.8%*	*-54.4%*	*-52.4%*	*-54.1%*	*-55.6%*	*-51.5%*
5. Waste	0.0%	0.0%	-25.3%	-44.8%	-62.0%	-63.9%	-66.0%	-67.8%	-69.6%	-70.9%	-72.1%	-73.5%
Emissions change, in each case with respect to the previous year; change in %	**1990**	**1995**	**2000**	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
1. Energy	0.0%	-0.2%	-0.4%	-2.4%	5.2%	-2.9%	0.8%	2.2%	-5.0%	0.7%	0.5%	-0.7%
2. Industrial processes	0.0%	-1.8%	3.9%	-4.1%	-4.6%	-0.1%	-1.5%	-0.2%	0.2%	-1.8%	3.2%	2.5%
3. Agriculture	0.0%	2.0%	-0.1%	-0.7%	-1.0%	2.6%	-0.6%	1.9%	2.1%	0.7%	-2.1%	-0.4%
4. Land Use, Land Use Change and Forestry (CO_2, CH_4 & N_2O)	*0.0%*	*1.6%*	*6.6%*	*28.8%*	*-9.2%*	*-3.9%*	*-8.0%*	*-1.3%*	*4.2%*	*-3.5%*	*-3.2%*	*9.2%*
5. Waste	0.0%	-2.5%	-5.2%	-6.5%	-7.2%	-5.2%	-5.7%	-5.4%	-5.3%	-4.4%	-4.2%	-4.8%

2.4 Description and interpretation of trends in emissions of indirect greenhouse gases and of SO_2

The relative development of emissions of indirect greenhouse gases and SO_2 are graphically depicted, in each case as time series since 1990, in Figure16 and in Table 13. Over this period, considerable reductions of emissions of these pollutants have been achieved. For example, emissions of SO_2 decreased by over 94.3 %, those of CO decreased by 77.5 %, those of NMVOC decreased by 68.9% and those of NO_X decreased by about 59.0 %.

The vast majority of emissions of sulphur dioxide, nitrogen oxide and carbon monoxide are caused by stationary and mobile combustion processes. In the category of NMVOC emissions, however, solvent use is the most important emissions factor.

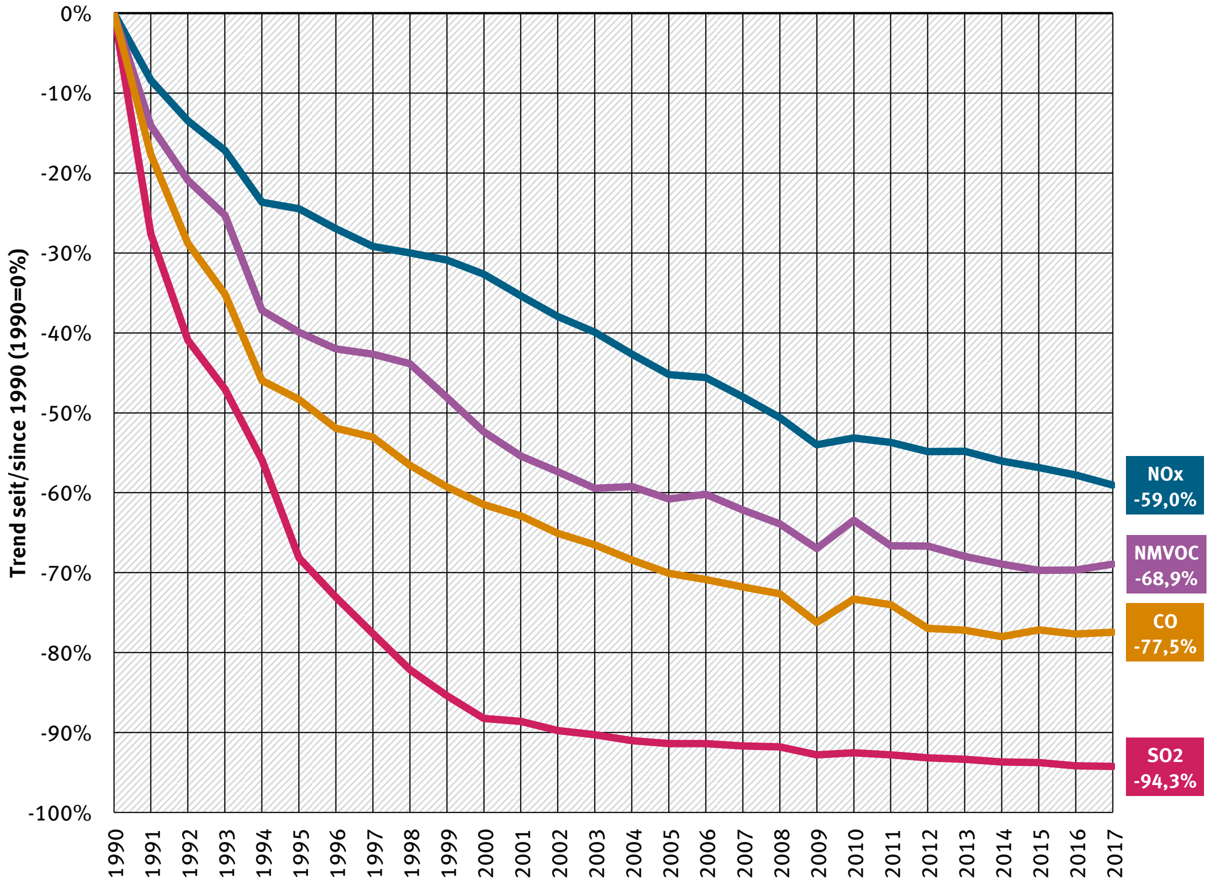
A range of different factors are responsible for this trend. These factors, which differ in the significance and extent of their relevance, include:

- As a result of Germany's reunification in 1990, emissions from the territory of the former GDR in particular made the starting level relatively high.
- In the years that followed, obsolete industrial facilities in the eastern part of Germany were decommissioned. Some of the old installations were replaced with new installations that met requirements for state-of-the-art systems at the time. Non-decommissioned old installations were extensively retrofitted with emissions-reduction and efficiency-enhancing equipment.
- In addition, changes were made in the mix of fuels used. In eastern Germany in particular, local-lignite fractions were reduced in favour of energy carriers such as natural gas and petroleum, which produce fewer emissions.
- In the transport sector, newer vehicles equipped with emissions-control technology were introduced.
- In the years since 1990, the immission-protection provisions of the former Federal Republic of Germany have become legally binding for eastern Germany. Following the expiration of provisional rulings, applicable laws have been repeatedly adapted in keeping with technological progress.
- Established legal regulations and market-economic incentives have led to thriftier use of energy and raw materials.
- International legislation, particularly from the European Community, has had an emissions-reducing effect.

- Increasing use of renewable energy sources (electricity/heat from solar and wind systems, and from geothermal systems) has also had an impact on emissions of indirect greenhouse gases, especially in recent years.

Descriptions of the emission calculations for these pollutants, along with additional, detailed parameters influencing the emissions trends for the various individual air pollutants involved, are provided on the website of the Federal Environment Agency[22].

Figure16: Emissions trends for indirect greenhouse gases and SO_2



2.5 Description and interpretation of emissions trends with regard to the KP-LULUCF inventory, for aggregated emissions and by activity and greenhouse gas

Germany reports under KP-LULUCF Article 3 (3) (Afforestation/Reforestation, AR; Deforestation, D). In the second commitment period, Germany has to credit Forest Management (FM) activities pursuant to Article 3 (4) of the Kyoto Protocol. The following activities have been selected and reported as voluntary activities under Article 3.4 of the Kyoto Protocol:

- 1. Cropland management (CM)
- 2. Grazing land management (GM).

Emissions of the greenhouse gases carbon dioxide, methane and nitrous oxide are reported.

[22] https://www.umweltbundesamt.de/themen/luft/emissionen-von-luftschadstoffen sowie direkt im Informative Inventory Report (IIR): http://iir.umweltbundesamt.de

Under Article 3.3, removals of -5,010.45 kt CO_2 equivalent for the year 2017 are being reported. The removals consist of -7,159.52 kt CO_2 equivalent of removals via afforestation and reforestation and 2,149.07 kt CO_2 equivalent of emissions from deforestation. In the category of afforestation and deforestation, CO_2 emissions of -5,168.58 kt CO_2, CH_4 emissions of 15.31 kt CO_2-eq. and N_2O emissions of 142.82 kt CO_2-eq. are being reported.

Under Article 3.4, it is reporting removals of -18,944.38 kt CO_2 equivalent in the year 2017. The figure comprises removals of -55,694.91 kt CO_2 equivalent from forest management, emissions of 14,797.01 kt CO_2 equivalent from cropland management and of 21,953.52 kt CO_2 equivalent from grazing-land management. The emissions for the three activities break down as follows by gases: CO_2: -20,107.23 kt; CH_4: 746.30 kt CO_2-eq.; and N_2O: 416.55 kt CO_2-eq.

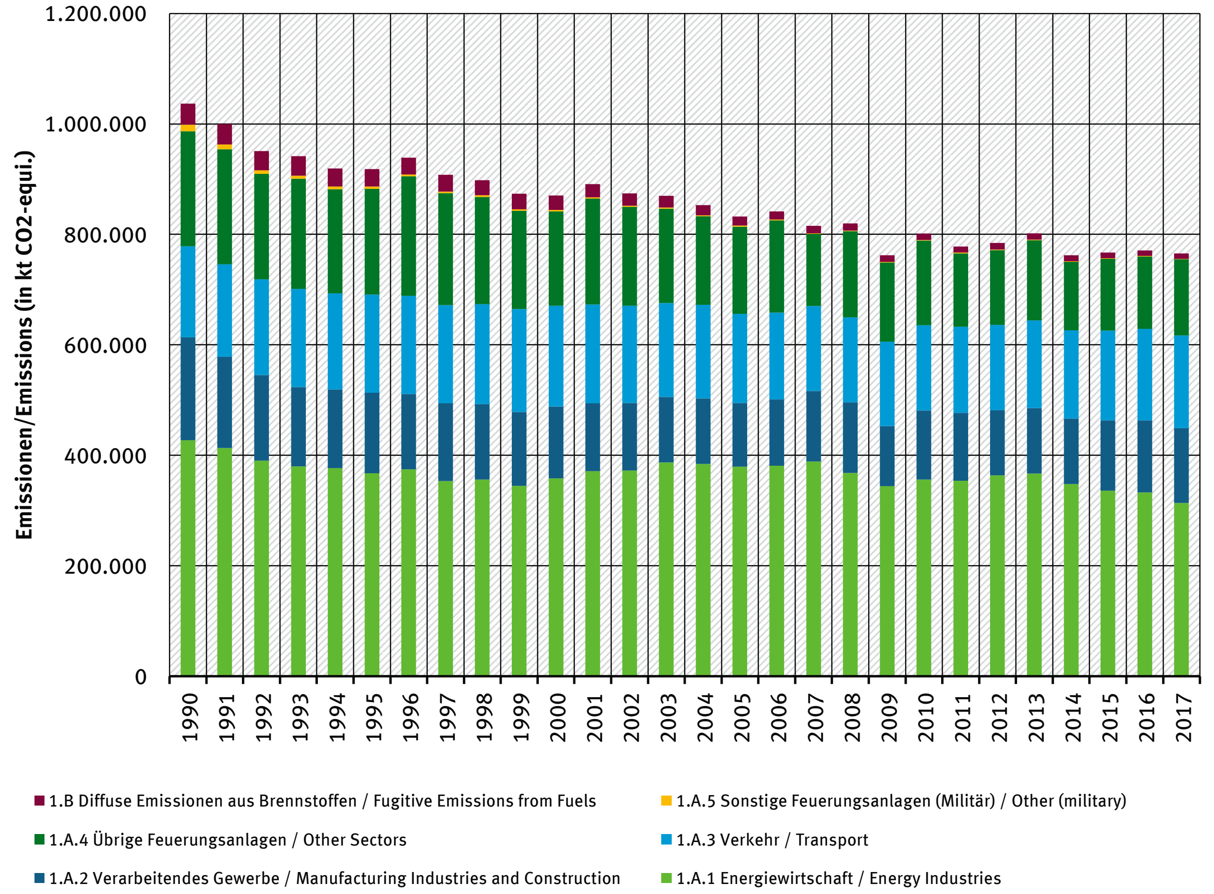
Table 15: Emissions in 2017 for the KP-LULUCF activities afforestation and deforestation, pursuant to Article 3.3, and for forest management, cropland management and grazing land management pursuant to Article 3.4.

Category	Emissions, 2017 [kt CO_2 equivalent]
KP 3.3 Afforestation/Reforestation	-7,159.52
KP 3.3 Deforestation	2,149.07
KP 3.4 Forest Management	-55,694.91
KP 3.4 Cropland Management	14,797.01
KP 3.4 Grazing Land Management	21,953.52

3 Energy (CRF Sector 1)

3.1 Overview (CRF Sector 1)

Figure 17: Overview of greenhouse-gas emissions in CRF Sector 1[23],



For determination of activity data from combustion, different models are used for mobile and stationary sources. The model used for stationary sources is the "Balance of Emissions Sources" ("Bilanz der Emissionsursachen" – BEU), while the model used for mobile sources is the "Transport Emission Estimation Model" (TREMOD). In both models, combustion-related activities are determined and then recorded in the "Central System of Emissions" (CSE) emissions database.

Within the CSE, relevant emissions are then calculated by multiplying these combustion-related activities by the pertinent emission factors (cf. Chapter 18.8). In the process, complete oxidation of the carbon contained in the fuels is assumed.

3.2 Combustion of fuels (1.A)

The activity data for stationary combustion are calculated in the "Balance of Emissions Sources" (BEU) model. This model, which was developed by the Federal Environment Agency, uses as its primary database the Energy Balance of the Federal Republic of Germany, which is prepared primarily on the basis of official statistics. The Energy Balance is described in detail in Chapters 18.1 through 18.4.

[23] CO_2 emissions from, and removals in, soils are reported under land-use changes and forestry.

With the help of additional statistics, and of various assumptions, these data on the various sectors of energy transformation and final consumption are then further disaggregated and supplemented to the extent necessary for adequate emissions representation. Relevant criteria for this work include permits under immissions-control laws, technologies and differentiation between certain fuels. The model consists of two parts: a sub-model for the old German Länder, covering the years 1987-1994, and a sub-model for all of Germany, covering the years as of 1995. The model for all of Germany has been revised and, in the reports of two research projects (FKZ 203 41 142: (Graichen et al., 2005) and 204 41 132: Heilwig (2002)) documented in detail. Since 2009, relevant calculations have been carried out with the help of a database-supported system of the BEU that is based on MESAP software and that was developed in the framework of the research projects FKZ 204 42 203/03 and FKZ 360 16 010 (GICON, 2008), via an approach similar to that used for the sub-model for Germany. The energy-data model has been regularly updated since then, by the Federal Environment Agency. Data for the new German Länder, for the period 1990-1994, have already been entered into the CSE. The manner in which those data were obtained is described in detail in Chapter 19.1.1.

The following Energy Balance lines are used for determination of emissions-relevant fuel inputs from stationary sources:

A: Transformation inputs (Energy Balance lines 9 through 19)

1. **Public thermal power stations** (line 11) are plants whose operators are sited within the public utlity sector. This category also includes industrial plants which operate their power stations together with electricity utility companies, as joint-venture power stations. The fuel input for electricity generation is reported here. This line of the Energy Balance also includes the fuel input in public thermal power stations attributable to electricity production.
2. **Industrial thermal power stations** (line 12) comprise the following operator groups:

- Power stations in the hard-coal-mining sector,
- Power stations in the lignite-mining sector,
- Power stations in the petroleum-processing sector (refinery power stations),
- Power stations that generate single-phase power for Deutsche Bahn AG (German Railways) (until 1999, the relevant input amounts for Deutsche Bahn power stations were reported under 1.A.2.g.vii (EB line 12); as of 2000, they have been reported together with public power stations under 1.A.1.a (EB line 11)),
- Industrial power stations (quarrying, other mining, manufacturing industry).

3. **Hydroelectric, wind-power, photovoltaic systems and other similar systems** (line 14) comprises all systems/plants that generate electricity from biogas, landfill gas, sewage-treatment gas or solid or liquid biomass and feed the electricity into the public grid. In addition, this section of the Energy Balance also reports on fuel inputs in mini-CHP systems fired with natural gas or light heating oil. Since no cut-off limit applies for such systems, this category includes very small systems in the residential and commercial/institutional sectors.
4. **Thermal (CHP) power stations** (line 15): only the fuel input which can be allocated to district heat generation is given. Adding lines 11 and 15 together produces the total fuel input in public thermal power stations. The district heat generated is fed into the public heating grid. These stations also supply industrial customers with process heat.
5. **District heating stations** (line 16): here, the fuel input for the public district heat supply, from heating stations, is given. The facilities are often used to cover peak loads in district heating networks in which the basic load is met by thermal power stations.

B: Energy consumption in the transformation sector (Energy Balance lines 33 through 39)

6. Lines 33 to 39 and the total line 40 (**Energy consumption in the transformation sector**) include the fuel input for heat generation which is needed to operate the transformation stations. No distinction is made here with regard to the type of heat generation involved. This means that fuel inputs for heat generation in combined heating and power stations, steam and hot water boilers and process firing installations are combined. There is an inconsistency in the Energy Balance with respect to summing-up for lignite pits and briquette plants. Since 1980, this own consumption has been listed together with production-related transformation inputs of briquette plants, in line 10. As a result, the emissions-causing inputs within own consumption can no longer be read out of the Energy Balance; they must be calculated from the transformation input. The fuel inputs used to generate heat in combined heat and power generation stations, together with fuel inputs used for electricity generation by the power stations of hard coal pits, lignite pits and refinery power stations, combine to form the total fuel input in such plants. Deduction, from the total listed in line 40, of fuel inputs for heat generation in power stations leaves the quantity of fuel used in process firing installations, steam and hot water boilers.

C: Final energy consumption (Energy Balance lines 46 through 67)

7. **Final energy consumption by industry** (line 60 of the Energy Balance) refers to the fuel used for heat generation which is required for both production purposes and space heating. Here as well, no distinction is made with regard to the type of heat generation involved. Hence, a part of the final energy consumption in these categories, together with industrial power stations' fuel input for generating electricity, constitutes the total fuel input in such facilities.
8. The data on **Final energy consumption in the residential sector** (line 66 of the Energy Balance) comprise fuel inputs for heat generation and include the application areas of heating, water heating and cooking.
9. The data on **final energy consumption in the commercial/institutional sector and by other consumers** (line 67 of the Energy Balance) comprise fuel inputs used for hot water production, space heating and process-heat generation in this sector/area.

The Energy Balance data scheme is no longer able to accommodate all of the diverse requirements of national and international energy and emissions reporting. For example, the Energy Balance combines fuel inputs

- in facilities with different requirements under immission protection legislation (e.g. large furnaces, medium-sized furnaces, small furnaces, waste incineration plants);
- In plants that operate according to different technical principles (e.g. steam turbine power stations, gas turbine power stations, combustion-engine stations)
- That exhibit regional peculiarities (e.g. different individual mining regions have different qualities of crude lignite)
- With different category allocations in national and international emissions reporting
- That are listed in different Energy Balance lines, in keeping with their intended purpose (for electricity or heat generation), but are used in a single facility group (e.g. steam turbine power stations)

These characteristics have impacts on emissions behaviour. In order to make allowance for the various differing requirements that thus arise, the Energy Balance data in the model *Balance of Emission Causes* (BEU) are disaggregated, using additional statistics as well as the Federal Environment Agency's own calculations. The following Figure 18 provides an overview of the relevant structure:

Balance of emission causes (BEU)
The categories include: • Public thermal power stations, • Hard-coal mining (until 2013), • Lignite mining, • Deutsche Bahn AG (until 1999) • Production of refined petroleum products, • District heating stations, • Other energy transformation • Quarrying of non-metallic minerals, other mining and manufacturing industry (further sub-classification of process combustion), (The residential, commercial/institutional and other consumers sectors are listed and analysed directly within the CSE, outside of the BEU model.)
The types of facilities involved include: • Steam turbine power stations, • Gas turbine power stations, • Gas and steam turbine power stations, • Motor power stations, • Boiler furnaces (excluding power station boilers), • Process furnaces (sub-classified into 12 processes).
By fuels/energy sources: • About 40 different fuels
On the basis of immission protection legislation provisions, the following are differentiated: • Installations under the 13th Ordinance on the Execution of the Federal Immission Control Act (13. BImSchV, • Facilities under the 17th Ordinance on the Execution of the Federal Immission Control Act (17. BImSchV, • Facilities under the 1st Ordinance on the Execution of the Federal Immission Control Act (1. BImSchV,   • Installations under the Technical Instructions on Air Quality Control (TA Luft) • Installations not subject to licensing

Abbreviations:

BImSchV	Ordinance on the Execution of the Federal Immission Control Act,
TA-Luft	First General Administrative Provision on the Federal Immission Control Act (Clean Air Directive)

Figure 18: Characteristics of the Federal Environment Agency's structure of the Balance of Emission Causes, with regard to disaggregation of the Energy Balance

The BEU model is designed to provide a data structure that can be used in meeting a range of different reporting obligations. In particular, finer disaggregation has been needed for determination of emissions of "classical" air pollutants, including calculation of nitrous oxide and methane emissions.

Despite the conversion of the Energy Balance to the classification of industrial sectors (WZ 93) and altered grouping of energy resources from the year 1995 onwards, it has been possible to fit the data within the outlined basic structure; this has facilitated preparation of consistent time series. As of 2008, classification of economic sectors (Wirtschaftszweige = WZ), in energy statistics, was again changed – from the "WZ 2003" standard to the "WZ 2008" standard. As a result, activity data relative to process combustion are now being taken from individual statistics, and documented, in keeping with the relevant key for the change (Statistisches Bundesamt (2008): "Umsteigeschlüssel WZ 2003 auf WZ 2008" (key for the change from WZ 2003 to WZ 2008)).

The structure and the characteristics of the Balance of Emissions Sources (BEU) were presented and described in the 2011 National Inventory Report – in Figure 20 and in Tables 16 through 22 (in tabular form). Since there have been no structural changes in the BEU since then, here we simply refer to that source, which assigns the structural elements of the BEU to the database of the Central System of Emissions (CSE), via unique names.

In addition to being classified in the aforementioned structure, the various fuels and energy sources are listed individually in the database. In the main, the various fuel categories are oriented to the Energy Balance. In some cases, there is a need to subdivide the individual fuel categories. This is done with the help of energy statistics, coal-industry statistics and a smaller number of sets of association statistics. The various fuel-quality levels, with their various carbon-content levels, are combined, in keeping with reporting provisions, in the following five categories: gases, liquid fuels, solid fuels, biomass and other fuels. Because of the many different fuels involved, and because the fuels' shares of the various categories vary, the implied emission factors listed in the CRF tables often change.

To determine activity data for waste in waste incineration plants and for co-combustion in combustion systems in the sectors Public electricity and heat generation (1.A.1) and Manufacturing (1.A.2), the Federal Environment Agency, working in the framework of a research project of its own, has carried out a thorough evaluation of fuel inputs in energy statistics (Energiestatistik) 060 and 066 (Statistisches Bundesamt, FS 3, R 3.1.7) and waste statistics (Statistisches Bundesamt, FS 19, R 1b) of the Federal Statistical Office. To ensure that all fuel quantities were taken into account, as completely as possible, the relevant waste quantities in both sets of statistics, broken down by individual industries and economic sectors, were compared. To that end, the waste quantities from waste statistics were allocated to the same fuel groups used in energy statistics: solid biomass, sewage sludge, household and settlement waste and industrial waste. In recent years, the fuel quantities recorded in energy statistics have continually increased. The reasons for this include the fact that in recent years more and more solid biomass (primarily waste and scrap wood) and processed settlement waste have been used for energy generation. Nonetheless, the waste quantities in energy statistics are still smaller than those in waste statistics. For that reason, the activity data for municipal and industrial waste are taken from the Energy Balance and then supplemented with the difference relative to waste statistics. In the Energy Balance, waste wood is listed as solid biomass, and not as waste. Consequently, to prevent double counting, in waste statistics it has to be deducted from the listed inputs for waste-incineration and combustion systems.

With regard to waste composition, as of the NIR 2006 the fossil and biogenic fractions of household / municipal waste are listed separately, in a ratio of 1:1. That split factor has been confirmed via a published research project, "Use of biogenic waste fractions for energy generation" ("Nutzung der Potenziale des biogenen Anteils im Abfall zur Energieerzeugung") (Hoffmann et al. (2011); Förderkennzeichen (funding reference number) 3707 33 303). The biogenic fractions of industrial waste vary widely by industrial sector and installation type. Accordingly, for the sector Manufacturing (1.A.2), and for the sectoral classifications iron and steel, paper, cement and lime, detailed substitute-fuel data continue to be used that are provided by the associations German Iron and Steel Institute (VDEh), German Pulp and Paper Association (VDP), the German Lime Association (BV Kalk) and the German Cement Works Association (VDZ). The biogenic fraction of the industrial waste in the aforementioned sectors was determined via the research project "Inputs of secondary fuels" ("Einsatz von Sekundärbrennstoffen") (Lechtenböhmer et al. (2006c), funding reference number 20442203/02).

3.2.1 Verification of the sectoral approach for CRF 1.A

3.2.1.1 Comparison with the CO_2 Reference Approach

Reporting on combustion-related CO_2 emissions is centrally important within the context of international climate protection, because such emissions account for a predominant share of total emissions. To this end, industrialised countries routinely adopt the category-specific approach, which addresses the level of individual energy consumption sectors and therefore permits greater differentiation in analysis of emissions structures.

In addition to being determined source-specifically, via this "Sectoral Approach" (1.AA), the CO_2 emissions are determined with the Reference Approach (1.AB) pursuant to the 2006 IPCC Guidelines (IPCC (2006) Vol. 2, Chapter 6: Reference Approach). This Reference Approach makes use of primary data relative to production, imports and exports of fuels, as well as of data on changes in stocks, that are taken directly from the National Energy Balances of the Working Group on Energy Balances (AGEB).

As with the Sectoral Approach, complete oxidation is assumed. In conformance with the 2006 IPCC Guidelines, the carbon emission factors used are equivalent to those of the Sectoral Approach and thus comprise nationally referenced values. The so-calculated CO_2 emissions data are used for verification of the Sectoral Approach.

The Reference Approach is carried out for all years as of 1990. In each case, the basis for relevant calculations consists of the National Energy Balances on primary energy consumption. At the time the inventory was being prepared, only a provisional balance was available for the year 2017.

The results of the Reference Approach (1.AB) are presented in Table 16 and in Chapter 19.4 in Annex 4 of this report. In Figure 19 and Figure20, they are compared with other available data sets, such as data of the IEA and of individual German Länder.

3.2.1.2 Verification with other data sets available for Germany

Below, for verification purposes, the results of the detailed category-based calculation of energy-related CO2 emissions for Germany, carried out in accordance with the specifications of the *IPCC Guidelines*, are compared with other available (for Germany) national and international data records on energy-related CO2 emissions for the years 1990 to 2015. For 2016, these comparative data are not yet available.

In the comparison, the calculation results are compared with data:

- from the IEA (category-specific approach) and
- from the CO_2 calculations performed at Länder level.

Table 16 and Figure 19 compare the results of the approaches for calculating CO_2 emissions, throughout the different years involved. The key development trends emerge in all calculation approaches, including the Reference Approach, albeit at differing levels. In Figure20, the relative discrepancies in the data records are depicted in order to illustrate these level differences.

Nevertheless, on the whole, these comparisons clearly confirm the CO_2 emissions figures calculated for Germany. On an average for the years 1990 to 2016, the total national energy-related emissions calculated with the *Sectoral Approach* (cf. UBA (CRF 1.A)) differ as follows from the relevant comparative data sets:

- IEA (detailed Sectoral Approach): IEA (SA)) 2.7 %
- National Reference Approach (UBA (RA)) 0.7 %
- Results of the Länder 0.7 %

Table 16: Comparison of CO_2 inventories with other independent national and international results for CO_2 emissions

Results, difference	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
IEA statistics, SA (sectoral approach)	**940.3**	**917.8**	**877.8**	**872.0**	**859.2**	**856.7**	**887.2**	**855.0**	**847.0**	**815.0**
How IEA (SA) differs from UBA (CRF 1.A)	-4.6	-3.6	-3.2	-2.8	-2.2	-2.4	-1.4	-1.7	-1.8	-2.7
Results of the Länder (energy)	**967.4**	**947.1**	**901.1**	**895.1**	**875.2**	**879.3**	**899.8**	**875.2**	**870.2**	**844.0**
How the Länder results (energy) differ from UBA	-1.8	-0.5	-0.6	-0.2	-0.3	0.1	0.0	0.7	0.9	0.8
Reference Approach UBA (RA)	**1004.0**	**960.5**	**912.4**	**903.8**	**886.3**	**877.4**	**901.0**	**870.2**	**861.2**	**840.5**
How UBA RA differs from UBA (CRF 1.A)	1.9	0.9	0.6	0.8	0.9	-0.1	0.1	0.1	-0.2	0.4
Sectoral approach UBA (CRF 1.A)	**985.6**	**951.7**	**906.6**	**896.9**	**878.2**	**878.1**	**900.1**	**869.4**	**862.8**	**837.5**
Results, difference	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
IEA statistics, SA (sectoral approach)	**812.4**	**831.6**	**818.0**	**820.8**	**804.8**	**786.8**	**799.3**	**766.8**	**775.3**	**720.3**
How IEA (SA) differs from UBA (CRF 1.A)	-2.9	-3.2	-3.2	-2.4	-2.7	-2.7	-2.5	-3.4	-3.0	-3.0
Results of the Länder (energy)	**843.8**	**870.1**	**846.9**	**842.8**	**829.1**	**817.0**	**821.8**	**798.6**	**803.2**	**751.7**
How the Länder results (energy) differ from UBA	0.9	1.3	0.3	0.2	0.2	1.0	0.3	0.6	0.5	1.2
Reference Approach UBA (RA)	**836.6**	**857.2**	**846.4**	**850.9**	**837.2**	**818.8**	**829.0**	**801.3**	**804.6**	**749.6**
How UBA RA differs from UBA (CRF 1.A)	0.0	-0.3	0.2	1.1	1.2	1.3	1.2	0.9	0.7	0.9
Sectoral approach UBA (CRF 1.A)	**836.6**	**859.4**	**844.6**	**841.3**	**827.3**	**808.6**	**819.5**	**794.2**	**798.9**	**742.6**
Results, difference	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**			
IEA statistics, SA (sectoral approach)	**758.9**	**731.3**	**744.8**	**763.9**	**723.3**	**729.7**	**731.6**			
How IEA (SA) differs from UBA (CRF 1.A)	-2.8	-3.5	-2.4	-2.1	-2.5	-2.3	-2.6			
Results of the Länder (energy)	**785.4**	**762.5**	**769.0**	**775.7**	**748.2**	**755.9**	**767.0**			
How the Länder results (energy) differ from UBA	0.6	0.6	0.8	-0.6	0.8	1.3	2.2			
Reference Approach UBA (RA)	**773.6**	**758.6**	**765.6**	**791.2**	**745.3**	**751.2**	**762.4**			
How UBA RA differs from UBA (CRF 1.A)	-0.9	0.1	0.3	1.4	0.5	0.6	1.5			
Sectoral approach UBA (CRF 1.A)	**781.0**	**757.7**	**763.0**	**780.5**	**741.9**	**746.5**	**750.8**			

Source: CO_2 Emissions from Fuel Combustion (2018 Edition), IEA, Paris.

Figure 19: CO_2 emissions in Germany – comparison of results of national and international calculations

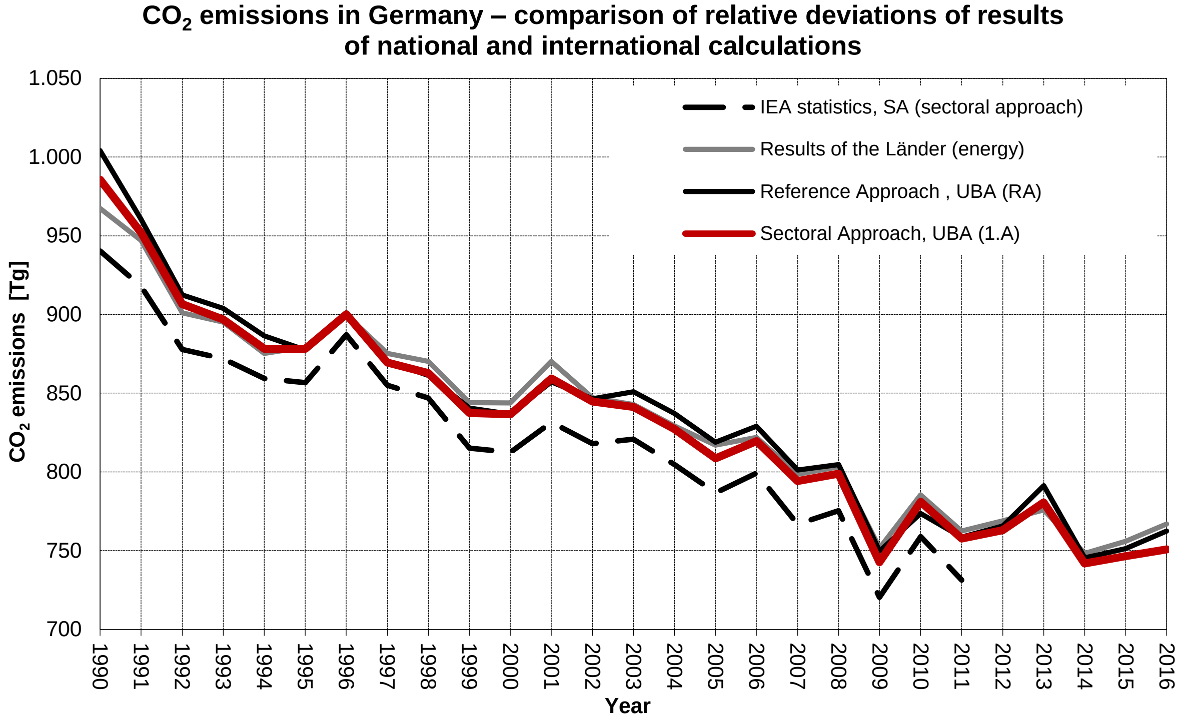
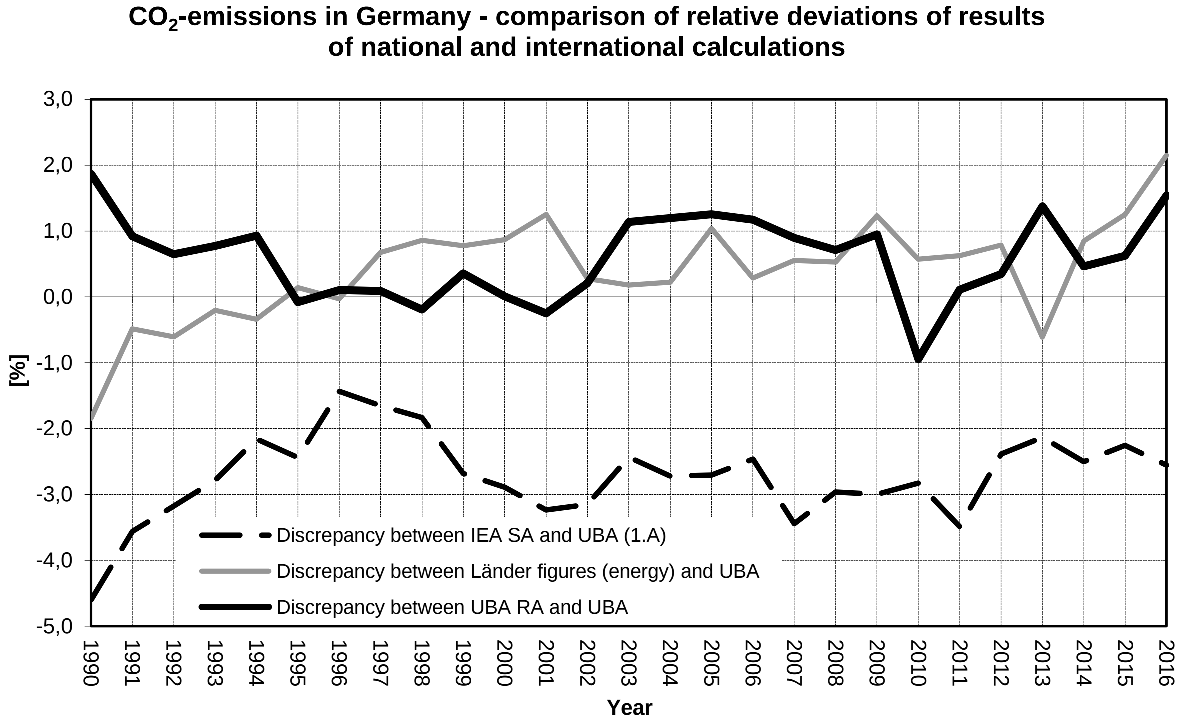


Figure20: CO_2 emissions in Germany – comparison of relative discrepancies of national and international calculations



3.2.1.2.1 Comparison with the IEA results

The data used are data published annually, in updated form, by the IEA (most recently: OECD/IEA 2018). Since the method for determining, processing and applying the basic data used for this purpose currently is not precisely comparable with the national procedure in Germany at present, and relevant addition methodological information is lacking – particularly information with regard to the detailed data used – this comparison is provided only for reasons of completeness.

In spite of this restriction, the comparison with the results obtained with IEA's Sectoral Approach confirm the data obtained via the national, detailed method: The average discrepancy over the period to date – 26 years – is 2.7 %. In all of the years concerned, the comparable national emissions are higher than the pertinent results published by the IEA. The individual discrepancies vary throughout a range of - 4.6 % (1990) to - 1.4% (1996).

3.2.1.2.2 Comparison with the data obtained for the individual Länder

The German Länder publish data on their own CO_2 emissions[24]. Regarding the relevant procedures, responsible and participating institutions, and methodological descriptions, we call the reader's attention to that Web site and to the pertinent more detailed remarks in the NIR 2009.

The following section presents a comparison, for energy-related CO_2 emissions, of a) available Länder results published to date in the Balance of Emissions Sources (BEU) and b) inventories calculated at the national level. One difficulty hampering the comparison is that pertinent information for the individual Länder is not always available in the form of complete time series. Gaps in the time series were closed primarily via interpolation. Since data for 2017 are currently available for only a few German Länder, the comparison is limited to the period 1990 to 2016, and the few missing values for 2016 are extrapolated on the basis of an expert judgement..

[24] Landesarbeitskreis Energiebilanzen – CO_2-Bilanzen http://www.lak-energiebilanzen.de/co2-bilanzen/

Table 17: Comparison of the results of CO_2 calculations of individual Länder with corresponding figures from the federal inventories

State (Land)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
					[Gg CO_2]					
Baden-Württemberg	74,299	78,782	78,071	78,831	74,155	77,861	81,343	78,244	79,643	77,050
Bavaria	83,814	88,347	86,403	89,517	87,162	87,535	91,796	89,407	90,506	88,172
Berlin	26,500	27,607	24,773	26,109	25,138	24,204	24,373	23,325	22,551	23,276
Brandenburg	80,451	64,579	57,684	55,976	52,954	50,261	49,825	50,306	58,615	57,841
Bremen	13,376	13,569	12,859	12,449	13,276	13,176	14,177	14,147	13,828	12,758
Hamburg	12,160	13,863	12,572	13,226	12,741	12,793	13,865	13,285	*13,209*	*12,811*
Hesse	42,638	46,377	46,081	47,414	47,068	47,019	50,270	47,278	47,125	43,908
Mecklenburg – West Pomerania	15,539	10,757	9,360	9,473	9,510	10,233	11,636	10,654	10,413	10,627
Lower Saxony	76,594	81,735	*77,507*	*77,021*	77,784	*77,862*	77,939	*78,766*	79,592	*76,433*
North Rhine – Westphalia	297,281	308,160	304,377	298,004	293,723	301,029	310,042	304,648	302,239	291,442
Rhineland-Palatinate	27,453	29,513	28,999	30,330	30,363	31,579	31,598	31,756	31,266	30,408
Saarland	23,680	25,750	24,378	23,194	24,289	23,109	23,829	21,802	23,769	22,800
Saxony	92,188	76,967	63,953	65,922	62,915	61,368	56,440	51,044	37,076	35,047
Saxony-Anhalt	49,522	35,226	31,172	26,901	25,715	24,865	25,250	24,538	24,735	26,566
Schleswig-Holstein	24,417	24,032	24,303	24,823	24,462	23,253	23,778	23,189	22,934	22,404
Thuringia	27,483	21,868	18,566	15,894	13,925	13,203	13,634	12,831	12,709	12,430
Result for all German Länder	**967,395**	**947,132**	**901,058**	**895,084**	**875,180**	**879,350**	**899,795**	**875,220**	**870,210**	**843,972**
National result (CRF 1.A + CRF 1.D.1.a)	**985,570**	**951,739**	**906,580**	**896,921**	**878,184**	**878,100**	**900,063**	**869,365**	**862,817**	**837,486**
Difference between the Länder results and the national results (Gg)	**-18,175**	**-4,607**	**-5,522**	**-1,837**	**-3,004**	**1,250**	**-268**	**5,855**	**7,393**	**6,486**
Difference between the Länder results and the national results (%)	**-1.8**	**-0.5**	**-0.6**	**-0.2**	**-0.3**	**0.1**	**0.0**	**0.7**	**0.9**	**0.8**

State (Land)	2000	2001	2002	2003	2004 [Gg CO_2]	2005	2006	2007	2008	2009
Baden-Württemberg	74,181	79,613	76,303	75,898	74,995	77,137	77,933	70,614	72,400	66,227
Bavaria	86,064	87,988	81,911	81,618	80,343	77,528	78,625	71,689	76,603	73,620
Berlin	23,167	23,521	20,705	20,691	19,621	19,391	19,243	16,758	17717	17240
Brandenburg	60,478	60,785	61,472	57,984	58,900	60,162	58,274	58,237	56,847	53,145
Bremen	14,029	14,115	13,988	14,693	13,076	12,152	12,627	13,558	12,947	12,665
Hamburg	*12,809*	*13,208*	*12,856*	12,065	11,997	11,958	11,579	11,063	11,173	11,300
Hesse	44,522	46,587	43,614	43,986	43,165	42,265	41,470	38,833	39,291	37,768
Mecklenburg – West Pomerania	10,256	10,718	10,908	10,696	10,906	10,354	11,133	10,044	10,835	9,515
Lower Saxony	73,273	*72,287*	71,300	*70,670*	70,040	*70,283*	70,526	*69,915*	69,304	66,087
North Rhine – Westphalia	291,407	297,628	293,074	293,626	288,415	279,180	283,310	285,647	282,936	256,712
Rhineland-Palatinate	28,946	29,659	27,946	26,832	26,153	26,080	26,786	25,876	27,479	26,333
Saarland	23,409	23,213	22,914	23,232	23,900	24,776	23,555	25,697	22,947	18,498
Saxony	41,511	48,837	49,006	49,605	48,437	47,312	48,493	46,830	46,115	46,894
Saxony-Anhalt	25,857	26,463	27,039	27,554	26,591	27,275	27,205	25,890	26,843	26,662
Schleswig-Holstein	21,905	23,184	21,865	21,800	20,795	19,733	19,763	17,490	18,838	18,553
Thuringia	12,017	12,309	12,034	11,885	11,794	11,445	11,265	10,418	10,893	10,513
Result for all German Länder	**843,831**	**870,114**	**846,935**	**842,835**	**829,128**	**817,031**	**821,787**	**798,559**	**803,168**	**751,732**
National result (CRF 1.A + CRF 1.D.1.a)*	**836,564**	**859,369**	**844,619**	**841,335**	**827,285**	**808,620**	**819,454**	**794,171**	**798,929**	**742,566**
Difference between the Länder results and the national results (Gg)	**7,266**	**10,745**	**2,315**	**1,500**	**1,843**	**8,411**	**2,333**	**4,388**	**4,239**	**9,166**
Difference between the Länder results and the national results (%)	**0.9**	**1.3**	**0.3**	**0.2**	**0.2**	**1.0**	**0.3**	**0.6**	**0.5**	**1.2**

State (Land)	2010	2011	2012	2013	2014 [Gg CO_2]	2015	2016
Baden-Württemberg	67,840	66,091	65,371	70,532	65,434	66,807	68,454
Bavaria	76,730	74,954	74,955	75,792	71,210	72,284	73,734
Berlin	18,912	16,572	16,644	17,306	16,326	15,679	16,061
Brandenburg	55,639	56,220	56,867	56,907	55,773	55,647	56,311
Bremen	14,038	13,157	13,361	13,542	12,868	13,284	12,954
Hamburg	11,636	10,972	10,822	10,614	11,628	14,620	15,289
Hesse	38,625	36,896	36,886	36,561	33,974	35,688	36,954
Mecklenburg – West Pomerania	10,939	10,346	10,987	10,429	10,365	*10,472*	*10,625*
Lower Saxony	68,021	66,729	64,355	65,100	66,384	65,582	65,212
North Rhine – Westphalia	271,891	264,618	268,337	263,936	255,798	*258,445*	*262,226*
Rhineland-Palatinate	27,318	25,336	25,604	26,783	25,331	25,747	26,238
Saarland	19,287	20,899	21,753	22,990	21,081	21,638	*21,955*
Saxony	47,153	44,973	47,020	49,635	49,418	47,719	48,129
Saxony-Anhalt	27,287	27,144	27,625	26,999	25,509	25,125	25,403
Schleswig-Holstein	19,362	17,507	18,027	18,103	17,179	17,239	17,125
Thuringia	10,750	10,079	10,362	10,496	9,878	9,922	10,286
Result for all German Länder	**785,428**	**762,493**	**768,976**	**775,725**	**748,156**	**755,898**	**766,956**
National result (CRF 1.A + CRF 1.D.1.a)*	**780,959**	**757,737**	**762,965**	**780,510**	**741,852**	**746,545**	**750,803**
Difference between the Länder results and the national results (Gg)	**4,469**	**4,756**	**6,011**	**-4,785**	**6,304**	**9,353**	**16,153**
Difference between the Länder results and the national results (%)	**0.6**	**0.6**	**0.8**	**-0.6**	**0.8**	**1.3**	**2.2**

Remark: The italicised figures, in grey table cells, are not part of consistent time series and were generated via gap-closure procedures or extrapolation on the basis of an expert judgement (see text).

Source: © 2018 Länderarbeitskreis Energiebilanzen (Last revision: 26 March 2018)

In terms of trend, the comparison found excellent agreement between the combined Länder results and the Federal inventory. On an average for the 26 years in question, the total CO_2 emissions for the Länder differed by 0.7 % from the Federal result. The extremes of the divergences ranged from -1.8 % in 1990 to + 2.2 % in 2016.

3.2.1.2.3 Planned improvements

Following the reporting process, the results of the comparison are regularly discussed, and reviewed with regard to potential for improvement, with the representatives of the Länder Working Group on Energy Balances (Länderarbeitskreis Energiebilanzen). At present, no concrete plans for further improvements are in place.

3.2.2 International bunker fuels

3.2.2.1 Emissions from international transports (1.D.1.a/1.D.1.b)

The area of international transports is divided into international civil air transports (1.D.1.a) and international water-borne navigation (1.D.1.b).

3.2.2.2 Emissions from international air transports (1.D.1.a)

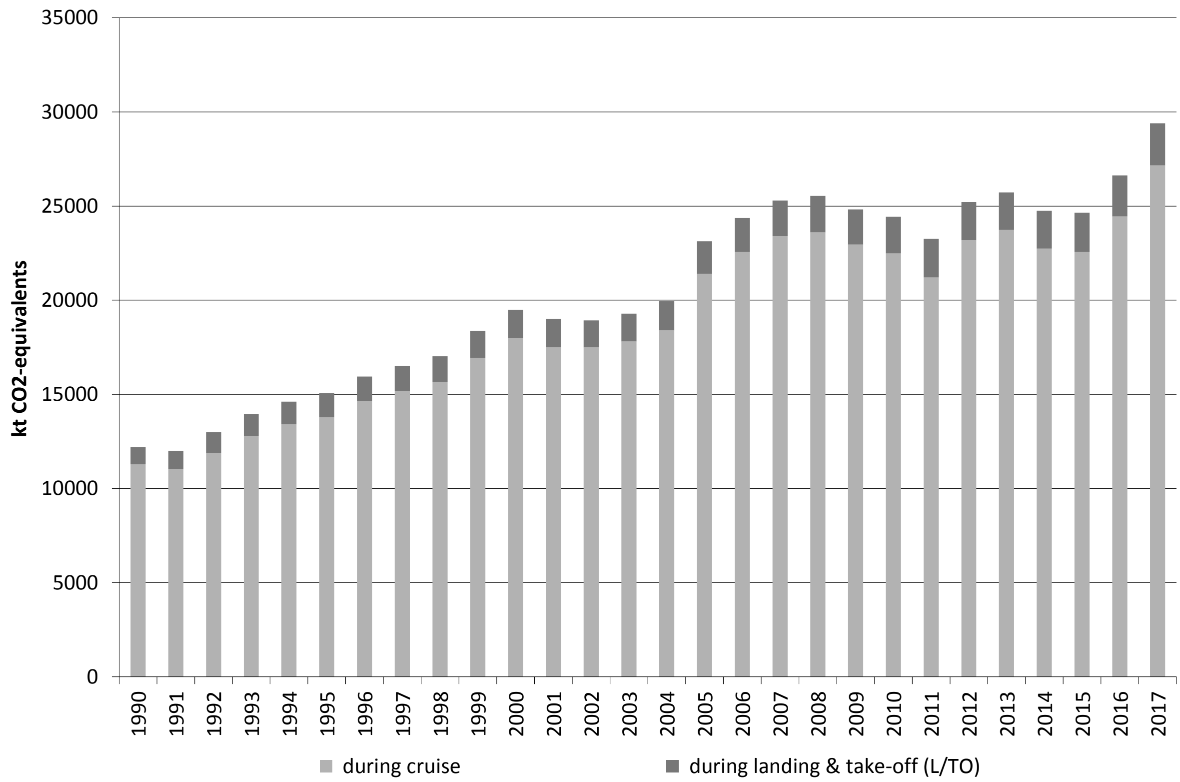
3.2.2.2.1 Category description (1.D.1.a)

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS (Tier 3)	NS/IS/M	CS / D [a]
CH_4	CS (Tier 3)	NS/IS/M	CS (M)
N_2O	CS (Tier 3)	NS/IS/M	CS (M)
NO_x, CO, NMVOC	CS (Tier 3)	NS/IS/M	CS (M)
SO_2	Tier 1	NS/IS/M	CS

[a] Co-combusted lubricants

The emissions from consumption of fuels for international civil aviation are included in the inventory calculations, but they are not reported as part of the national overall inventories, and thus they are not included in key-category analysis.

Figure 21: Greenhouse-gas emissions of international air transports departing from Germany, since 1990



3.2.2.2.2 Methodological issues (1.D.1.a)

Since German energy statistics do not break annual fuel quantities down by international and domestic air transports, that breakdown is carried out after the fact, on the basis of national air transports' annual shares of total kerosene inputs, a total calculated, using a Tier 3 method, within TREMOD-AV (Knörr et al., 2018c). Avgas consumption is reported separately, and solely for domestic aviation. It does not enter into calculation of the split factor.

International air transports' so-determined shares of the kerosene quantities listed in AGEB (2018) and in the official mineral-oil data (Amtliche Mineralöldaten) of the Federal Office of Economics and Export Control (BAFA, 2018a), are as follows:

Table 18: International flights' annual shares of domestic kerosene deliveries, in [%]

1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
85.40	87.27	88.69	91.00	91.22	91.35	91.31	91.42	91.34	90.86	91.98	92.86	92.52	92.17	92.55	93.49

Source: TREMOD AV (Knörr et al., 2018c)

Additional information relative to the activity data and emission factors used is presented in Chapter 3.2.10.1 on national civil aviation.

In addition, pertinent quantities of co-combusted lubricants, along with the resulting CO_2 emissions, are recorded and reported. Pursuant to Wallfarth (2014), it is assumed that the quantities of co-combusted lubricants are equivalent to 0.01 % of the fuel quantities used (cf. the Annex Chapter 19.1.4).

3.2.2.2.3 Uncertainties and time-series consistency (1.D.1.a)

Cf. Domestic aviation, Chapter 3.2.10.1.3.

3.2.2.2.4 Category-specific quality assurance / control and verification (1.D.1.a)

Cf. Domestic aviation, Chapter 3.2.10.1.4.

3.2.2.2.5 Category-specific recalculations (1.D.1.a)

Recalculations with respect to the 2018 Submission were carried out for all years concerned.

The revision of the specific LTO-consumption figures that is described in Chapter 3.2.10.1.4 included correction of international flights' annual shares of total fuel sales.

Table 19: Revised annual shares of domestic deliveries of kerosene, in percent

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
2019 Submission	85.40	87.27	88.69	91.00	91.34	90.86	91.98	92.86	92.52	92.17	92.55
2018 Submission	84.45	86.27	87.71	90.18	90.54	89.99	91.21	92.15	91.76	91.39	91.83
Absolute change	0.95	1.00	0.98	0.82	0.80	0.87	0.76	0.70	0.76	0.78	0.72
Relative change	1.13%	1.16%	1.11%	0.91%	0.89%	0.97%	0.84%	0.76%	0.83%	0.85%	0.78%

Table 20: Resulting revision of data on kerosene sales for flights leaving for other countries, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
2019 Submission	165,101	203,715	263,643	312,891	330,413	314,492	340,833	347,912	334,793	333,317	360,038
2018 Submission	163,258	201,388	260,737	310,074	327,514	311,464	338,004	345,271	332,038	330,500	357,241
Absolute change	1,843	2,327	2,906	2,816	2,899	3,028	2,829	2,640	2,755	2,817	2,797
Relative change	1.13%	1.16%	1.11%	0.91%	0.89%	0.97%	0.84%	0.76%	0.83%	0.85%	0.78%

The emission factors, by contrast, have remained unchanged. With them, the above adjustments yield the following changed greenhouse-gas-emissions figures:

Table 21: Revised GHG emissions, in kt CO_2 equivalents

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
Carbon dioxide[a]											
2019 Submission	12,095	14,923	19,313	22,921	24,205	23,038	24,968	25,487	24,526	24,417	26,375
2018 Submission	11,960	14,753	19,101	22,715	23,992	22,817	24,761	25,293	24,324	24,211	26,170
Absolute change	135	170	213	206	212	222	207	193	202	206	205
Relative change	1.13%	1.16%	1.11%	0.91%	0.89%	0.97%	0.84%	0.76%	0.83%	0.85%	0.78%
Methane											
2019 Submission	0.04	0.05	0.06	0.07	0.08	0.09	0.09	0.08	0.09	0.09	0.09
2018 Submission	0.05	0.06	0.07	0.08	0.09	0.10	0.10	0.10	0.10	0.10	0.10
Absolute change	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
Relative change	-14.3%	-13.1%	-12.2%	-12.6%	-12.3%	-12.4%	-12.5%	-12.7%	-12.7%	-12.8%	-12.3%
Nitrous oxide											
2019 Submission	0.381	0.470	0.608	0.722	0.762	0.725	0.786	0.803	0.772	0.768	0.830
2018 Submission	0.376	0.464	0.601	0.715	0.754	0.717	0.778	0.795	0.765	0.761	0.823
Absolute change	0.005	0.006	0.007	0.007	0.008	0.008	0.008	0.007	0.007	0.008	0.008
Relative change	1.27%	1.30%	1.24%	1.03%	1.01%	1.12%	0.97%	0.89%	0.96%	0.99%	0.91%
Total for all greenhouse gases [a]											
2019 Submission	12,209	15,065	19,496	23,138	24,434	23,257	25,204	25,728	24,758	24,649	26,625
2018 Submission	12,073	14,893	19,281	22,930	24,220	23,033	24,995	25,533	24,554	24,440	26,418
Absolute change	136	172	215	208	214	224	209	195	204	208	207
Relative change	1.13%	1.16%	1.11%	0.91%	0.89%	0.97%	0.84%	0.76%	0.83%	0.85%	0.78%

[a] Not including CO_2 from lubricant co-combustion

Source: Own calculations

3.2.2.2.6 Category-specific planned improvements (1.D.1.a)

Cf. Domestic aviation, Chapter 3.2.10.1.6.

3.2.2.3 Emissions from international water-borne navigation (1.D.1.b)

3.2.2.3.1 Category description (1.D.1.b)

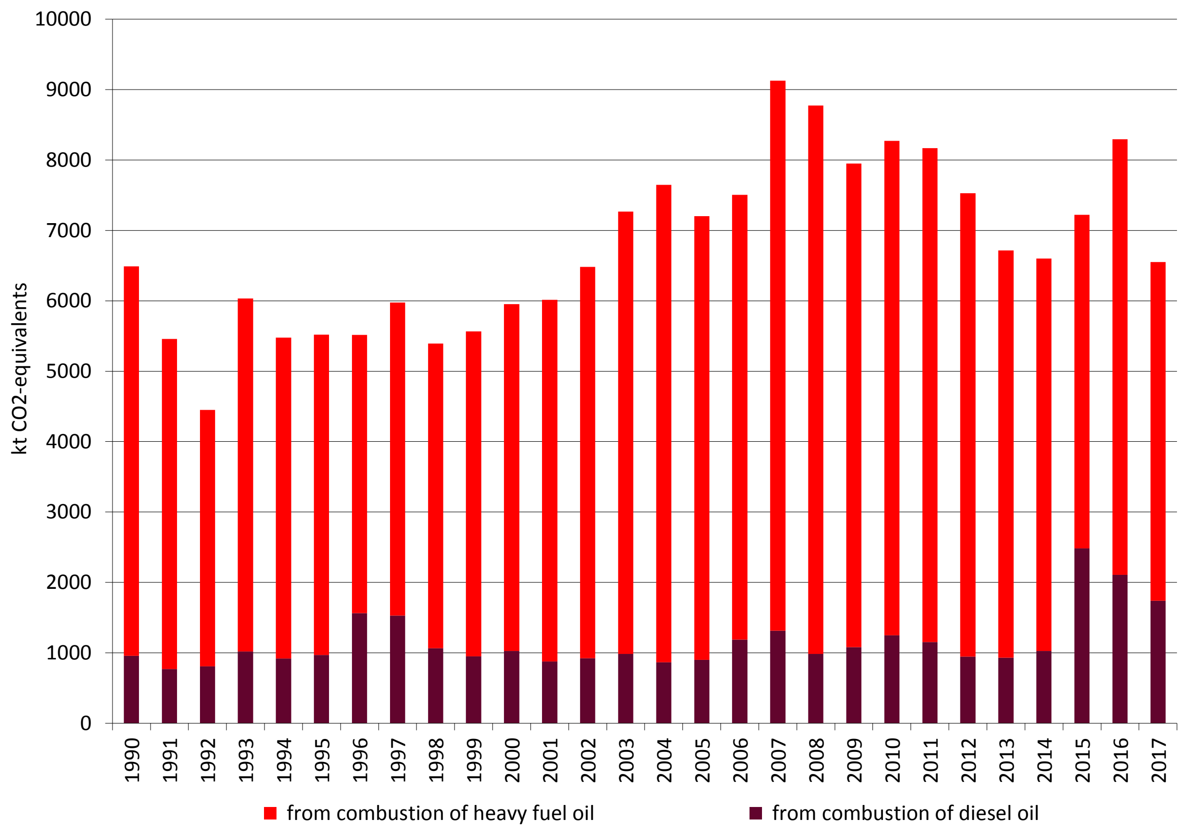
Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS (Tier 2)	NS/IS/M	D [a] / CS
CH_4	CS (Tier 2)	NS/IS/M	CS (M)
N_2O	CS (Tier 2)	NS/IS/M	CS (M)
NO_X, CO, NMVOC, SO_2	CS (Tier 2)	NS/IS/M	CS (M)

[a] Co-combusted lubricants

The emissions caused by international sea transports leaving German ports are not reported as part of the national overall inventories, and thus they are not included in the key-category analysis.

Since 1984, consumption of heavy fuel oil has been increasing, as high oil prices have pushed up prices for diesel fuels, the maritime-transport sector has grown worldwide and use of diesel engines that can run on heavy fuel oil has increased. Temporary emissions reductions, especially those that occurred in 1992 and 2009, have been / were caused by trade and oil crises.

Figure 22: Development of GHG emissions from international water-borne navigation since 1990 [a]



3.2.2.3.2 Methodological issues (1.D.1.b)

Germany reports in keeping with Tier 1. This means that emissions are calculated as the product of fuel sales in Germany, country-specific emission factors for CO_2 and default emission factors for CH_4 and N_2O.

In general, the **activity data** for sea-going ships are taken from the Energy Balances of the Federal Republic of Germany (AGEB, 2018). In Energy Balance line 6 (EBZ 6), those Balances list international bunkering for IMO-registered ships separately, because such bunkering is subject to different taxation.

For years for which an NEB does not become available on time, data published in (BAFA (2018a); for the present context: Table 6j, column: "Bunker int. Schifffahrt" ("bunkering, international shipping")) are used that enter into the National Energy Balances.

As a rule, the bunkered quantities, included in these statistics, of ocean ships traveling domestic routes (freight and passengers (1.A.3.d), fisheries (1.A.4.c iii) and military (1.A.5.b iii)) are calculated separately, pursuant to Deichnik (2018), and deducted from the total quantities listed in EBZ 6. The resulting remainder is allocated to the international water-borne navigation departing from Germany.

The sharp increase seen between 2014 and 2015 in the quantities of diesel used results from a de-facto ban on heavy fuel oil in "SECAs" *(Sulphur Emission Control Areas)*. That ban is tied to the entry into force of considerably tighter standards for the sulphur content of ship fuels.[25]

In addition, pertinent quantities of co-combusted lubricants, along with the resulting CO_2 emissions, are recorded and reported. Pursuant to Wallfarth (2014), it is assumed that the quantities of co-combusted lubricants are equivalent to 0.15 % of the fuel quantities used (cf. the Annex Chapter 19.1.4).

With regard to the pertinent **emission factors** for carbon dioxide, we refer to Chapter 18.8.

The pertinent methane and nitrous oxide emissions are calculated with the emission factors from Deichnik (2018) that are used for domestic water-borne navigation. On the other hand, also with regard to co-incineration of lubricants, it is assumed that the pertinent N_2O and CH_4 emissions are already included in the emission factors for the fuels used and thus have to be reported here as IE *(included elsewhere)*.

3.2.2.3.3 Uncertainties and time-series consistency (1.D.1.b)

Cf. Chapter 3.2.10.4.3.

3.2.2.3.4 Category-specific quality assurance / control and verification (1.D.1.b)

Cf. Chapter 3.2.10.4.4.

3.2.2.3.5 Category-specific recalculations (1.D.1.b)

Only slight recalculations have been carried out with respect to the data provided in the 2018 Submission.

The recalculations were necessitated in part by revision of the specific-fuel-consumption figures modelled in Deichnik (2018) for the years 2015 and 2016.

Table 22: Revised activity data for reported years 2015 and 2016, in terajoules

	2016			2016		
	Diesel	Heavy fuel oil	Σ	Diesel	Heavy fuel oil	Σ
2019 Submission	33,088	57,850	90,938	28,093	74,837	102,930
2018 Submission	33,592	57,850	91,442	27,455	75,564	103,018
Absolute change	-504	0	-504	639	-727	-88
Relative change	-1.50%	0.00%	-0.55%	2.33%	-0.96%	-0.09%

Source: Own calculations, based on AGEB (2018), Deichnik (2018) and Knörr et al. (2018a)

In addition, the modelled implied emission factors for methane and nitrous oxide emissions from combustion of heavy fuel oil, for the year 2016, were slightly revised.

[25] Since 1 January 2015: 0.10 %, instead of the previous maximum permitted level of 1.00 % http://www.imo.org/en/OurWork/environment/pollutionprevention/airpollution/pages/sulphur-oxides-(sox)-%E2%80%93-regulation-14.aspx

Table 23: Revised implied emission factors for heavy fuel oil, in kg/TJ

	Methane	Nitrous oxide
2019 Submission	0.736	3.393
2018 Submission	0.728	3.361
Absolute change	0.007	0.033
Relative change	0.97%	0.97%

Source: (Deichnik, 2018)

The revision of the input data leads to the recalculated emissions quantities for the years 2015 and 2016 that are shown below.

Table 24: Revised GHG emissions, in kt and kt CO_2-eq

	2015				2016			
	CO_2	CH_4	N_2O	GHG	CO_2	CH_4	N_2O	GHG
2019 Submission	7,128	0.0644	0.311	7,222	8,188	0.0801	0.348	8,294
2018 Submission	7,165	0.0648	0.313	7,260	8,200	0.0796	0.346	8,305
Absolute change	-37	-0.0005	-0.002	-38	-12	0.0006	0.002	-11
Relative change	-0.52%	-0.70%	-0.54%	-0.52%	-0.15%	0.72%	0.62%	-0.14%

Not including CO_2 from co-incineration of lubricants; source: own calculations

3.2.2.3.6 Category-specific planned improvements (1.D.1.b)

No improvements are currently planned, apart from ongoing routine revisions of the calculation model used.

3.2.3 Storage

This emissions are taken into account in the framework of the CO_2 Reference Approach.

3.2.4 CO_2 capture and storage (CCS) (CRF 1.C)

At present, CO_2 capture and storage (CCS) technology is still in the research phase in Deutschland. One pilot system is in place. According to the operator of that system, some 67 kt of CO_2 in have been injected into storage in Germany, on a trial basis (GFZ, 2018). Monitoring of the relevant experimental facilities, with measurements, has found no evidence of leakage of CO_2 from such storage. In the interest of conservative reporting, the so-stored quantities have not been deducted from the German inventory, however. For this reason, any possible leakage has already been taken into account.

In keeping with recommendations from the 2016 In Country Review, the notation key has been changed from *NE* to *NO*.

3.2.5 Special country-specific aspects

There are no special aspects that would influence reporting.

3.2.6 Public electricity and heat production (1.A.1.a)

3.2.6.1 Category description (1.A.1.a)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
L/T	**1.A.1.a Public electricity and heat production**	**All fuels**	**CO_2**	**338,451.2**	**27.67%**	**277,858.6**	**31.17%**	**-17.9%**
-/-	1.A.1.a Public electricity and heat production	All fuels	N_2O	2,407.5	0.20%	2,309.3	0.26%	-4.1%
L/T	**1.A.1.a Public electricity and heat production**	**All fuels**	**CH_4**	**172.2**	**0.01%**	**2,845.6**	**0.32%**	**1552.8%**

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	NS	CS
CH_4	Tier 2	NS	CS
N_2O	Tier 2	NS	CS
NO_X, CO, NMVOC, SO_2	CS	NS	CS

The category *Public electricity and heat production* is a key category for CO_2 and CH_4 emissions in terms of level and trend.

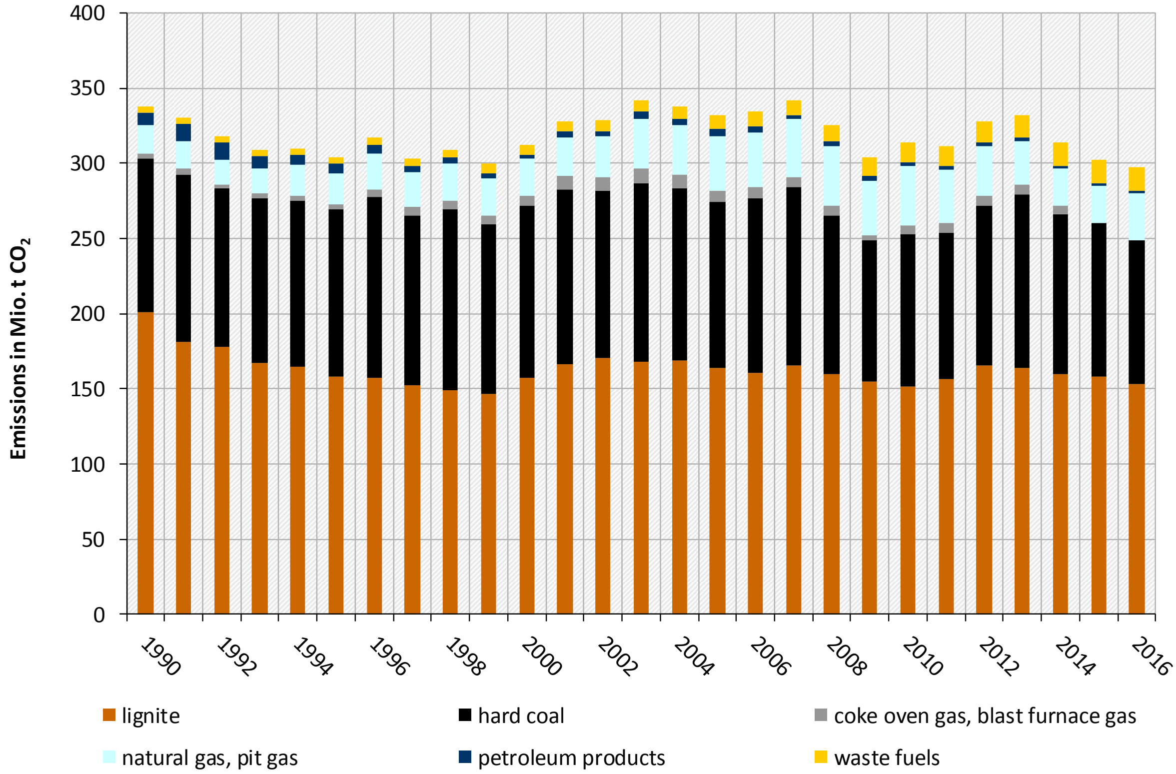
Under category 1.A.1.a, "Public electricity and heat production", the CSE includes district heating stations and electricity and heat production of public power stations. Plants that feed electricity produced from biomass into the public grid are also assigned to category 1.A.1.a.

Some 95 GW of net bottleneck capacity were in place in the public electricity generating sector in 2017. Of this amount, about 71 GW were operated with fossil fuels or with transformation products of fossil fuels. As a group, all fossil-driven plants generated some 287 TWh of electrical work (gross). This corresponds to about 71 % of all public electricity generation (about 406 TWh). About 234 TWh of electricity were generated solely with lignite and hard coal.

In 2017, combined heat and power (CHP) stations contributed net electricity production of about 51 TWh, and net heat production of 95 TWh, to the public energy supply. The district-heat supply is supplemented with heat from heat-only boiler stations that are normally run in peak-load operation. (Statistisches Bundesamt, FS 19, R 2.1.3).

The following figure presents an overview of development of CO_2 emissions in category 1.A.1.a:

Figure 23: Development of CO_2 emissions in category 1.A.1.a



Overall, emissions until 1999 show a falling trend, due primarily to closure of four lignite-fired installations in the new German Länder. Thereafter, a number of installations were replaced. As of 2000, then, the newly installed capacities, in the category of lignite-fired power stations, exceeded those of the decommissioned power stations, and thus emissions began increasing again. In 2012, and once again, several new power-station units went online, and this led to further increases in emissions from lignite. Thereafter, the emissions decreased as a result of plant closures. Throughout the entire time series, emissions from lignite-based electricity generation remained considerably below the corresponding level seen in 1990.

In the main, the emissions trend is shaped by the development and structures of the electricity generation installations involved, since those installations account for the majority of the pertinent emissions. From 1990 through 1993, electricity consumption decreased, as a result of the collapse of industry in the new German Länder. From 1994 until 2007, a marked increase in electricity consumption occurred in all sectors, sparking increases in electricity production. As a result, emissions from electricity production also increased. In addition, electricity exports increased. Those exports begin showing up in the overall balance as of 2003. The increasing trend continued through 2007, as low prices for emissions certificates prompted consumption of particularly large quantities of coal for electricity generation. Thereafter, beginning in 2008, a temporary marked emissions decrease occurred, as a result of increased use of nuclear power, natural gas and renewable energies. In 2009, the financial and economic crisis occurred, also affecting the public energy supply. In 2010, emissions increased again as a result of economic recovery. As seen via the relevant time series, hard-coal-fired power stations show higher fluctuations in fuel inputs than lignite-fired power stations do. The reason is that they, in contrast to lignite-fired power stations, are operated primarily in the medium-load range, where they respond more markedly to fluctuations in demand. What is more, they are dependent on import prices. Furthermore, as of the mid-1990s sectoral shifting occurred, from industry (1.A.1.c and 1.A.2.g) to the public electricity supply (1.A.1.a), as more and more operators reported their data in the public electricity supply category. In 2012, the classification for another major company in the hard-coal mining sector (1.A.1.c) shifted to the public electricity supply (1.A.1.a), also as part of a trend whereby operators increasingly reported data in the public electricity supply category. In 2012, the classification for another major company in the hard-coal mining sector (1.A.1.c) shifted to the public electricity supply (1.A.1.a), and this led to a significant shift of emissions between the two sectors. Another reason for the emissions increase from hard-coal-fired power stations in source category 1.A.1.a is that world-market prices for hard coal have fallen considerably since 2012. In addition, natural gas prices have increased at the same time, and this has tended to shift the fuel mix in favour of hard coal. In 2016, this effect became reversed with respect to price ratios and fuel inputs. Petroleum plays only a minor role in Germany's electricity supply. It is used primarily for auxiliary and supplementary firing in coal-fired and waste-to-energy CHP power stations, as well as for peak-load generation. Use of petroleum in these roles has dropped by more than half since 1990. In the crisis year 2009, when petroleum became considerably cheaper than natural gas, use of petroleum for peak-load generation increased again somewhat. Since then, fuel inputs have been decreasing again, and thus emissions from use of petroleum have been decreasing as well.

Use of natural gas for electricity generation has increased markedly since 1990. That trend has not led to an equivalent emissions increase, however, since the specific CO_2 emissions of natural gas are considerably lower than those of coal. The significant increase in natural gas use seen since 2005 is due especially to the commissioning of a considerable number of major gas and steam turbine power stations and medium-sized gas-turbine power stations. What is more, natural gas is increasingly being used as balancing energy for electricity generation with fluctuating renewable energies. Use of natural gas for electricity generation began decreasing again in 2010, as of result of price factors. By 2015, gas consumption even fell considerably below its level in 2005. In 2016, gas consumption finally began increasing again. That trend continued in 2017.

Since 2005, waste inputs in waste-incineration plants and for co-incineration have also been increasing, as a result of a prohibition, in force since June 2005, on landfilling of non-pretreated settlement waste. While increased use of waste in this area produces additional emissions, it helps prevent methane emissions from landfills. Use of blast furnace gas and basic oxygen furnace gas for electricity generation depends on the gas quantities produced in steel production, and is thus subject to economic fluctuations. No blast furnace gas has been used in the public supply system since 2015. In addition, operators of relevant facilities are free to report, in the framework of statistical surveys, either in the context of industry or as part of the public supply. Overall, changes in sectoral classification repeatedly occur in connection with all fuels.

In 2010, electricity generation with nearly all fossil fuels increased – sharply, in some cases – as a result of economic recovery, and this led to increased CO_2 emissions. Emissions continued to increase until 2013. This can be explained as the result of a high export surplus. On the other, it was tied to a considerable reduction in nuclear power's share of the electricity mix. Cold winters have been another reason why CO_2 emissions increased in 2010, 2012 and 2013. Overall, growing use of renewable energies has been tending to reduce emissions. CO_2 emissions have been decreasing again since 2014. The marked emissions reduction seen in 2015 is due primarily to statistical reclassification of steel industry power stations fired with blast furnace gas, as well as to considerable efficiency increases tied to ther commissioning of new hard-coal-fired power stations. Trends for 2016 and 2017 were led by price-related shifting, in the fuel mix, from hard coal to natural gas. In addition, a number of older hard-coal-fired units went offline. In the current reporting year, this has led to decreasing emissions overall.

The trend for the greenhouse gas N_2O is determined primarily by coal use. Since energy generation plants are not known to have any measures in place for reducing N_2O emissions, the decreasing trend seen since 1990 is due to reductions in coal use.

CH_4 emissions, by contrast, have been increasing since 1990. The considerable increases in biogas use since 2003 have played an especially noticeable role in this trend. Biogas is used primarily in combustion engines that have high specific methane emissions.

3.2.6.2 Methodological issues (1.A.1.a)

Activity data

In the "Balance of Emissions Sources" model, the energy inputs listed in the Energy Balance are divided among several time series, with the help of statistical data. The aim of the calculations is to produce a database that is adjusted to the special technical characteristics of electricity and heat production. As a result, fuel-specific and technology-specific emission factors can be applied to the relevant activity data.

In 2014, the Federal Environment Agency (UBA) developed a procedure for taking account of known efficiencies (with the help of the UBA's power-station database) in calculations. This was done in order to make it possible to calculate use of natural gas and light heating oil for electricity and heat generation, in gas turbines, gas-and-steam (combined cycle) systems, steam turbines and gas engines. As a result, fuel inputs can now be calculated via the electricity-generation data for the aforementioned installation types as shown in energy statistics.

As of 2012, the Energy Balance lists mini-CHP systems as producers for the public grid (i.e. to be feeding energy into the grid). Consquently, emissions from combustion of natural gas, and of light heating oil, in these installations are reported in source category 1.A.1.a. The fuel inputs for heat generation are reported in source category 1.A.4. Since the installations lie below the relevant statistical cut-off thresholds, additional data sources had to be used for this purpose. For example, analyses of sales of engine manufacturers were carried out, and the resulting data were checked by comparison with pertinent invoicing pursuant to the German Combined Heat and Power Act (KWK-Gesetz). Since relevant data are available only for the years 2012, 2013 and 2014, inconsistencies can occur in the IEF, especially that for methane.

For the 2006 report, the activity data for the new German Länder for the year 1990 were revised and substantiated in the framework of a research project (Zander and Merten (2006), FKZ 205 41 115 / sub-project A, "Revision and Documentation of Fuel Inputs for Stationary Combustion System in the new German Länder for the year 1990").

In the case of electricity and heat generation in waste incineration plants of public power stations, and of heat generation in waste incineration plants of public district heating stationsthe pertinent activity data for household and municipal waste, and for industrial waste, are taken both from the Energy Balance and from waste statistics (Statistisches Bundesamt, FS 19, R 1a).

Until a few years ago, the waste quantities listed in energy statistics and in the Energy Balance were both considerably smaller than those shown in the waste statistics of the Federal Statistical Office (Statistisches Bundesamt, FS 19, R 1b). The quality of the data provided by energy statistics has increased considerably in recent years. Such statistics now differentiate fuel data in a way that makes it possible, via calculation, to separate out figures for solid biomass (especially waste and scrap wood), biogenic gases, sewage sludge and waste heat. Industrial waste appeared as a fuel category in energy statistics for the first time in 2008. To ensure that all waste-related fuel inputs are taken into account as completely as possible, i.e. to close the gap that emerges with respect to energy statistics, it is necessary to make use of additional data from waste statistics.

As of the NIR 2006, the fossil and biogenic fractions of household / municipal waste are listed separately, in a ratio of 1/1. The fossil/biogenic composition of industrial waste varies in keeping with the type of facility involved. As a result, the biogenic fractions for co-combustion in lignite-fired and hard-coal-fired power stations, and for electricity and heat generation in public utilities' power stations fired with substitute fuels, are listed separately.

The activity data for other fuels are taken directly from the Energy Balance. Where pertinent statistical indications or experts' assessments are available, fuel inputs are additionally divided into two size classes (combustion systems smaller and larger than 50 MW). The dividing line between these two categories is based on legal regulations pertaining to licensing of combustion systems in the Federal Republic of Germany.

As of the NIR 2011, CO_2 emissions from blast-furnace-gas combustion in public power stations are reported in category 1.A.1.a. In 2015, all power stations fired with blast furnace gas that, until then, had reported in the public supply sector transferred their reporting to the industry sector. For this reason, category 1.A.1.a no longer includes use of blast furnace gas. The following table provides an overview of relevant emissions from use of blast-furnace gas, for the entire time series since 1990.

Table 25: CO_2 emissions from blast-furnace-gas combustion in public power stations

[Millions of t of CO2]									
1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
3.244	3.291	3.015	2.631	3.647	3.764	4.816	5.305	5.465	5.808
2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
5.956	9.284	9.030	9.766	9.640	6.738	7.086	6.370	5.851	3.425
2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**		
6.276	6.258	6.080	6.465	5.532	0.014	0.000	0.000		

Emission factors

Since CO_2 emissions depend on fuel quality, CO_2 emission factors are calculated and used on an overaching, inter-sectoral basis. A detailed description of the relevant procedures, and a list of the factors used, is presented in the Annex, Chapter 18.8.

The underlying data for the emission factors used for all other greenhouse gases and precursor substances is provided by the report on the research project "Ermittlung und Evaluierung von Emissionsfaktoren für Feuerungsanlagen in Deutschland für die Jahre 1995, 2000 und 2010" ("Determination and evaluation of emission factors for combustion plants in Germany for the years 1995, 2000 and 2010"; (Rentz et al., 2002)). The values for the intermediate years 1996 - 1999 and 2001 - 2009 are obtained via linear interpolation. That project, along with the linear interpolation for the intermediate years, has also provided the underlying data for the emission factors presented in Chapters , 3.2.7, 3.2.8 and 3.2.9, where the factors include power stations, gas turbines and boilers for generation of steam and hot/warm water. The research project was carried out by the Franco-German Institute for Environmental Research (Deutsch-Französisches Institut für Umweltforschung – DFIU) at the University of Karlsruhe, and it was completed at the end of 2002. The project aim was to determine and evaluate representative emission factors for the main air pollutants produced by combustion systems in Germany that are subject to licensing requirements, and to do so for the years 1995, 2000 and 2010. The procedure for achieving that aim consists primarily of analysing and characterising the relevant emitter structures, and the pertinent emission factors, for the year 1995, and then of adequately carrying that data forward for the years 2000 and 2010. The procedure systematically determines emission factors for the substances SO_2, NO_X, CO, NMVOC, particulates and N_2O. Furthermore, it differentiates between 12 coal fuels, 4 liquid fuels, 7 gaseous fuels and firewood. In addition, the available data relative to emission factors of other substances are also compiled; these other substances include PAH, PCDD/F, As and Cd for combustion systems subject to licensing requirements, and CH_4 for gas turbines and combustion systems subject to licensing requirements that fall under the TA Luft. Annex 3 (Chapter 19.1.2) discusses the procedure used in the research project.

In connection with a major research project that began at the end of 2008 and was completed in 2011 Fichtner et al. (2011), we have updated the described database for emission factors (except for that for CO_2). The reference year for the proposed values is 2004. On that basis, emission factors are being predicted for the years 2010, 2015 and 2020. As described in the reports for 2012, 2013 and 2014, numerous emission factors in the Central System of Emissions (CSE) have been updated on the basis of the research results. In Germany, N_2O is monitored only in exceptional cases; for this reason, no relevant data from regular measurements are available. On the other hand, relevant emissions behaviour in combustion of hard coal and lignite, especially in fluidised-bed combustion, has been specifically studied (this occurred especially in the 1990s). The project Fichtner et al. (2011) has reviewed and updated the values used to date. Table 26 shows the results for large installations of public power stations (with thermal outputs from combustion of 50 megawatts or more), while Table 27 shows the results for smaller installations of the energy sector and of industry. These factors have been used as a basis for calculating the category-specific emission factors for the CSE.

Table 26: Technological emission factors for nitrous oxide from large combustion systems

Fuel / combustion technology	N_2O emission factor [kg/TJ]
Public power stations:	
Hard coal / dry firing	1.0
Hard coal / slag tap firing	1.9
Lignite / dry firing	3.5
Liquid fuel / boiler firing	1.0
Natural gas / boiler firing	0.5
Industrial power stations, industrial boilers and district heating stations:	
Hard coal / dry firing	1.0
Hard coal / slag tap firing	2.0
Hard coal / fluidised bed combustion	20
Hard coal / grate firing	4.0
Lignite / dry firing	3.4
Lignite / fluidised bed combustion	8.0
Lignite / grate firing	3.5
Liquid fuel / boiler firing	1.0
Natural gas / boiler firing	0.5
Gas turbines and gas and steam turbine plants:	
Natural gas	1.7
Light heating oil	2.0
Waste incineration plants	1.2

Table 27: Technological emission factors for nitrous oxide from systems < 50 MW furnace thermal output

Fuel / combustion technology	N_2O emission factor [kg/TJ]
Boiler firing with:	
Hard coal	10.0
Lignite	10.7
Biomass	3.0
Light heating oil	1.1
Heavy heating oil	3.0
Natural gas	0.6
Gas turbines and gas and steam turbine plants:	
Natural gas	1.7
Light heating oil	2.0

Table 28: Methane emission factors for combustion systems with at least 50 MW furnace thermal output and for gas turbines

Facility type	Fuel	CH_4 emission factor [kg/TJ]
Combustion systems ≥ 50 MW furnace thermal output	Hard coal	1.0
	Lignite	0.63
	Heating oil, heavy	4.1
	Heating oil, light	3.3
	Natural gas	2.0
Gas turbines (including gas-and-steam systems)	Heating oil, light	8.0
	Natural gas	10.925
Combustion engines	Natural gas	309.0
	Biogases	312.3
Waste incineration		1.8

In a research project carried out by the Institute for Future Studies and Technology Assessment (IZT), "Aufbereitung von Daten der Emissionserklärungen gemäß 11. BImSchV" ("Processing of data in emissions declarations pursuant to the 11th Ordinance on the Execution of the Federal Immission Control Act" (Jörß & Gronewäller, 2010)), special CH_4 emission factors for gas engines were determined. The average value for natural gas as a fuel, 309 kg/TJ, is markedly higher than the previously used value, 0.3 kg/TJ, which is approximately the same as the value for steam-turbine power stations. With emissions-monitoring data, it was possible to confirm that significant methane leakage occurs via leakage of unburned natural gas. The pertinent measurements can vary considerably, in keeping with the type of engine and engine-maintenance standards involved. For biogas, sewage gas and landfill gas, an average CH_4 emission factor of 312.3 kg/TJ is used. That value was determined in the project "Emissions analysis and quantification of material flows through biogas plants, with regard to ecological assessment of agricultural biogas production and to inventory-taking in the German agricultural sector" ("Emissionsanalyse und Quantifizierung von Stoffflüssen durch Biogasanlagen im Hinblick auf die ökologische Bewertung der landwirtschaftlichen Biogasgewinnung und Inventarisierung der deutschen Landwirtschaft"), carried out by the Deutsches Biomasseforschungszentrum (German biomass research centre (DBFZ, 2011)).

Most of the emission factors used for waste incineration have been obtained from a research project carried out by the waste-management and recycling firm ATZ, "Review of emission factors for waste incineration" ("Überprüfung der Emissionsfaktoren für die Abfallverbrennung" (Daschner et al., 2010)). The N_2O emission factors have been obtained from a Danish study, "Emissions from decentralized CHP plants 2007" (Nielsen, 2010). Since the emission factors for other pollutants agree well with those for German waste incineration plants, the relevant N_2O

factors may be adopted for purposes of the German inventory. For co-combusted waste, weighted emission factors are used that vary in keeping with the pertinent shares for the various coal types that are used as the main fuel.

Information on process-related CO_2 emissions from flue-gas scrubbing (flue-gas desulphurisation) in large combustion systems is provided by Annex 3 in Chapter 19.1.2.2.

3.2.6.3 Uncertainties and time-series consistency (1.A.1.a)

Uncertainties for activity data were determined, for the first time ever, for the 2004 report year (Juhrich & Wachsmann, 2007). The method for determining the uncertainties is described in Annex 2, Chapter 13.6 of the NIR 2007.

Other aspects relative to time-series consistency of activity data are explained in Chapter 18.4 and Chapter 18.7.

The figures for the uncertainty of the CO_2 emission factor, and for the statistical distribution function for that uncertainty, have been estimated by the Federal Environment Agency. The figures are based on the range covered by the carbon contents of the various individual fuels.

The uncertainty of the determined emission factors was evaluated in the framework of the project (mentioned in Chapter 3.2.6.2) Rentz et al. (2002) and Fichtner et al. (2011).

3.2.6.3.1 Methods for determining uncertainties of emission factors

The uncertainties in emissions data result from several different factors. These include *precision*, which is influenced by chance and systematic errors in the framework of emission measurement, as well as by the completeness of the database with regard to available measurements. Another factor consists of *variability* of emissions. In this area, a distinction must be made between variability in emissions of a single plant, within the period in question (*intra-plant variability*) and differences between the emissions behaviours of the various sources considered (*inter-plant variability*).

Other sources of possible uncertainties can affect calculation of emissions with the help of emission factors. In the framework of IPCC-GPG (Penman et al. (2000): Chapter 6), methods – adapted, in each case, to data availability – are proposed:

Where *continuous* measurements have been carried out, uncertainties should be characterised via direct determination of statistical indexes such as standard deviation and the 95%-confidence interval.

In determination of *plant-specific emission factors*, any available local measurements should be used. In addition, any special operational states (start-up and shut-down processes) and load changes should be taken account of, and available measurements should be reviewed for representativeness in light of the relevant plant's emissions behaviour.

In use of *emission factors from the literature*, all of the data-quality information provided by the sources in question should also be used. Furthermore, transferability should be reviewed – to what extent is the emission factor in question representative of the situation in the relevant area being studied? If the factor is not representative, an experts' assessment should be carried out.

In general, use of *expert judgements* is recommended in cases in which available empirical data do not suffice for quantification. A sample explanation is provided in Annex 3, Chapter 14.1.2.2, of the NIR 2007.

3.2.6.3.2 Result for N_2O

The individual evaluations of the uncertainties for the N_2O emission factors are described in the final report of the research project Fichtner et al. (2011). A Monte Carlo simulation carried out by the research contractor yielded percentage uncertainties of up to +/- 50 % for CRF category 1.A.1.a (as well as for categories 1.A.1.b, 1.A.1.c and 1.A.2.gviii / all other) (remark: values for +/- ranges must be divided by 2; cf. IPCC-GPG (Penman et al. (2000): Chapter 6, p. 6.14). In the process, we continue to assume a uniform distribution of uncertainties.

3.2.6.3.3 Result for CH_4

Combustion systems in Germany are not subject to monitoring of CH_4 emissions; for this reason, no systematic-measurement data are available in this area. Consequently, relevant individual data items available in Germany and Switzerland have been relied on. As a result of this database limitation, the research project did not attempt any systematic correlation with source categories treated by the project (cf. Chapter 3.2.6.2). The CH_4 emission factors that were determined in the research project Fichtner et al. (2011) for various fuels, and that are used in the present report for combustion and gas-turbine systems (including gas-and-steam systems), have been compiled in Annex 19.1.2.2. As part of an expert judgement carried out by the research contractor, pursuant to Tier 1 of the IPCC-GPG (Penman et al. (2000): Chapter 6), an upper limit of +/- 50 % was estimated for the percentage uncertainty in source category 1.A.1.a (as well as in source categories 1.A.1.b, 1.A.1.c and 1.A.2.gviii / all other); in the process, we assume a uniform distribution of uncertainties – as was the case for N_2O.

3.2.6.3.4 Time-series consistency of the emission factors

The emission factors for N_2O were determined in the framework of a research project Fichtner et al. (2011), for the year 2004 (reference year). The research project saw no indications of changes over time in the individual emission factor. Earlier assumptions to the effect that at least the values for gas turbines might vary over time were not confirmed. For this reason, we have used constant values in each time series, for the period 1995 to 2017, and assumed that the values are valid predictive values for the period through 2020.

In this light, the time series for N_2O between 1995 and 2017 must be assessed as consistent overall. The time series of CH_4 emission factors for 1995 to 2017 were also reviewed and assessed as internally consistent.

In the NIR 2009, we reported on the period from 1990 to 1994.

To ensure time-series consistency, the CH_4 emission factors determined for combustion-engine systems were retroactively applied for the period back to 1990. Methane leakage is likely to have been higher in the early 1990s than it is with modern engine systems. Too little relevant measurement data is available for that period, however.

For most biogenic fuels, statistical fuel-input data are available only for the period since 2003. As a result, it is not possible to provide a consistent time series, for the period since 1990, for such fuels. That limitation affects only the trend for CH_4 emissions, which increases sharply as of the year 2003.

3.2.6.4 Category-specific quality assurance / control and verification (1.A.1.a)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

To document its quality-assurance measures in preparation of Energy Balances, the Working Group on Energy Balances (AGEB) submits pertinent quality reports to the Federal Environment

Agency (UBA) (cf. Chapter 18.4.1). Since 2012, the AGEB has carried out systematic comparisons of the estimated Energy Balance of year x-1 (provisional) and the Energy Balance of year x-2 (final); this was done for the first time for the report year 2010 (cf. Chapter 18.4.1).

Quality assurance for official statistics is carried out via an internal quality system. That system's quality reports are available for inspection within the Internet publications of the *Federal Statistical Office*.

In addition to these measures, the AGEB plays a role in the annual review process, and regular exchanges take place with the AGEB in the framework of an annual meeting to which the Federal Environment Agency (UBA) invites all institutes that take part in preparing the Energy Balance. At such meetings, methodological issues are discussed, and general exchanges take place for the purposes of clarifying data-collection issues and verifying data. All of this is done in light of experience gained in inventory preparation and inventory review.

General measures for assuring the quality of emission factors for combustion plants, as used in the framework of the research projects Rentz et al. (2002) and Fichtner et al. (2011), are outlined in the methods description in Annex 3, Chapter 19.1.2.1 (after Figure 89). Their results were reported in the NIR 2005.

3.2.6.5 Category-specific recalculations (1.A.1.a)

Table 29: Recalculations, CRF 1.A.1.a

Units [kt]	2018 NIR	2019 NIR	Difference, absolute					Difference, relative
Year	Total	Total	gas	liquid	other	solid	Total	Total
2008	325,961	325,956	0	0	-5	0	-5	0.00%
2009	304,532	304,023	0	0	-509	0	-509	-0.17%
2010	314,993	314,306	0	0	-687	0	-687	-0.22%
2011	312,275	311,964	0	0	-311	0	-311	-0.10%
2012	328,736	328,315	0	0	-421	0	-421	-0.13%
2013	332,132	331,764	0	0	-368	0	-368	-0.11%
2014	314,395	313,820	0	0	-575	0	-575	-0.18%
2015	302,801	301,927	-20	0	-538	-315	-874	-0.29%
2016	297,658	297,834	265	9	173	-271	175	0.06%

Recalculations of the data on waste fuels were carried out for the period 2008 – 2015, to take account of changes in classification of municipal sewage sludge in waste statistics. Waste fuels are now classified as biomass, and no longer as fossil fuels. Error correction in the area of lignite dust led, for the year 2015, to minor recalculations of the figures for solid fuels. In addition, revision of the emission factor for natural gas, for the year 2015, led to minor recalculations of the figures for gaseous fuels. For the year 2016, recalculations were carried out, as usual, to take account of the fact that provisional data were replaced by figures from the final Energy Balance.

The gaseous fuels figures for the period as of 2004 have undergone very minor recalculations that were necessitated by rounding differences that emerged from revision of a split factor.

3.2.6.6 Category-specific planned improvements (1.A.1.a)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

3.2.7 Petroleum refining (1.A.1.b)

3.2.7.1 Category description (1.A.1.b)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
L/T	**1.A.1.b Petroleum refining**	**All fuels**	**CO_2**	**20,165.6**	**1.65%**	**20,301.3**	**2.28%**	**0.7%**
-/-	1.A.1.b Petroleum refining	All fuels	N_2O	100.4	0.01%	64.6	0.01%	-35.7%
-/-	1.A.1.b Petroleum refining	All fuels	CH_4	16.1	0.00%	15.1	0.00%	-6.3%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	NS	CS
CH_4	Tier 2	NS	CS
N_2O	Tier 2	NS	CS
NO_X, CO, NMVOC, SO_2	CS	NS	CS

The category *Petroleum refining* is a key category for CO_2 emissions in terms of emissions level and trend.

The figures given above apply for refinery power stations (part of category 1.A.1.b).

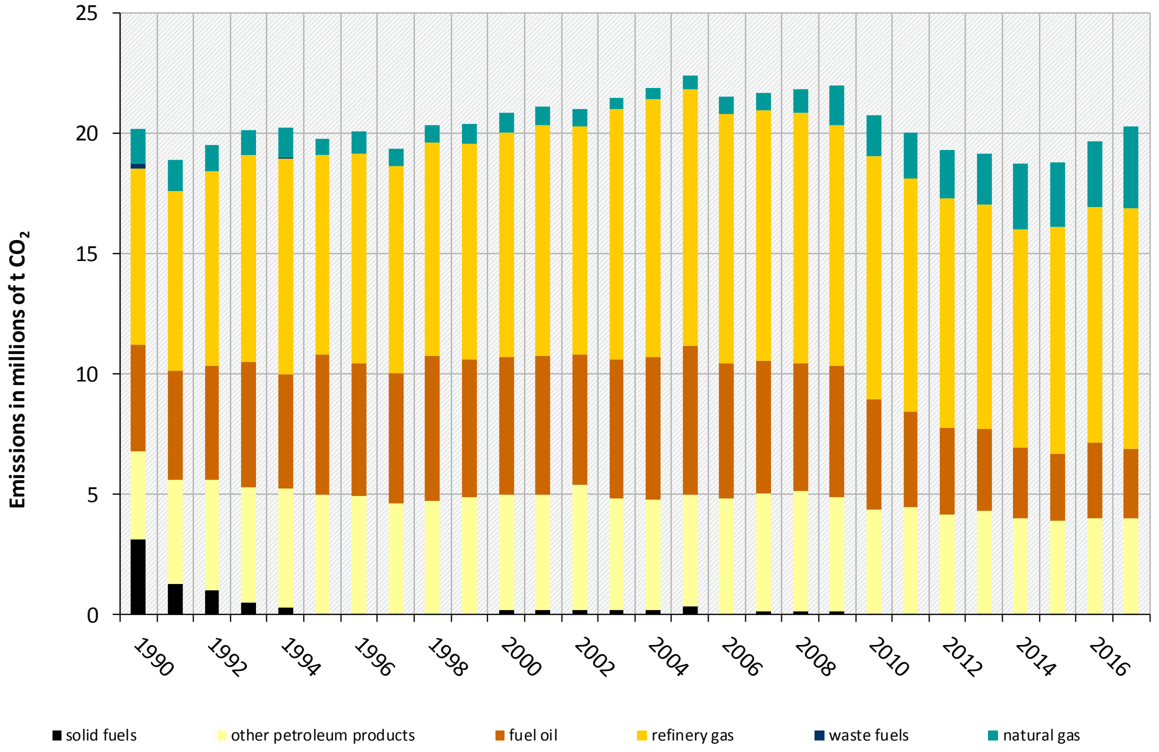
The crude oil distillation capacity of German petroleum refineries totalled around 103 Mt in 2017. In that period, 92.9 Mt of crude oil, along with 14.3 Mt of intermediate products, were input for processing. Production of petroleum products totalled 105 Mt, of which about 53 Mt consisted of fuels, about 20.8 Mt consisted of heating oils, about 8 Mt consisted of naphtha and about 23.3 Mt consisted of other products. (MWV (2018), Tab PRE1.1, Tab 4, Tab 5j).

Petroleum processing plants operate power stations with electrical output of about 1.0 GW. In 2017, those power stations generated 5 TWh of electricity (Statistisches Bundesamt, 2018b).

Under category 1.A.1.b, Petroleum refining, the CSE lists the sub-categories "refinery bottom-heating systems" and "electricity and heat production of refinery power stations".

The following figure provides an overview of emissions trends in category 1.A.1.b:

Figure 24: Development of CO_2 emissions in category 1.A.1.b



In the early 1990s, raw lignite was still being used in the new German Länder. Now, only a small quantity of coke-oven gas is reported under solid fuels in this category. Overall, the emissions show a slightly increasing trend through 2005. Thereafter, they decreased again. While some relevant installations have been decommissioned since 1990 – although such decommissioning has taken place on a smaller scale than that seen in the hard-coal and lignite mining sectors – production increased nevertheless. And while installation efficiencies were improved, increased production of lighter petroleum products, and intensified ultra-hydrodesulphurisation, initially led to increases in specific fuel consumptions. The emissions fluctuations that have occurred over the years can be explained as the result of differences in production quantities. The maximum production of petroleum products to date, totalling 123.6 million t, occurred in 2005. The pertinent emissions were correspondingly high. Thereafter, production decreased, to a level of 103.3 million t of petroleum products in 2011, and emissions decreased as a result. The market situation for oil refineries is still difficult, due to overcapacities – especially in Europe. One German refinery terminated its operations in 2010, thereby making it possible to increase capacity utilisation somewhat at the other German refineries. Emissions decreased in 2012, even though the overall production quantity increased slightly, to 104.4 million t. This trend is due to increased use of natural gas, which has lower emissions, and to improvements in plant efficiency. Following a production decrease in 2013 and 2014, gross refinery production increased in 2015, 2016 and 2017. In keeping with this trend, CO_2 emissions have also increased in the current year.

3.2.7.2 Methodological issues (1.A.1.b)

Activity data

All Energy Balance data relative to production of petroleum products have been obtained from the Official Mineral Oil Statistics. The Mineral Oil Statistics provide a comprehensive picture of petroleum imports, of transformation inputs in refineries and of refineries' own consumption. To ensure consistency, reporting in this area adheres to the structure and the definitions used in

Mineral Oil Statistics. In energy statistics, other types of companies and plants, such as companies that process coal and refineries for waste oil and lubricants, also report under industrial sector (Wirtschaftszweig) 19.2 Petroleum processing (Mineralölverarbeitung). Such installations are reported in category 1.A.1.c. Consequently, only crude oil processing is reported in category 1.A.1.b.

For purposes of reporting on emissions from crude oil refineries, the relevant plants are subdivided into refinery power stations and bottom-heating systems. The activity data for refinery-process bottom heating are obtained by subtracting fuel inputs in refinery power stations (as taken from the energy statistics) from refineries' own energy consumption (as taken from the Official Mineral Oil Statistics). This distinction plays no role in calculation of the pertinent greenhouse-gas emissions. The distinction is important, however, with regard to calculation of emissions of precursor substances and of other air pollutants, since the relevant plants differ in their emissions behaviour.

The figures for own consumption of petroleum coke that are listed in the Official Mineral Oil Statistics represent coke burn-off in catalyst regeneration within the plants. Since the basis on which the plant operators calculate their petroleum-coke inputs is not known, it is not possible to obtain a suitable CO_2 emission factor. For the years 2005 through 2014, it has been possible to determine emission factors from data, available via emissions trading, on total emissions from coke burn-off in catalyst regeneration and from plants' own consumption of petroleum coke. As a result, therefore, it has been possible to determine emissions from coke burn-off in catalyst regeneration precisely, for the relevant current years, and in agreement with in the data available from emissions trading. To make it possible to determine the pertinent factors retroactively, back to 1990, first a specific factor was defined that is oriented to the capacity of the reforming plants involved. Various reviews have found that this procedure comes closest to the underlying reality, since the available statistics do not include data on inputs and outputs of the reformers and of fluid catalytic cracking (FCC) plants. The result obtained is that emissions from coke burn-off in catalyst regeneration were considerably lower in 1990 than they were in the current year. This seems plausible, since processing of heavy petroleum products has increased considerably since 1990.

For the years 1990 – 1993, no data on own consumption of petroleum coke are available for the new German Länder. As a result, the pertinent data for those Länder had to be calculated from the emission factor determined from the emissions-trading data.

Since virtually all of oil refineries' emissions result from combustion processes, the refineries' emissions are reported in category 1.A.1.b. In two exceptions, fugitive emissions from production of calcined petroleum coke, and flare emissions, are reported in category 1.B.2.a.iv.

Emission factors

A detailed description of the relevant procedures, and a list of the CO_2 emission factors used, is presented in the Annex, Chapter 18.8.

The emission factors for N_2O, CH_4 and precursor substances for refinery power stations have been taken from the research projects Rentz et al. (2002) and Fichtner et al. (2011). A detailed description of the procedure is presented in Chapter 3.2.6.2 and in Chapter 19.1.2.1 in Annex 3. The cited project does not provide any emission factors for the bottom-heating systems that supply process heat. To compensate for this gap, for bottom-heating systems the same values for N_2O and CH_4 were chosen that are used for refinery power stations.

3.2.7.3 Uncertainties and time-series consistency (1.A.1.b)

Uncertainties for the activity data were determined for the first time in reporting year 2004 (Juhrich & Wachsmann, 2007). The method for determining the uncertainties is described in Annex 2, in the Chapter "Uncertainties in the activity data of stationary combustion systems" (Chapter 13.6 of the NIR 2007).

3.2.7.3.1 Result for N_2O

The results of Chapter 3.2.6.3.2 apply mutatis mutandis.

3.2.7.3.2 Result for CH_4

The results of Chapter 3.2.6.3 apply mutatis mutandis.

3.2.7.3.3 Time-series consistency of the emission factors

The results of Chapter 3.2.6.3.4 apply mutatis mutandis.

3.2.7.4 Category-specific quality assurance / control and verification (1.A.1.b)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

With regard to refineries, comparisons with data from the British inventory were carried out. The two countries' refinery capacities are roughly similar in size. To enhance comparability, numerous indicators were defined, for factors such as transformation inputs and production data, in addition to emissions-relevant own consumption. Comparisons of the indicators show excellent agreement.

In addition, a carbon balance is prepared for the purpose of checking data quality. The balance shows only very minor statistical differences over the relevant years.

For further information on quality assurance, cf. CRF 1.A.1.a (Chapter 3.2.6.4).

With regard to emission factors, the results of Chapter 3.2.6.3 apply mutatis mutandis.

3.2.7.5 Category-specific recalculations (1.A.1.b)

Table 30: Recalculations, CRF 1.A.1.b

Units [kt]	2018 NIR	2019 NIR	Difference, absolute				Difference, relative
Year	Total	Total	gas	liquid	solid	Total	Total
2015	18,781	18,779	-2	0	0	-2	-0.01%
2016	19,810	19,654	-137	0	-18	-155	-0.78%

Minor recalculations of the gaseous fuels figures for the year 2015 were carried out to take account of revision of the emission factor for natural gas. Provisional values for the year 2016 were replaced when the figures from the final Energy Balance for 2013 became available. That led to recalculations for all fuels.

3.2.7.6 Planned improvements, category-specific (1.A.1.b)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

3.2.8 Manufacture of solid fuels and other energy industries (1.A.1.c)

3.2.8.1 Category description (1.A.1.c)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
L/T	**1.A.1.c Manufacture of solid fuels and other energy industries**	**All fuels**	**CO_2**	**65,289.1**	**5.34%**	**9,719.0**	**1.09%**	**-85.1%**
-/-	1.A.1.c Manufacture of solid fuels and other energy industries	All fuels	N_2O	659.2	0.05%	152.9	0.02%	-76.8%
-/-	1.A.1.c Manufacture of solid fuels and other energy industries	All fuels	CH_4	92.0	0.01%	180.6	0.02%	96.4%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	NS	CS
CH_4	Tier 2	NS	CS
N_2O	Tier 2	NS	CS
NO_X, CO, NMVOC, SO_2	CS	NS	CS

The category *Manufacture of solid fuels and other energy industries* is a key category, in terms of both emissions level and trend, of CO_2 emissions.

The above figures refer to power stations, and to other boiler furnaces for production of steam and hot/warm water, in category 1.A.1.c.

Category 1.A.1.c includes hard-coal and lignite mining, coking and briquetting plants and extraction of crude oil and natural gas. In 2017, the German hard-coal mining sector extracted 3.7 million t of usable hard coal (6.2 million t in 2015) [26]. Coke production in 2017 amounted to 6.7 million t (2016: 7.6 million t)[27]. Production of hard-coal briquettes was discontinued at the beginning of 2008.

In 2017, a total of 171.3 million t of crude lignite was extracted in Germany (2016: 171.5 million t)[28]. Production of lignite briquettes and other lignite products (fluidised-bed lignite, dry lignite and lignite coke) amounted to 6.7 million t (2016: 6.42 million t). Steam for drying of raw lignite, for production of refined lignite products, is obtained from lignite-fired power stations with process-steam extraction (CHP plants). From these plants, steam is drawn off for drying crude lignite for production of lignite products.

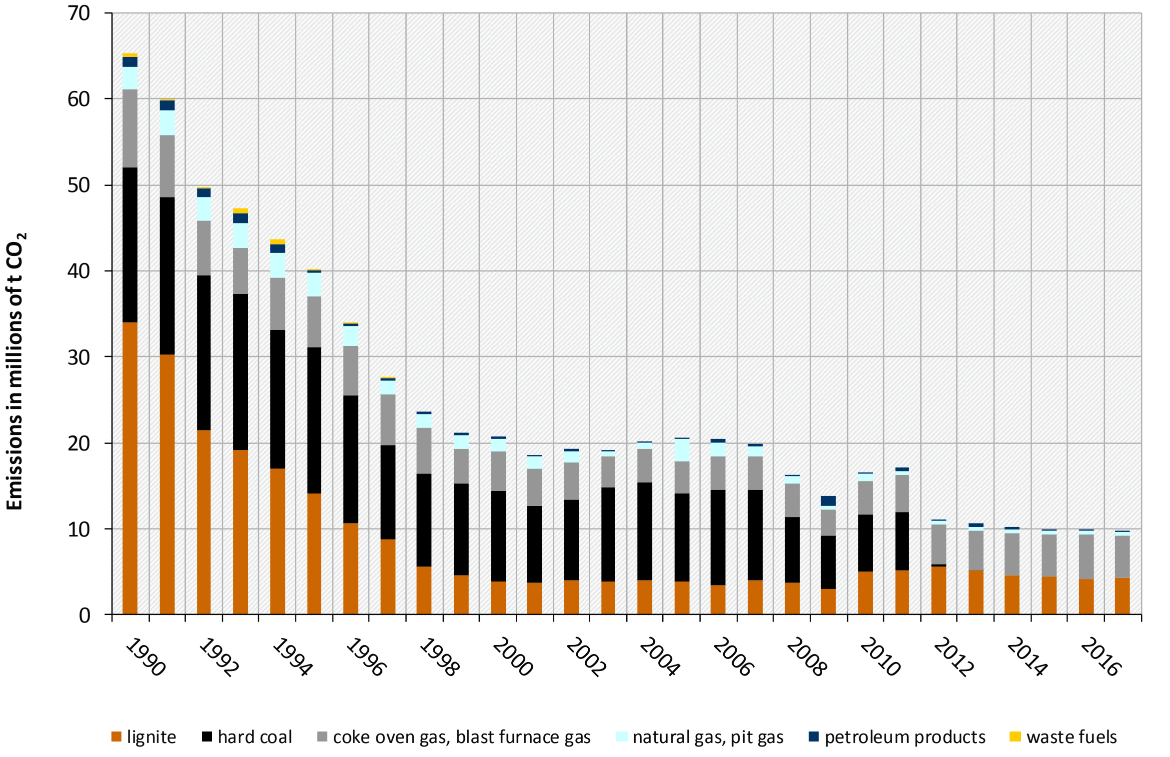
German oil production in 2017 amounted to 2.21 million t (2016: 2.36 million t)(MWV, 2018), while natural gas production in 2017 amounted to about 70.5 billion kWh Hs (2016: about 77 billion kWh Hs) (BVEG, 2018). The fuel inputs required for installations' own operations are reported in category 1.A.1.c.

In the CSE, category 1.A.1.c Manufacture of solid fuels and other energy industries includes electricity and heat production in steam-turbine power stations, broken down by hard-coal mining and lignite mining (mine power stations); electricity and heat production in gas turbines, gas engines and diesel engines of all colliery and mine power stations; other heat production in industrial boilers within the transformation sector (not including refineries); and manufacture of hard-coal coke and operation of diesel engines for propulsion purposes in colliery and mine power stations. In reporting, they are broken down into the categories "large combustion systems" and "plants falling under the Technical Instructions on Air Quality Control" (TA Luft).

The following figure provides an overview of emissions trends in category 1.A.1.c:

[26] Statistik der Kohlenwirtschaft coal-sector-statistics association 2015; cf. http://www.gvst.de/site/steinkohle/kennzahlen2015.htm of 19 September 2017
[27] Verein deutscher Kokerei-Fachleute VdKF – cf. http://web.vdkf-ev.de/site/index.php/produktionskennzahlen/ of 19 September 2017
[28] Cf. DEBRIV - http://www.braunkohle.de/122-0-Kohlenfoerderung.html of 19 September 2017

Figure 25: Development of CO_2 emissions in category 1.A.1.c



The figure clearly shows how sharply emissions in this category have decreased since 1990. The largest emissions decrease occurred in the area of lignite, use of which decreased strongly in the new German Länder in the early 1990s. The industry of the former GDR was based centrally on lignite. From raw lignite, a range of refined products used to be produced for industry, households and small commercial operations. A comprehensive transition from lignite to other fuels then took place until the end of the 1990s. In a – then considerably reduced – number of industrial plants and commercial operations, use of hard coal, petroleum and natural gas intensified, while coal-burning stoves in homes were replaced with more modern heating systems fired with heating oil and natural gas. As a result, coal briquette and dust production in the new German Länder decreased from nearly 39 million t in 1990 to about 2.6 million t in 1997. Most lignite-processing plants were closed in that period, and thus emissions decreased sharply. As of 1998, energy for drying lignite products in the new German Länder was provided solely via process steam from public power stations. In the old German Länder, improvements in plants' efficiencies, along with reduced production in that area as well, until 2003, reduced emissions. Thereafter, slight increases occurred again, as a result of production increases.

Emissions from use of hard coal in sector 1.A.1.c have been decreasing markedly since 1990. That decrease is due, firstly, to a sharp reduction in hard coal mining; while hard coal production still exceeded 70 million t in 1990, by 2016 it amounted to about 4 million t. Secondly, the decrease is due to the fact that over the years some installations have shifted, for reporting purposes, from the hard coal mining category to the public electricity supply category, thereby shifting their emissions as well. The power stations remaining in category 1.A.1.c until 2011 also fed electricity into the public grid. Beginning in 2010, fuel inputs in the lignite-fired and hard-coal-fired power stations allocated to category 1.A.1.c. increased, as a result of economic recovery and related increased electricity demand. Another explanation for the increased lignite consumption is that some power stations have been taken from the public electricity generation sector and placed in the lignite mining sector. This has led to higher emissions overall.

Use of industrial gases (coke-oven gas, blast furnace gas and basic oxygen furnace gas) also decreased until the end of the 1990s. The primary reason for this is that city-gas production was phased out through 1996, in a process involving decommissioning of local gas works. Coke production also decreased markedly. Production of hard coal coke decreased from 19 million t in 1990 to just less than half of that figure in 2008. Production in 2009 amounted to only 6.7 million t, as a result of low steel production. In 2010, then, as the economic situation improved, hard-coal-coke production increased again, to about 8 million t. Production then remained at that level through the year 2013. As a result of the expansion of one coking plant, in 2014, coke production increased again, reaching 9.3 million t in 2016. Emissions from combustion of blast-furnace gas and coke oven gas also increased as a result. In 1990, a total of 8 mine coking plants were still in operation. Today, only five coking plants remain in operation, and all belong to the steel industry ("metallurgical coking plants"). Overall, plant closures and efficiency increases have decreased emissions markedly in this sector.

In 2012, several important installations in the hard-coal mining sector were shifted, for reporting purposes, into the public sector. This very markedly reduced emissions in category 1.A.1.c. At the same time, this statistical effect led to an increase of emissions from hard-coal use in sector 1.A.1.a. For all sectors overall, emissions from hard-coal-fired electricity generation increased in 2012.

The slight emissions decrease seen in 2013 is due mainly to the closure of a mine-mouth power plant in the central German lignite-mining district and to decreased fuel inputs in mine-mouth power plants in the Rhineland area. The emissions decrease was considerably smaller, since natural gas inputs for "other energy producers" increased at the same time. Emissions remained largely stable in the years 2014 through 2017.

3.2.8.2 Methodological issues (1.A.1.c)

The calculation method has been selected on the basis of the latest key-category analysis.

Fuel inputs for electricity production in power stations of the hard-coal and lignite mining sector are listed in Energy Balance line 12, "Industrial thermal power stations". Fuel inputs for heat production in the transformation sector are listed in Energy Balance lines 33-39 and in sum line 40 ("Total energy consumption in the transformation sector").

Fuel inputs for electricity production in power stations of the hard-coal mining sector are determined with the help of figures of the Federal Statistical Office (2018b). The activity data for heat production in power stations of the hard-coal mining sector correspond to Energy Balance line 34 "Energy input in collieries and briquette plants of the hard-coal mining sector".

The listed fuel input for electricity production in mine power stations is based on association information (personal communication from DEBRIV, the federal German association of all lignite producing companies and their affiliated organisations). Inputs for heat production, especially for lignite drying for production of lignite products, are not shown in the Energy Balance. Those are calculated from figures for production of lignite products[29] and from the specific fuel inputs required for drying, and they are listed as "non- Energy-Balance inputs" in the CSE, and reported as such. The data are collected and updated via annual surveys.

The quantities of fuel used for production of hard-coal coke are taken directly from the Energy Balance, line 33 (coking plants). That line includes the coking plants' own consumption. Fuel combustion for bottom-heating systems is the largest emission source in the coking plant sector.

[29] Statistik der Kohlenwirtschaft coal-sector-statistics association 2015; cf. http://www.gvst.de/site/steinkohle/kenzahlen2015.htm of 19 September 2017

In the coking process, fugitive emissions also occur before the coke is quenched, however; these are reported in category 1.B.1.b.

The fuel input for heat production in the other transformation sector is obtained by combining the energy consumption figures in Energy Balance lines 33 to 39 (total energy consumption in the transformation sector). Those figures include mines' own consumption; facilities for petroleum and natural gas production and for processing of waste oil; plants that produce coal products; plants for production and processing of fissile and fertile materials; and wastewater-treatment facilities' own consumption.

As of the 2011 report, CO_2 emissions from blast-furnace-gas combustion in coking plants are reported in category 1.A.1.c. The following table provides an overview of CO_2 emissions from use of blast-furnace gas in coking plants, for the entire time series since 1990.

Table 31: CO_2 emissions from blast-furnace-gas combustion in coking plants

[Millions of t of CO2]									
1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
5.340	5.251	4.590	4.083	5.066	4.924	4.707	4.969	4.362	3.145
2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
3.652	3.741	3.684	3.029	3.356	3.247	3.281	3.226	3.226	2.500
2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**		
3.245	3.895	4.289	4.341	4.554	4.648	4.872	4.618		

Revision of the data for 1990, and for the years 1991-1994, for the new German Länder is described in Annex Chapter 19.1.1.

Emission factors

A list of the CO_2 emission factors used, and a description of the relevant methods, are provided in the Annex, Chapter 18.8.

The emission factors for power stations and other boiler combustion for production of steam and hot/warm water, in category 1.A.1.c, have been taken from Rentz et al. (2002) and Fichtner et al. (2011). A detailed description of the procedure is presented in Chapter 3.2.6.2 and in Chapter 19.1.2.1 in Annex 3. Within the sector, the research projects differentiate between STEAG power stations, other power stations in the hard-coal mining sector, power stations in the lignite mining sector and other boiler combustion for production of steam and hot/warm water.

The majority of emission factors for coking plants have been obtained from Hensmann et al. (2012). That data source's emission factors for contained sources have been allocated to category 1.A.1.c, since those emissions result primarily from bottom-heating of coke ovens. By contrast, the emission factors determined for fugitive sources have been allocated, by definition, to category 1.B.1.b. In both categories, calculations cover CO emissions from coking plants, along with other pollutants.

3.2.8.3 Uncertainties and time-series consistency (1.A.1.c)

Uncertainties for the activity data were determined for the first time in reporting year 2004 (research project FKZ 204 41 132, Juhrich and Wachsmann (2007)). The method for determining the uncertainties is described in Annex 2, Chapter 13.6 of the NIR 2007.

The procedure for determining uncertainties for the emission factors is described in Chapter 3.2.6.3.1.

3.2.8.3.1 Result for N_2O

Relatively large numbers of fluidised-bed combustion systems are used in plants within the lignite-mining sector – which plants are part of sector 1.A.1.c. Such systems are known to have relatively higher N_2O emissions than systems using other types of coal-combustion technologies. On the other hand, relevant emissions behaviour in combustion of hard coal and lignite, particularly in fluidised-bed combustion, has been specifically studied, especially in the 1990s. For this reason, enough measurement data were available to permit systematic survey of N_2O emission factors in the research project. The remarks made in Chapter 3.2.6.3.2 apply mutatis mutandis.

3.2.8.3.2 Result for CH_4

The results of Chapter 3.2.6.3.3 apply mutatis mutandis.

3.2.8.3.3 Time-series consistency of the emission factors

The results of Chapter 3.2.6.3.4 apply mutatis mutandis.

3.2.8.4 Category-specific quality assurance / control and verification (1.A.1.c)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The results of Chapter 3.2.6.2 apply mutatis mutandis.

3.2.8.5 Category-specific recalculations (1.A.1.c)

Table 32: Recalculations, CRF 1.A.1.c

Units [kt]	2018 NIR	2019 NIR	Difference, absolute					Difference, relative
Year	Total	Total	gas	liquid	other	solid	Total	Total
2016	9,071	9,811	0	0	0	739	739	8.15%

Provional figures for the year 2016 were replaced with figures from the now-available final Energy Balance for that year. This necessitated recalculations, primarily for the area of coking-plant and blast-furnace gas.

3.2.8.6 Category-specific planned improvements (1.A.1.c)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

3.2.9 Manufacturing industries and construction (1. A.2)

This category consists of several sub- source categories defined in close harmony with the IPCC categorisations (CRF). It is described in detail via the relevant sub-chapters.

The calculation algorithms for BEU structural elements in category 1.A.2 were revised, within the research project "Substantiation of the data quality of activity data" (FKZ 204 41 132, Juhrich and Wachsmann (2007)), and they are now governed by a consistent system. For the most part, they are based on reliable data of the Federal Statistical Office.

Sectoral differentiation of activity data was carried out solely for process combustion. A number of reallocations were carried out, as of the 2015 NIR, as a result of the new CRF categorisation.

As of 2008, classification of economic sectors (Wirtschaftszweige = WZ), in energy statistics, was again changed – from the "WZ 2003" standard to the "WZ 2008" standard. As a result, activity data relative to process combustion are now being taken from individual statistics, and documented, in keeping with the relevant key for the change (Statistisches Bundesamt (2008): "Umsteigeschlüssel WZ 2003 auf WZ 2008" (key for the change from WZ 2003 to WZ 2008))

As of the 2015 report, this creates difficulties in allocations to the new CRF categories of the 2006 Guidelines. At the time the 2006 Guidelines were prepared, the 2008 economic sectors (WZ) were not yet known and thus were not taken into account.

With respect to power and heat production, industrial power stations and boiler systems are aggregated by technologies (gas engines, gas turbines, gas and steam plants and steam turbines), as well as by permit-law provisions (TA-Luft and 13th BImSchV). The calculation of the split between installations subject to the TA Luft and installations approved pursuant to the 13th BImSchV was updated in 2018.

The various individual calculation algorithms were substantiated in detail in the aforementioned research project.

Following emission calculation at the structural-element level, the sum values for the sub-categories in 1.A.2 were produced pursuant to the 1996 Guidelines – through the 2014 NIR. As of the 2015 NIR, the sum values are produced pursuant to the 2006 Guidelines. In all cases, the aggregation is largely IPCC-conformal. Since the NIR 2006, most process combustion has been reported on a sector-specific basis. The available data do not permit fully IPCC-conformal disaggregation. For example, heat and power production of industrial power stations and thermal power stations cannot be completely oriented to specific sectors; for this reason, it is reported in combined form, under 1.A.2.gviii Other.

Differentiation of energy-related process combustion for heat and power production in industrial power stations and in boiler systems was carried out via Statistik 067 (Statistics 067; electricity-production systems of the manufacturing sector, and of the mining and quarrying sectors (Stromerzeugungsanlagen des Verarbeitenden Gewerbes sowie des Bergbaus und der Gewinnung von Steinen und Erden); (Statistisches Bundesamt, 2018b).

A change in Statistics 067 (op. cit.) of the Federal Statistical Office has led to a jump in the activity data for heat and electricity production. Until 2001, only the fuel inputs for electricity production in electricity production systems were listed. As of 2002, fuel inputs for heat and electricity production are listed. No data are available for inputs for heat production for years prior to 2002.

The ratio between the fossil and biogenic fractions of industrial waste is determined from waste statistics (Statistisches Bundesamt, FS 19, R 1b), from the figures provided by the relevant industrial associations relative to substitute fuels and from the research project "Inputs of secondary fuels" ("Einsatz von Sekundärbrennstoffen") (Lechtenböhmer et al. (2006c), FKZ 204 42 203/02). All of the listed amounts of standard fuels used in all sub-categories have been taken from the Energy Balance of the Federal Republic of Germany and disaggregated in the Balance of Emission Causes (BEU). In addition to the figures provided from the Energy Balance, in various sub-categories substitute fuels have now been listed. The relevant amounts were determined in a research project Lechtenböhmer et al. (2006c) and are now updated annually with the help of association data (see below). This work has shown that substitute fuels are increasingly being used as replacements for more-expensive conventional fuels.

In the aforementioned research project "Inputs of secondary fuels" ("Einsatz von Sekundärbrennstoffen" (Lechtenböhmer et al., 2006c), the required improvements relative to the topic of "waste fuels" in the energy sector were found to be tied to substitute fuels in four industrial sectors, and the pertinent data were obtained from the relevant industrial associations. As a result, considerably improved, sector-specific data are now available relative to use of substitute fuels in process combustion, and in industrial power stations, in the industrial sectors pig-iron production, pulp and paper production and lime and cement production.

Special aspects of the various sub-categories are described in the relevant sub-chapters. Special note should be taken of the collective group 1.A.2.g Other.

The uncertainties for the new structural elements created in the research project "Substantiation of the data quality of activity data" (Juhrich & Wachsmann, 2007) were determined in keeping with the method described in the research project Lechtenböhmer et al. (2006c). That determination is described in the final report for the research project Juhrich and Wachsmann (2007) and in Annex 13.6 of the NIR 2007.

Carbon dioxide emissions predominate in CRF category 1.A.2. Other greenhouse gases account for only very small shares of total emissions.

A sharp reduction in greenhouse-gas emissions occurred in the period 1990 through 1994. It was caused by decommissioning of inefficient manufacturing plants in the new German Länder following the 1990 political transition in Germany.

The emissions fluctuations that occurred in subsequent years reflect production trends in Germany's manufacturing sector, which were tied to overall economic trends.

3.2.9.1 Manufacturing industries and construction – iron and steel (1.A.2.a)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
L/T	**1.A.2.a Manufacturing industries and construction: iron and steel**	**All fuels**	**CO_2**	**35,269.3**	**2.88%**	**38,437.7**	**4.31%**	**9.0%**
-/-	1.A.2.a Manufacturing industries and construction: iron and steel	All fuels	N_2O	155.1	0.01%	111.6	0.01%	-28.1%
-/-	1.A.2.a Manufacturing industries and construction: iron and steel	All fuels	CH_4	62.5	0.01%	60.1	0.01%	-3.7%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	NS	CS
CH_4	CS	NS	CS
N_2O	CS	NS	CS
NO_X, CO, NMVOC, SO_2	CS	NS	CS

The category *Manufacturing industries and construction – iron and steel* is a key category, in terms of emissions level and trend, for CO_2 emissions.

The iron and steel industry (sub-category 1.A.2.a) is the second important CO_2-emissions source, along with the cement industry, in the area of process combustion.

3.2.9.1.1 Category description (1.A.2.a)

The category comprises the production areas of pig iron (blast furnaces), sponge iron (direct reduction), sinter, rolled steel, iron and steel casting, Siemens-Martin steel, electric steel and the power stations and boilers of the entire steel industry.

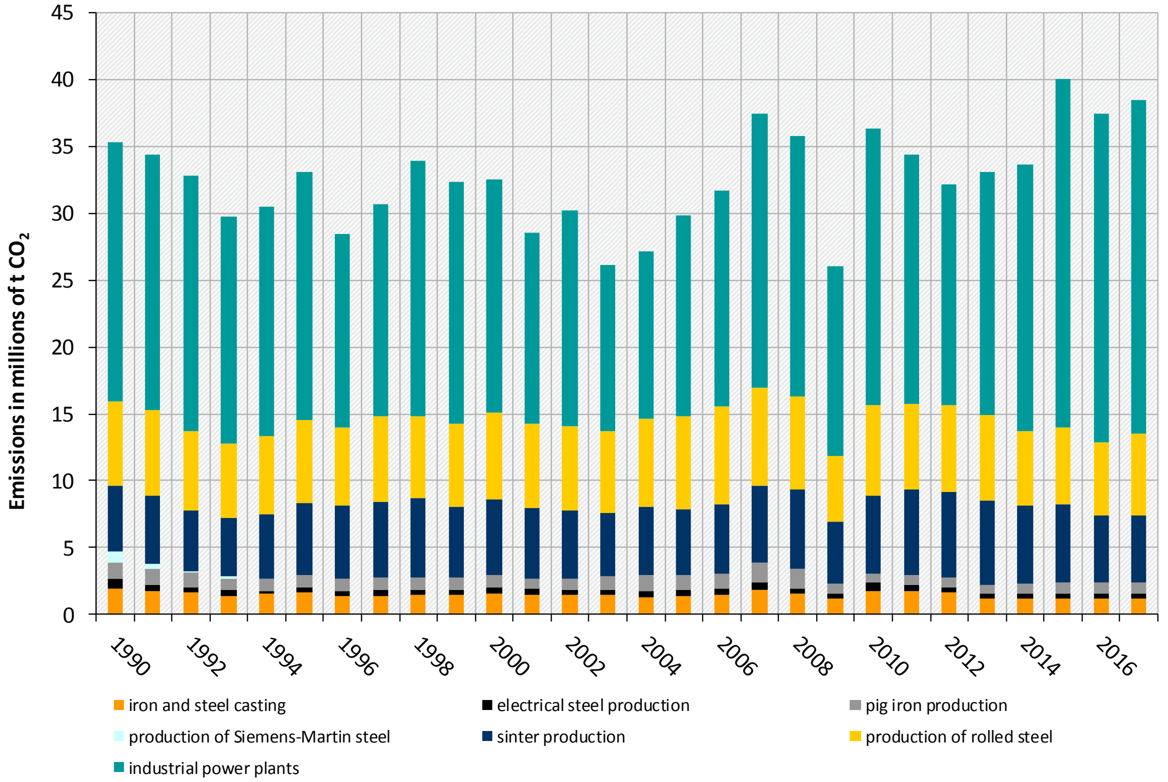
Production of Siemens-Martin steel generated emissions only in the new German Länder, and only until shortly after 1990. In the old German Länder, production of Siemens-Martin steel was discontinued before 1990.

Sponge iron (direct-reduced iron (DRI)) is produced in Germany only on a relatively small scale (about 0.5 million t per year), and only in one plant. The CO_2 emissions that occur in DRI production result from the use of natural gas, i.e. from use of a reducing-agent mixture, comprising H_2 and CO, obtained from natural gas. The relevent quantities of natural gas used are included, throughout the entire time series, in the natural-gas inputs that are reported under 1.A.2.a. Consequently, CO_2 emissions from DRI production are reported, throughout the entire time series, under 1.A.2.a. The CO_2 emissions from DRI production cannot be listed separately, because such disclosures could be used to derive confidential production-quantity data for individual installations.

In production of pig iron, large amounts of the fuels used in blast furnaces are needed for the reduction processes that take place in the furnaces, while most of the fuel used in other production areas of the iron and steel industry is used for heat production.

The following figure provides an overview of CO_2 emissions in the various sub-categories in 1.A.2.a.

Figure 26: Development of CO_2 emissions in category 1.A.2.a



As the overview reveals, major fluctuations have occurred over the years. In most cases, those swings were tied to fluctuations in production. In the period 1990 through 1994, emissions reductions occurred primarily as a result of restructuring of the iron and steel sector in the new German Länder following the political transition of 1990.

The drop in CO_2 emissions is particularly pronounced in the crisis year 2009, in which the steel industry registered a sharp production decrease. The recurring emissions increase in 2010 resulted from an economic recovery in which the steel industry nearly reattained its production level of 2008. In subsequent years, through 2013, raw steel production – and, thus, CO_2 emissions – decreased, but only slightly. In 2014 and 2015, pig-iron production and emissions both increased again, in keeping with the trend in raw steel production.

The noticeably high emissions increase in 2015 is due to shifting, for reporting purposes, of several power stations fired with blast furnace gas – from the public electricity supply (CRF 1.A.1.a) to industry (1.A.2.a). This has led, in turn, to shifting of emissions as well. Overall, CO_2 emissions have been increasing only slightly as a result of the increase in production. This relationship is clearly apparent in Figure 45 in Chapter 4.4.1. In 2016, emissions in category 1.A.2.a decreased, thereby following the production decreases in this industrial sector. In 2017, the emissions increased again, as a result of increasing production.

Installations in the areas of rolled-steel and sinter production account for the second-highest shares of emissions, after industrial power stations (which generate electricity for their own use from blast furnace gas and basic oxygen furnace gas). In the blast furnace category, only the natural-gas and coking-gas inputs required for furnace operation are reported in category 1.A.2.a. Process-related emissions are listed in category 2.C.1.

In the area of pig-iron production in blast furnaces, inputs of heavy fuel oil have been decreasing continuously since 2010. The heating oil is being replaced largely by PCI coal. This is made possible by conversions of the relevant injection systems. The fuel changes are price-driven. In some blast furnaces, ground lignite is also used along with ground hard coal, with the choice between the two alternatives depending solely on price. Overall, this has led to a slight increase in specific emissions.

3.2.9.1.2 Methodological issues (1.A.2.a)

This sub-category comprises process combustion in the various production areas of the iron and steel industry. The relevant fuel-use amounts, including those for secondary fuels, are contained in the Balance of Emission Causes (BEU).

In work to obtain activity data for conventional fuels in this category, a new data source was developed as of reporting year 2011: the so-called "BGS" group (fuel, gas and electricity industries of blast furnaces, steelworks and rolling mills; and forging plants, press works and hammer mills, including the various other plants (without their own coking plants) locally connected to such operations). That source allows enhanced disaggregation of energy data in the Balance of Emissions Sources (BEU). While the legal basis for surveys relative to the BGS group was no longer available as of reporting year 2012, the pertinent data have since been provided, in the same structure, on the basis of an agreement with the Wirtschaftsvereinigung Stahl German steel industry association. This change has no impact on relevant calculations.

In addition to providing activity data for sintering plants, blast furnaces, basic oxygen furnaces (converters) and rolling mills, BGS-group data support additional disaggregation of the electric steel sector.

The BGS-group data also permit data-based differentiation of the solid-fuel categories "hard coal and hard coal briquettes"; "coke" and "coke breeze with particle size less than 10 mm". In the database, the fuel inputs for coke and coke breeze are listed in sum as "coke", since the energy statistics list the aggregated fuel "coke". The "liquid fuels" listed for the BGS group are classified under "heating oil, heavy".

The BGS-group data list fuel inputs in natural units. For the present purpose, those units are converted into energy units, using the relevant net calorific values listed by the Working Group on Energy Balances (AGEB) for the various solid and liquid fuels. For gases, the BGS-group data use a norm of 35.16912 MJ/m^3. That figure has been adopted in the methods for calculating activity data for blast-furnace gas, coke-oven gas, natural gas and basic oxygen furnace gas.

The method for calculating emissions from secondary fuels has been retained, in keeping with the results of the research project "Einsatz von Sekundärbrennstoffen" ("Inputs of secondary fuels"; Lechtenböhmer et al. (2006c), FKZ 204 42 203/02).

In the area of emissions from the iron and steel industry, a distinction is made, for the entire time series as of 1990, between process-related emissions and energy-related emissions. The method for calculation of process-related emissions is described in Chapter 4.4.1.2 of category 2.C.1.

The fuel inputs for the year 2017 had to be calculated on the basis of the development of production data from emissions trading, because the steel industry association was unable to provide the BGS-group data. The association's inability to supply the BGS data occurred as a result of provisions of antitrust law. This problem is currently being addressed.

3.2.9.1.3 Uncertainties and time-series consistency (1.A.2.a)

Uncertainties were determined for all fuels in 2004 (except for substitute fuels), and for substitute reducing agents, with regard to the entire time series. The method is explained in the research report Lechtenböhmer et al. (2006c). The uncertainties for the activity data were updated in the research project "Substantiation of the data quality of activity data" ("Dokumentation der Datenqualität von Aktivitätsraten" (FKZ 204 41 132) and included in the relevant final report.

The statistical data used for calculation until the 2011 report, from the Federal Statistical Office's Fachserie 4 Reihe 8.1, were aggregated in keeping with the BGS-group framework in those statistics. When production of those statistics has been discontinued, the basic BGS-group data will be used directly for calculation.

Direct use of the BGS-group data does not increase the uncertainties. The uncertainties as determined on the basis of the research report were retained, in keeping with the conservative approach applied.

The fuel inputs for 2017 had to be calculated on the basis of production data (and their trends) obtained from emissions trading, because it was not possible to obtain the data directly from the BGS form, the data source used in earlier years. This led to an increase in the uncertainties.

3.2.9.1.4 Source-specific quality assurance / control and verification (1.A.2.a)

General quality control and, for the emission factors and emissions data, category-specific quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

For further information on quality assurance, cf. CRF 1.A.1.a (Chapter 3.2.6.4).

The aforementioned agreement with the steel-industry association calls for the association to carry out quality assurance for the BGS-group data in keeping with the QSE manual. The association's quality report is provided along with the data.

3.2.9.1.5 Category-specific recalculations (1.A.2.a)

Error correction in the area of foundries, for the year 2015, necessitated recalculations of the figures for gaseous fuels. The liquid fuels figures for 2015 also had to be recalculated, to take account of correction of the net calorific value for heavy fuel oil in connection with production of rolled steel. Provisional figures for the year 2016 were replaced with figures from the now-available final Energy Balance for that year. That necessitated recalculations for nearly all fuels.

Table 33: Recalculations in CRF 1.A.2.a

Units [kt]	2018 NIR	2019 NIR	Difference, absolute				Difference, relative
Year	**Total**	**Total**	gas	liquid	solid	**Total**	**Total**
2015	39,962	40,004	39	3	0	42	0.11%
2016	37,210	37,422	35	-1	178	212	0.57%

3.2.9.1.6 Planned improvements, category-specific (1.A.2.a)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

3.2.9.2 Manufacturing industries and construction – non-ferrous metals (1.A.2.b)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
-/-	1.A.2.b Manufacturing industries and construction: non-ferrous metals	All fuels	CO_2	1,629.2	0.13%	1,818.5	0.20%	11.6%
-/-	1.A.2.b Manufacturing industries and construction: non-ferrous metals	All fuels	N_2O	17.1	0.00%	10.6	0.00%	-38.1%
-/-	1.A.2.b Manufacturing industries and construction: non-ferrous metals	All fuels	CH_4	1.4	0.00%	2.0	0.00%	47.5%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	NS	CS
CH_4	CS	NS	CS
N_2O	CS	NS	CS
NO_X, CO, NMVOC, SO_2	CS	NS	CS

The category *Non-ferrous metals* is not a key category.

3.2.9.2.1 Category description (1.A.2.b)

This category aggregates process combustion of various areas of non-ferrous-metal production. The available data do not support more detailed description.

3.2.9.2.2 Methodological issues (1.A.2.b)

The pertinent fuel inputs are contained in the Balance of Emission Causes (BEU). The source for fuel inputs consists of statistics for the manufacturing sector (Statistik 060 – Energieverwendung des produzierenden Gewerbes (energy use in the manufacturing sector; (Statistisches Bundesamt, 2018a) (Melde-Nr. (reporting number) 27.43 (WZ 2003 old; WZ = classification system for economic data) → 24.43 (WZ 2008 new); Erzeugung und erste Bearbeitung von Blei, Zink und Zinn (production and initial processing of lead, zinc and tin) 27.44 (WZ 2003 old) → 24.44 (WZ 2008 new); Erzeugung und erste Bearbeitung von Kupfer (production and initial processing of copper)) and, for differentiations relative to heat and electricity production, Statistik 067 (Statistisches Bundesamt, 2018b).

Descriptions of calculation algorithms for activity data in the Balance of Emissions Sources (BEU) were revised in the interest of standardisation, consistency and transparency.

As a result of such revision, production and initial processing of precious metals, aluminium and other non-ferrous metals are now taken into account in determination of activity data.

The relevant calculation algorithms are described in detail in the final report for the research project "Substantiation of the data quality of activity data" ("Dokumentation der Datenqualität von Aktivitätsraten") (FKZ 204 41 132).

The 1990 activity data for the new German Länder were revised and substantiated, with the help of new data, in the project "Base year and updating" ("Basisjahr und Aktualisierung") Zander and Merten (2006): FKZ 205 41 115); see Annex Chapter 19.1.1).

3.2.9.2.3 Uncertainties and time-series consistency (1.A.2.b)

Uncertainties for all activity data were determined in 2004. The relevant method is described in Annex Chapter 13.6 of the NIR 2007.

3.2.9.2.4 Category-specific quality assurance / control and verification (1.A.2.b)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

For further information on quality assurance, cf. CRF 1.A.1.a (Chapter 3.2.6.4).

3.2.9.2.5 Category-specific recalculations (1.A.2.b)

Table 34: Recalculations in CRF 1.A.2.b

Units [kt]	2018 NIR	2019 NIR	Difference, absolute				Difference, relative
Year	Total	Total	gas	liquid	solid	Total	Total
2015	1,596	1,595	-1	0	0	-1	-0.08%
2016	1,576	1,603	-39	63	3	27	1.70%

Provisional values for the year 2016 were replaced when the figures from the final Energy Balance for 2013 became available. This has led to recalculations for all fuels. The natural gas figures for the year 2015 had to be slightly adjusted (recalculated), because the emission factor was revised.

3.2.9.2.6 Category-specific planned improvements (1.A.2.b)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

3.2.9.3 Manufacturing industries and construction – Chemicals (1.A.2.c)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
-/-	1.A.2.c	All fuels	IE	IE	IE	IE	IE	IE

In the chemical industry, the main relevant plants consist of industrial power stations and boilers. Such installations are reported, for all sectors, in sub-category 1.A.2.g Other.

Fuel inputs in calcium-carbide production are process-related and are reported under CRF 2.B.5 (cf. Chapter 4.3.5).

This approach has been confirmed by the research project "Base year and updating" (Zander and Merten (2006), FKZ 205 41 115), for 1990 in the new German Länder (the most important production location): the relevant coke was used as a production material and not as a fuel for energy. Calcium-carbide production is thus not a source of energy-related CO_2 emissions.

The emissions for the entire sub-category 1.A.2.c are thus included elsewhere (IE). For this reason, sub-category 1.A.2.c is not listed separately in the key-category analysis.

The majority of the emissions in the chemical industry originate in combustion processes. Since fuel-input data for the chemical industry are available only as of the year 2003, no time series as of 1990 can be produced. For this reason, emissions from energy-related use of fuels in the chemical industry are reported together with emissions for other industrial sectors in category 1.A.2.gviii "Other". Nonetheless, the available data can be cross-checked against relevant available data from emissions trading. As this is done, double counting with the IPPU Sector has to be avoided. In addition, it is important to ensure that emissions from combustion of other produced gases are not underestimated. The comparison shows that the data reported in energy statistics for the period as of 2012 agree well with the fuel-quantity data from emissions trading. The gas quantities given by statistics for earlier years are too low overall. The first analytical step, therefore, was to identify the chemical industry areas in which other produced gases occur and are used for energy generation. Overall half of the total gas produced is used in production of other organic basic materials and chemicals. The next-largest share is used in production of other inorganic basic materials and in production of dyes and pigments. A still-smaller share of these gases is used in production of plastics in primary forms. For recalculation of the relevant gas consumption, the main products produced in each sector were determined. The pertinent data are available, for the period back to 1990, in the annual "Chemiewirtschaft in Zahlen" ("Chemical industry figures") reports of the VCI. Data are lacking only for the new German Länder in the year 1990. Since the Energy Balance lists major quantities of "fuel gases" ("Brenngase") for the new German Länder, it may be assumed that those gases have been taken into account at least in the area of energy use. With the help of the production data, and the gas-quantity data listed in the energy statistics for the year 2013, specific factors were developed, for each sub-sector, with which it was possible to calculate the pertinent fuel inputs retroactively.

3.2.9.4 Manufacturing industries and construction – Pulp, paper and print (1.A.2.d)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
-/-	1.A.2.d Manufacturing industries and construction: Pulp, paper and print	All fuels	CO_2	3.6	0.00%	3.9	0.00%	6.4%
-/-	1.A.2.d Manufacturing industries and construction: Pulp, paper and print	All fuels	N_2O	2.8	0.00%	11.3	0.00%	303.7%
-/-	1.A.2.d Manufacturing industries and construction: Pulp, paper and print	All fuels	CH_4	0.7	0.00%	2.6	0.00%	303.7%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	NS	CS
CH_4	CS	NS	CS
N_2O	CS	NS	CS
NO_X, CO, NMVOC, SO_2		IE	

The category *Pulp, paper and print* is not a key category.

3.2.9.4.1 Category description (1.A.2.d)

The energy consumption for production of pulp, paper and printed products – otherwise referred to as the "pulp and paper industry" for short – can be described only for substitute fuels, of which this industry uses large amounts.

Emissions from use of regular fuels in process combustion, and emissions generated by plants in own-power production, have not been listed separately. They are summarised under 1.A.2.g Other.

3.2.9.4.2 Methodological issues (1.A.2.d)

Only some of the substitute fuels used by the paper industry are listed in the Energy Balance. The fuels in question consist of waste from the relevant sectors' own production areas. The data on the types and amounts of substances used were provided by the German Pulp and Paper Association (VDP). The great majority of the substitute fuels used in the sector consist of wood and pulp fibres – and, thus, of biomass. The biogenic and fossil fractions of pertinent fuels were derived in the research project "Inputs of secondary fuels" ("Einsatz von Sekundärbrennstoffen") (Zander and Merten (2006), FKZ 204 42 203/02). In addition, CO_2 emission factors were derived on the basis of data on carbon content, water content and net calorific values.

The official statistical data on inputs of standard fuels in the paper industry were reviewed.

In the statistics for the manufacturing sector (Statistik 060 – Energieverwendung des produzierenden Gewerbes ("energy use in the manufacturing sector"); Statistisches Bundesamt (2018a)), under the new system for classification of economic activities (Wirtschaftszweigsystematik – WZ 2008 new), the source for the fuel inputs is assigned WZ number 17 "Herstellung von Papier, Pappe und Waren daraus" (production of paper, cardboard and related goods").

At present, the source for one time series cannot be unambiguously assigned in keeping with the old system for classification of economic activities (WZ 2003).

The class WZ 17 within the new system for classification of economic activities (Wirtschaftszweigsystematik 2008) corresponds to classes WZ 17, 21, 22 and 36 under the old system, WZ 2003.

Currently, the individual fuel inputs cannot be listed in disaggregated form, due to the need to protect confidentiality.

The same applies for Statistik 067 (Statistisches Bundesamt, 2018b), which is used for differentiation from electricity and heat generation.

3.2.9.4.3 Uncertainties and time-series consistency (1.A.2.d)

In the framework of a research project, the uncertainties of the CO_2 emission factors derived for substitute fuels were determined using the Monte Carlo method (Zander and Merten (2006), FKZ 204 42 203/02). In the procedure, figures for C content, water content and net calorific value were taken into account. Such figures are based on varying estimates, as well as on small numbers of measurements and analysis results, and thus show wide spreads. The CO_2 emission factors for secondary fuels, along with the relevant uncertainties, apply throughout the entire relevant time series, because no findings on trends are available. The time series are thus consistent.

3.2.9.4.4 Category-specific quality assurance / control and verification (1.A.2.d)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The paper industry has long kept records of inputs of secondary fuels. The data are published annually, in a performance report. In spite of small structural breaks in the time series in such records, the records clearly show the paper industry's increasing use of substitute fuels in place of regular fuels.

3.2.9.4.5 Category-specific recalculations (1.A.2.d)

Table 35: Recalculations in CRF 1.A.2.d

Units [kt]	2018 NIR	2019 NIR	Difference, absolute	Difference, relative
Year	Total	Total	Total	Total
2015	6	4	-2	-31.87%
2016	4	4	0	-0.49%

Recalculations resulted for the years 2015 and 2016, as a result of revision of the calculations for secondary fuels.

3.2.9.4.6 Category-specific planned improvements (1.A.2.d)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

3.2.9.5 Manufacturing industries and construction – Sugar production (1.A.2.e)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
-/T	**1.A.2.e Manufacturing industries and construction: Food processing**	**All fuels**	**CO_2**	**2,015.9**	**0.16%**	**242.0**	**0.03%**	**-88.0%**
-/-	1.A.2.e Manufacturing industries and construction: Food processing	All fuels	N_2O	24.6	0.00%	2.3	0.00%	-90.6%
-/-	1.A.2.e Manufacturing industries and construction: Food processing	All fuels	CH_4	4.5	0.00%	0.2	0.00%	-95.7%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	NS	CS
CH_4	CS	NS	CS
N_2O	CS	NS	CS
NO_X, CO, NMVOC, SO_2	CS	NS	CS

The category *Sugar production* is a key category for CO_2 emissions in terms of trend (cf. Table 6). Because relevant emissions have fallen sharply since 1990 (-89.6 %), and thus an extremely low emissions level has been attained, the Single National Entity has decided, as part of its resources prioritisation, not to apply the more stringent methods to this category that are required for key categories.

3.2.9.5.1 Category description (1.A.2.e)

This category includes only the sugar industry's process combustion. Plants generating their own power are not listed separately; they are reported under 1.A.2.g Other.

3.2.9.5.2 Methodological issues (1.A.2.e)

Descriptions of calculation algorithms for activity data in the Balance of Emissions Sources (BEU) were revised in the interest of standardisation, consistency and transparency.

As a result of this revision, it was determined that the statistics publications Statistik 060 (Statistisches Bundesamt, 2018a) and Statistik 067 (Statistisches Bundesamt, 2018b) list all of the fuels required for calculation of the pertinent activity data and should be used as data sources.

The relevant calculation algorithms, and special analyses relative to fuel inputs, are described in detail in the final report for the research project "Substantiation of the data quality of activity data" ("Dokumentation der Datenqualität von Aktivitätsraten" (Juhrich & Wachsmann, 2007)).

3.2.9.5.3 Uncertainties and time-series consistency (1.A.2.e)

For 2004, the uncertainties for all activity data were determined for the first time. The relevant method is described in Annex Chapter 13.6 of the NIR 2007.

3.2.9.5.4 Category-specific quality assurance / control and verification (1.A.2.e)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

For further information on quality assurance, cf. CRF 1.A.1.a (Chapter 3.2.6.4).

3.2.9.5.5 Category-specific recalculations (1.A.2.e)

Table 36: Recalculations in CRF 1.A.2.e

Units [kt]	2018 NIR	2019 NIR	Difference, absolute				Difference, relative
Year	Total	Total	gas	liquid	solid	Total	Total
2016	210	208	8	13	-23	-2	-1.00%

Provional figures for the year 2016 were replaced with figures from the now-available final Energy Balance for that year. That necessitated recalculations for nearly all fuels.

3.2.9.5.6 Planned improvements (category-specific) (1.A.2.e)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

3.2.9.6 Manufacturing industries and construction – Non-metallic minerals industry (1.A.2.f)

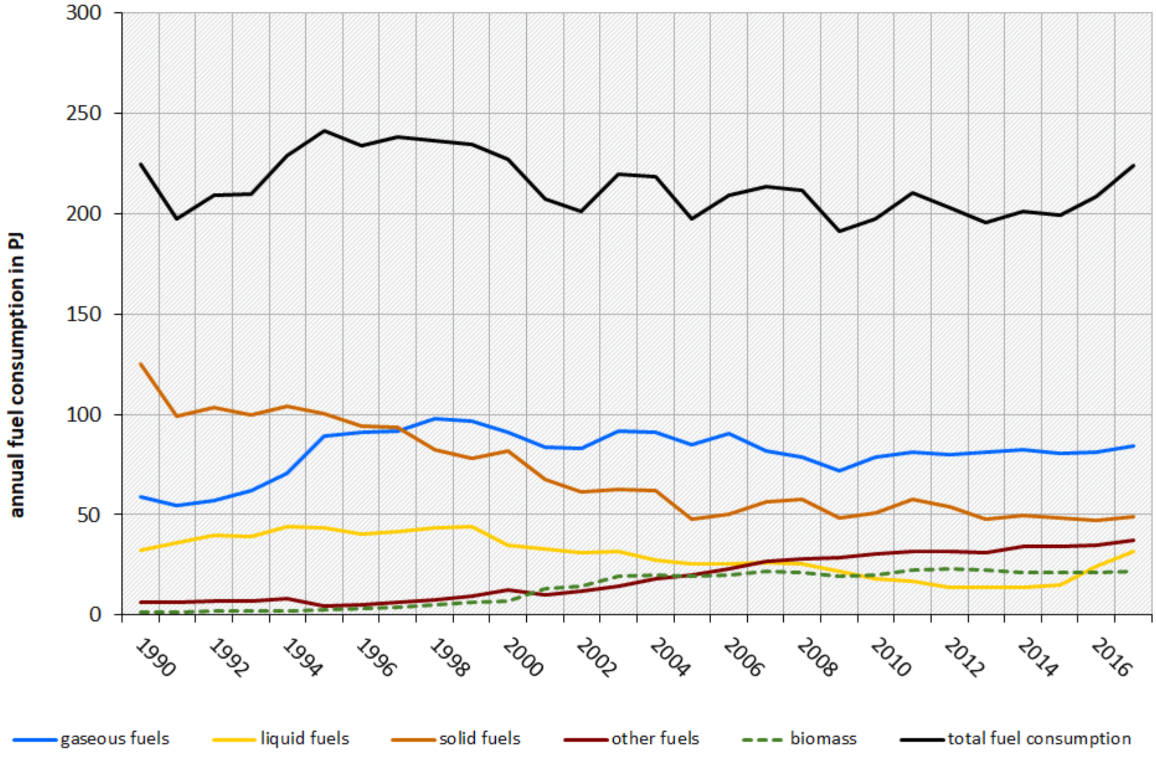
KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
L/T	**1.A.2.f Manufacturing industries and construction: Non-metallic minerals**	**All fuels**	**CO_2**	**18,507.4**	**1.51%**	**15,233.5**	**1.71%**	**-17.7%**
-/-	1.A.2.f Manufacturing industries and construction: Non-metallic minerals	All fuels	N_2O	205.3	0.02%	142.5	0.02%	-30.6%
-/-	1.A.2.f Manufacturing industries and construction: Non-metallic minerals	All fuels	CH_4	50.3	0.00%	17.3	0.00%	-65.6%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	NS	CS
CH_4	CS	NS	CS
N_2O	CS	NS	CS
NO_X, CO, NMVOC, SO_2	CS/IE	NS/IE	CS/IE

The category *Manufacturing industries and construction – Non-metallic minerals industry*, which comprises all other sub-categories, is a key category, in terms of emissions level and trend, for CO_2 emissions.

In general in the inventory, those categories are listed separately in which combustion systems with a specific emissions behaviour – so-called "process combustion" systems – are used. For this reason, the sub-categories 1.A.2.f Cement (structural element "Production of cement clinkers (process combustion)"), 1.A.2.f Ceramics (structural element "Production of ceramics products (process combustion)"), 1.A.2.f Glass (structural element "Production of glass (process combustion)") and 1.A.2.f Lime (structural element "Production of lime (process combustion)") are listed individually.

Figure 27: Development of fuel inputs in category 1.A.2.f Non-metallic minerals



Two changes of fuels occurred in the area of the non-metallic minerals industry.

In the mid-1990s, gaseous fuels increasingly began to be used instead of solid fuels. These two fuel groups are currently predominant in this source category.

In the 2000s, the majority of liquid fuels (petroleum products) began to be replaced – first by waste and secondary fuels, and then by biomass.

In 2016, use of natural gas, solid fuels and petroleum increased slightly, while use of biomass, petroleum and waste fuels remained at about the relevant levels seen in 2014. As a result, total fuel inputs increased with respect to the previous year.

3.2.9.6.1 Category description (1.A.2.f, Non-metallic minerals industry)

In this category, process combustion from burning of clinkers is listed. The final step in cement production, i.e. grinding and mixing, is not included. As a power-intensive process, it is included in power production (1.A.1). In addition, process combustion in the brick industry, and in production of other structural ceramics, are reported as well. In the glass industry, process combustion includes production of flat glass, hollow glass and glass fibres; shaping and processing of flat glass; and production and shaping of other types of glass and technical glassware. Process combustion in lime production is also taken into account. Some plants within this category also generate power for their own use; such generation is not listed separately, but is included under 1.A.2.gviii "Other".

3.2.9.6.1 Methodological issues (1.A.2.f, Non-metallic minerals industry)

The pertinent inputs of conventional fuels are contained in the Balance of Emission Sources (BEU). The fuel-input data for energy-related process combustion are obtained from the manufacturing sector's own statistics. The following numbers from the WZ classification of industrial sectors are relevant: Reporting number (Melde-Nr.) 26.51(WZ 2003 old) → 23.51 (WZ 2008 new), Cement production; Reporting number 26.40 (WZ 2003 old) → 23.32 (WZ 2008 new), Brick production,

Production of other structural ceramics; Reporting number 26.1 (WZ 2003 old) → 23.1 (WZ 2008 new), Production of glass and glassware; and Reporting number 26.52 (WZ 2003 old) → 23.52 (WZ 2008 new), Lime production. As a result of the change in the reporting numbers, the data for lime can no longer be easily separated from those for gypsum. The necessary differentiation is achieved with the help of a split factor determined on the basis of old individual statistics. For differentiation from heat and electricity production, cf. Statistik 067 (Statistisches Bundesamt, 2018b).

As of 2002, the data for Statistik 067 (op. cit.) are found only among three-digit reporting numbers. This means that only data for reporting number 26.5 (WZ 2003 old) → 23.5 (WZ 2008 new) (production of cement, lime and burnt plaster) can be used as a basis.

The relevant calculation algorithms are described in detail in the final report for the research project "Substantiation of the data quality of activity data" ("Dokumentation der Datenqualität von Aktivitätsraten" (Juhrich & Wachsmann, 2007)) and in the 2013 NIR, 3.2.9.7 through 3.2.9.10.

The fuel inputs for the new German Länder in 1990 were calculated on the basis of specific fuel consumption in 1989 and production in 1990.

The cement industry uses significant amounts of substitute fuels that do not appear in national statistics and in the Energy Balance. Relevant production figures and fuel-use quantities are taken from statistics of the relevant industry associations. The procedure used to compile activity data oriented to the old and new German Länder as of 1990, and to all of Germany as of 1995, is described in the final report of the research project "Inputs of secondary fuels" ("Einsatz von Sekundärbrennstoffen"; Lechtenböhmer et al. (2006c), FKZ 204 42 203/02). In a first step, fuel inputs were allocated to the groups "Biomass" or "Other fuels (waste)", in keeping with IPCC procedures. In the research project "Inputs of secondary fuels", the biogenic fractions of relevant fuels were derived and then entered into the calculations, with the help of split factors. In the same project, CO_2 emission factors were derived for substitute fuels, on the basis of data on carbon content, water content and net calorific value (Lechtenböhmer et al., 2006c).

3.2.9.6.2 Uncertainties and time-series consistency (1.A.2.f, Non-metallic minerals industry)

Uncertainties were determined for all fuels in 2004 and for the aforementioned substitute fuels with regard to the entire time series. The relevant methods are explained in Annex Chapter 13.6 of the NIR 2007 and in the final report of the research project (Lechtenböhmer et al., 2006c).

The uncertainties for the activity data were updated in the research project "Substantiation of the data quality of activity data" ("Dokumentation der Datenqualität von Aktivitätsraten" (Juhrich & Wachsmann, 2007)) and included in the relevant final report.

The activity data for the new German Länder, for the base year and the subsequent years 1991-1994, were adjusted in keeping with the findings from the research project (Zander and Merten (2006): FKZ 205 41 115 / Teilvorhaben (sub-project) A "Revision and substantiation of fuel inputs for stationary combustion systems in the new German Länder, for the year 1990" ("Überarbeitung und Dokumentation der Brennstoffeinsätze für stationäre Feuerungsanlagen in den neuen Bundesländern für das Jahr 1990").

3.2.9.6.3 Category-specific quality assurance / control and verification (1.A.2.f, Non-metallic minerals industry)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

For further information on quality assurance, cf. CRF 1.A.1.a (Chapter 3.2.6.4).

3.2.9.6.4 Category-specific recalculations (1.A.2.f, Non-metallic minerals industry)

Table 37: Recalculations in CRF 1.A.2.f

Units [kt]	2018 NIR	2019 NIR	Difference, absolute					Difference, relative
Year	Total	Total	gas	liquid	other	solid	Total	Total
2015	13,176	13,172	-4	0	0	0	-4	-0.03%
2016	13,775	14,085	-121	1,049	69	-688	310	2.25%

Revision of the emission factor for natural gas led to a minor recalculation for the year 2015. For the year 2016, extensive recalculations were carried out, to take account of the fact that provisional data were replaced by figures from the final Energy Balance.

3.2.9.6.5 Planned improvements (category-specific) (1.A.2.f, Non-metallic minerals industry)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

3.2.9.7 Manufacturing industries and construction – Other energy production (1.A.2.g, Other, stationary + mobile)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
L/T	**1.A.2.g Manufacturing industries and construction: Other**	**All fuels**	**CO_2**	**127,682.1**	**10.44%**	**78,617.3**	**8.82%**	**-38.4%**
-/-	1.A.2.g Manufacturing industries and construction: Other	All fuels	N_2O	944.7	0.08%	635.4	0.07%	-32.7%
-/-	1.A.2.g Manufacturing industries and construction: Other	All fuels	CH_4	132.3	0.01%	213.2	0.02%	61.1%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	NS	CS
CH_4	CS	NS	CS
N_2O	CS	NS	CS
NO_X, CO, NMVOC, SO_2	CS	NS	CS

The stationary and mobile sources in 1.A.2.g are grouped together for purposes of assignment to key categories. As a result, category *1.A.2.g Manufacturing industries and construction – Other energy production* is a key category for CO_2 in terms of emissions level and trend.

As a result of its function as a collective category for fuel inputs that cannot be disaggregated to the individual-sector level, this sub-category is particularly significant; it contributes substantially to the entire energy sector's CO_2 emissions.

3.2.9.7.1 Category description (1.A.2.g Other, stationary)

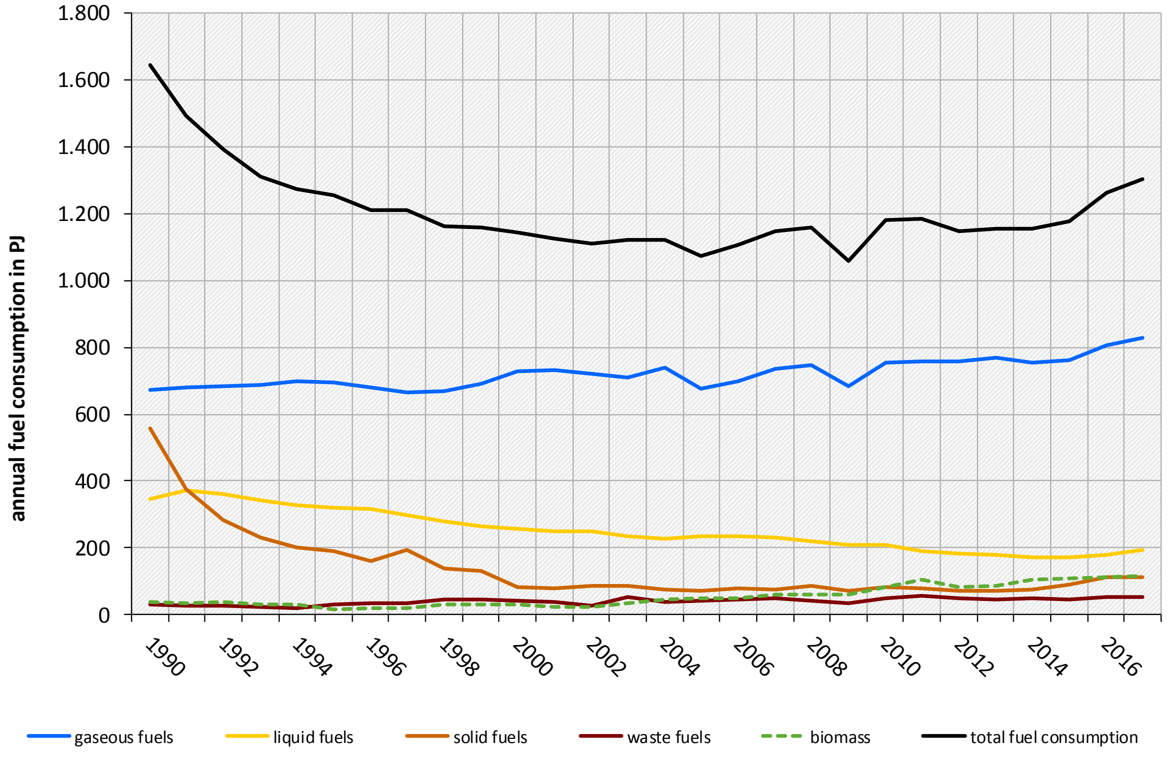
In this sub-category, all those emissions are reported for which the relevant energy inputs cannot be disaggregated in keeping with the categories in 1.A.2. This sub-category is responsible for about 70 % of all CO_2 emissions of category 1.A.2.

All electricity and heat generation in industrial power stations and boilers is listed in this sub-category, because such systems can justifiably be grouped together, in light of their emissions behaviour. Since the chemical industry primarily uses CHP systems and boilers, the pertinent emissions from category 1.A.2.c are reported in sub-category 1.A.2.gviii "Other". Any further subdivision of industrial power stations and boilers, among the otherwise planned sub-categories, would not improve the data, since such systems' emissions behaviour does not depend on the industrial sector involved. Time series are difficult to prepare, since in 1990 Germany consisted of two countries. Those two countries had two different statistical systems, and those systems were combined during a transition period lasting until 1994. Great efforts were made to provide the required documentation and quality data for the reference year, 1990. In addition, in 2003 the Act on Energy Statistics (Energiestatistikgesetz) was amended. This considerably improved data collection, especially for CHP systems. Such data for the period cannot be retroactively collected for the period 2002 – 1990, however. By and large, time-series consistency has been achieved at the aggregated level. Any further disaggregation would lead to breaks in the time series, however, because the data are not all available in disaggregated form, and cannot all be systematically allocated. Nonetheless, the possibilities for further disaggregation have been carefully reviewed. No successful solution for this problem has been found, however. Also, many energy data in Germany are subject to confidentiality restrictions, and thus often must be aggregated (aggregation safeguards confidentiality). In some sectors that have been listed separately to date, data for certain fuels now have to be combined, for reasons of confidentiality, and reported in category 1.A.2.gviii "Other". This considerably reduces the conclusiveness of the data in various individual sectors.

Ultimately, the boundary between the various individual industrial sectors and the public supply sector cannot be unambiguously drawn. The "autoproducers" described in the IPCC Guidelines hardly exist in reality in the clear-cut form outlined. Different companies manage their electricity and heat generation in different ways. Some companies operate power stations of their own that often also feed electricity into the public grid. Other companies draw electricity and/or heat from the public grid. As a result of energy-market liberalisation, the structures in this area often change. Since national statistics serve as the basis for inventory preparation, the inventory adopts those statistics' sectoral allocations of the various kinds of installations and plants involved. Such allocations do not remain constant throughout the time series, and they are not thoroughly consistent with the corresponding allocations in the emissions trading sector. As a result, they cannot be harmonized in the existing data records.

International comparisons of those sub-categories in which industrial power stations play the primary role are not feasible, since the pertinent supply structures differ considerably from country to country.

Figure 28: Development of fuel inputs in category 1.A.2.g viii Other



This category exhibits a marked change in fuel inputs.

The decrease in the use of solid fuels through 2014 – including, especially, a significant reduction in the use of lignite – is especially striking. Use of solid fuels has been increasing again, slightly, since 2014. In addition, consumption of natural gas, biomass and substitute fuels (waste) has also been increasing, with the result that total fuel consumption has been increasing again.

A statistical discontinuity is seen in the area of biomass. Prior to the entry into force of the Act on Energy Statistics (Energiestatistikgesetz), biomass inputs for energy generation either were not recorded statistically or were recorded only in part. The biomass fraction has grown over the years.

3.2.9.7.2 Methodological issues (1.A.2.g Other, stationary)

The fuel inputs for electricity generation in industrial power stations are shown in Energy Balance line 12. The difference resulting after deduction of the fuel inputs for refinery power stations, mine power stations, power stations in the hard-coal-mining sector and, for the period until 1999, for the power stations of Deutsche Bahn (German Railways) consists of the activity data for other industrial power stations. These data cannot be further differentiated at present.

Additional data from the Federal Statistical Office are needed for allocation of fuel inputs to heat production in industrial power stations and boiler systems. Fuel inputs for heat production in CHP systems can be determined from relevant statistics. The activity data for boiler systems are calculated as the pertinent difference.

For both electricity generation and heat generation, the data are broken down into the categories steam turbines, gas turbines, gas-and-steam (combined cycle) systems and gas engines, since (for the present purpose) these different combustion technologies differ especially in terms of their methane emissions. This breakdown, which was extensively revised in the 2015 Submission, is described under 1.A.1.a.

A detailed description of the relevant calculation algorithms, which were extensively revised for reporting year 2008, is provided in the final report for the research project "Substantiation of the data quality of activity data" ("Dokumentation der Datenqualität von Aktivitätsraten"; (Juhrich & Wachsmann, 2007)).

With the new data source "BGS-Bogen" ("BGS form; see above), it has become possible to list, separately, use of blast furnace gas for energy production in live-steam boilers in the iron and steel industry. Considerations tied to provisions of antitrust law ruled out provision of the BGS form for the year 2017. As a result, trends for fuel inputs in live-steam boilers of the iron and steel industry were assumed to move in lockstep with production trends.

In some years, the total energy quantity listed in Energy Balance line 54 (metal production), for use of blast furnace gas, is lower than the total blast-furnace-gas input as shown by the BGS data. In such cases, the Energy Balance data are supplemented with the BGS-form data.

Emission factors

A list of the CO_2 emission factors used, and a description of the relevant methods, are provided in the Annex, Chapter 18.8.

All other emission factors for greenhouse gases and precursor substances, for power stations and other boiler combustion for production of steam and hot/warm water, in category 1.A.2.gviii / all other, have been taken from Rentz et al. (2002) and Fichtner et al. (2011). A detailed description of the procedure is presented in Chapter 3.2.6.2 and in Chapter 19.1.2.1 in Annex 3. The research projects break down the relevant sector into power stations of Deutsche Bahn AG, other industrial power stations and other boiler combustion systems for production of steam and hot/warm water.

3.2.9.7.3 Uncertainties and time-series consistency (1.A.2.g, Other, stationary)

Activity data

The uncertainties were determined, for the first time, for 2004. The relevant method is described in Annex Chapter 13.6 of the NIR 2007.

The uncertainties for the activity data were updated in the research project "Substantiation of the data quality of activity data" ("Dokumentation der Datenqualität von Aktivitätsraten" (Juhrich & Wachsmann, 2007)) and included in the relevant final report.

In the iron and steel industry (CRF 1.A.2.a), the uncertainties for the year 2017 have increased. The occurred because the steel industry association was unable to supply fuel input data via the BGS form, with the result that the data had to be calculated on the basis of the development of production data from emissions trading. The association's inability to supply the BGS data occurred as a result of provisions of antitrust law.

Emission factors

The procedure for determining uncertainties is described in Chapter 3.2.6.3.1.

Result for N_2O: The results of Chapter 3.2.6.3.2 apply mutatis mutandis.

Result for CH_4: The results of Chapter 3.2.6.3.3 apply mutatis mutandis.

The results obtained in Chapter 3.2.6.3.4 in determination of time-series consistency apply mutatis mutandis.

3.2.9.7.4 Category-specific quality assurance / control and verification (1.A.2.g, Other, stationary)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

For further information on quality assurance, cf. CRF 1.A.1.a (Chapter 3.2.6.4).

Activity data

The quality of the data was reviewed in the research project "Substantiation of the data quality of activity data" ("Dokumentation der Datenqualität von Aktivitätsraten" (Juhrich & Wachsmann, 2007)) and improved via use of statistics of the Federal Statistical Office as a database. No other data sources with long-term availability have been identified.

Emission factors

The results obtained in Chapter 3.2.6.2, in the general procedure for source-specific quality assurance / control and verification, apply mutatis mutandis.

3.2.9.7.5 Category-specific recalculations (1.A.2.g, Other, stationary)

Table 38: Recalculations in CRF 1.A.2.gviii

Units [kt]	2018 NIR	2019 NIR	Difference, absolute					Difference, relative
Year	Total	Total	gas	liquid	other	solid	Total	Total
2011	68,733	68,672	0	0	-62	0	-62	-0.09%
2012	66,879	66,855	0	0	-24	0	-24	-0.04%
2013	67,156	67,117	0	0	-39	0	-39	-0.06%
2014	65,304	65,665	0	394	-33	0	362	0.55%
2015	67,568	67,700	-78	241	-30	0	132	0.20%
2016	69,245	72,516	1,168	-209	551	1,761	3,271	4.72%

Provisional values for the year 2016 were replaced when the figures from the final Energy Balance for 2013 became available. This has led to recalculations for all fuels. In addition, the change in the calculation method used for the other produced gases that are assigned to the liquid fuels has required minor recalculations of the CO_2 emissions, as a result of rounding differences.

3.2.9.7.6 Planned improvements (category-specific) (1.A.2.g, Other, stationary)

Activity data:

No further improvements are planned at present.

Emission factors:

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

3.2.9.8 Construction-sector transports (1.A.2.g vii)

3.2.9.8.1 Category description (1.A.2.g vii)

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1 [a], CS	NS/M	CS, D [a]
CH_4	CS (Tier 2)	NS/M	CS (M)
N_2O	CS (Tier 2)	NS/M	CS (M)
NO_x, CO, NMVOC, SO_2	CS (Tier 2)	NS/M	CS (M)

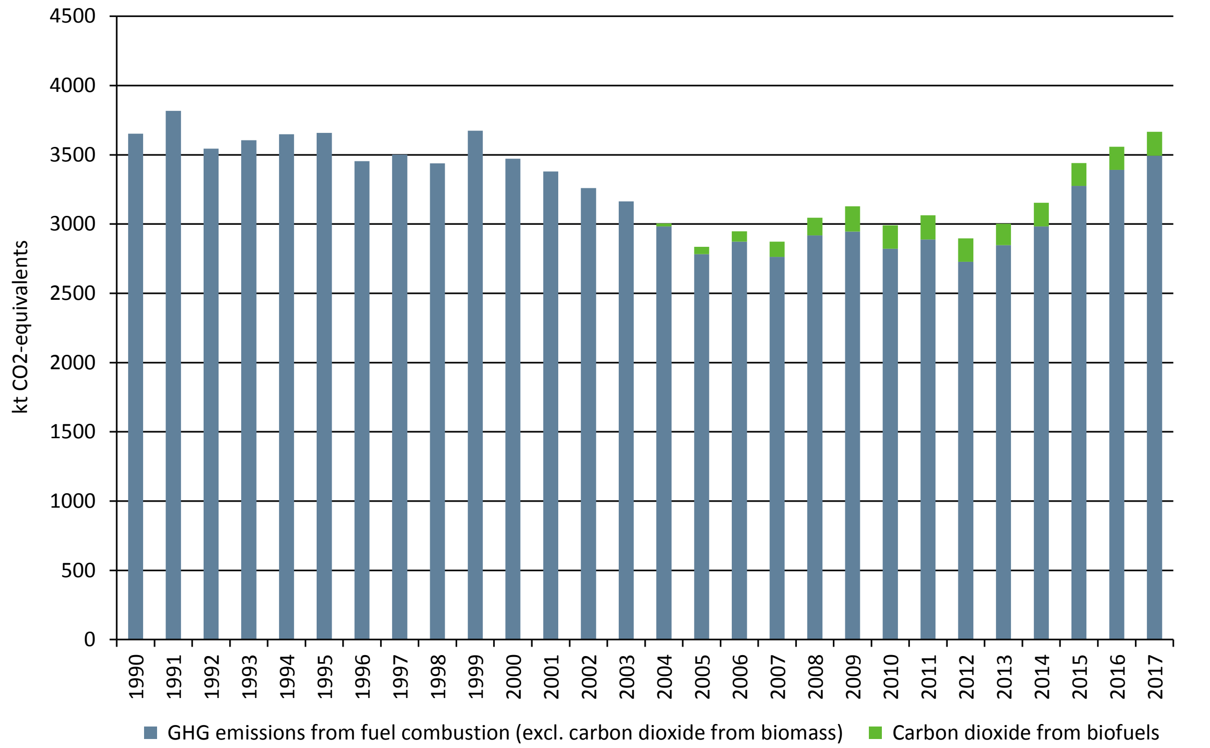
[a] Biodiesel: pursuant to (IPCC (2006): Volume 2, Tab. 2.4).

The stationary and mobile sources in 1.A.2.g are grouped together for purposes of assignment to key categories. (For an overview, cf. Chapter 3.2.9.7.). Accordingly, the category 1*.A.2.g vii – Other: Offroad vehicles and other machines*, in which emissions from construction-sector transports are taken into account, is a key category for CO_2 in terms of emissions level and trend.

3.2.9.8.2 Methodological issues (1.A.2.g vii)

Pursuant to the IPCC 2006 Guidelines (IPCC (2006): page 3.33; equation 3.3.2), the emissions are calculated, using a Tier 2 method, as products of consumed fuels and technology-specific emission factors.

Figure 29: Development of GHG emissions from vehicles and mobile construction-sector machinery, since 1990



The **activity data** for fossil diesel fuel and gasoline, including their biogenic admixtures, are calculated, following deduction of energy inputs for military transports, from the data in Energy Balance lines 79 (until 1994) and 67 *"Commercial and Institutional" ("commerce, trade, services and other consumers*"). For the years 2005 through 2009, figures of the Association of the German Petroleum Industry (MWV) are used in the area of diesel-fuel and gasoline consumption in the various vehicle categories (cf. the following chapters on road and railway transports). To assure the necessary consistency with the relevant total quantities pursuant to the NEB, therefore, the primary data on which the figures for those five years are based are calculated within TREMOD. Inputs of biofuels are also determined via calculation, on the basis of the official admixture quotas.

Finer allocation of fuel quantities to mobile sources in the construction sector, commerce & trade (1.A.4.a ii) and agriculture and forestry (1.A.4.c ii) is achieved with the help of annually fluctuating split factors modelled in TREMOD-MM (Transport Emission Model-Mobile Machinery (Knörr et al., 2018b)).

The relevant **emission factors** are based on the results of various Federal Environment Agency research projects and expert opinions.

With regard to carbon dioxide, we refer in general to Chapter 18.8. Both country-specific and default values (biodiesel, avgas) are used. Further information regarding co-incineration of lubricants in particular is provided in Chapter 19.1.4.

For methane and nitrous oxide, country-specific values from Knörr et al. (2018b) are used. The development of these values reflects the gradual phasing-in of emissions standards, since the mid-1990s, for construction-sector machinery.

With regard to releases of methane and nitrous oxide from co-incineration of lubricants, it is assumed that such emissions are already taken into account in the pertinent emission factors for the fuels used and thus are to be reported as IE *(included elsewhere)*.

Table 39: Emission factors used for reported year 2017, in kg/TJ

	CH_4	N_2O	Origin
Diesel	0.96 (4.15)	2.92 (28.60)	Pursuant to Knörr et al. (2018b)
Biodiesel	0.96 (-)	2.92 (-)	Equivalent to the EF for diesel
Gasoline	19.75 (50)	1.41 (2.00)	Pursuant to Knörr et al. (2018b)
Bioethanol	19.75 (-)	1.41 (-)	Equivalent to the EF for gasoline

In parentheses: Defaults pursuant to IPCC (2006): Volume 2 – Energy, Chapter 3 – Mobile , Tab. 3.3.1: Industry

3.2.9.8.3 Uncertainties and time-series consistency (1.A.2.g vii)

The uncertainty figures for the specific energy inputs, which are shaped primarily by the mathematical uncertainty in the distribution key developed in TREMOD MM (cf. above: Methodological aspects), are based on experts' assessments. The same holds for the carbon-dioxide emission factors used. While the emission factors for methane are based on results from (IFEU & INFRAS, 2009), the emission factors for nitrous oxide – for the time being – have to be oriented to guideline values pursuant to the IPCC.

3.2.9.8.4 Category-specific quality assurance / control and verification (1.A.2.g vii)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

Quality reports of the Working Group on Energy Balances (AG Energiebilanzen – AGEB) have been submitted to the Federal Environment Agency, for purposes of quality assurance of the Energy Balances.

Table 40: Overview of relevant data comparisons

	Comparison with...	Remark
CO_2	Alternative emissions inventories for Germany	No comparable data sets
CO_2	Default EF pursuant to IPCC (2006): Volume 2, Chapter 3, Table 3.3.1: Industry	cf. Table 41
CH_4, N_2O	Default EF pursuant to IPCC (2006): Volume 2, Chapter 3, Tab. 3.3.1: Industry	cf. Table 39
CO_2, CH_4, N_2O	IEF of other countries	cf. Table 42

Table 41: Comparison of a) the EF(CO_2) used and b) default values, in kg/TJ

	Inventory values[a]	Default [b]	*Lower bound*	*Upper bound*
Diesel fuel	74,027	74,100 [c]	*72,600*	*74,800*
Gasoline	75,285	69,300 [c]	*67,500*	*73,000*
Biodiesel	70,800 [d]		*59,800*	*84,300*
Bioethanol	71,607	70,800 [d]	*59,800*	*84,300*

[a] for reported year 2017; [b] pursuant to IPCC (2006): Volume 2, [c] Chapter 3, Tab. 3.3.1; [d] Chapter 2, Tab. 2.4

The following table provides a comparison with specific implied emission factors of other countries. It should be noted that the comparison is hampered by the fact that the factors involved represent a heterogeneous group of source categories.

Table 42: International comparison of IEF for liquid fossil fuels, in kg/TJ

	CO_2	CH_4	N_2O
Germany	74,131	2.52	2.79
Denmark	72,868	2.99	3.30
Netherlands	71,962	1.53	0.85
UK	74,061	11.73	28.32

Germany: Current IEF for report year 2017; all other countries: IEF for 2016, pursuant to 2018 CRF Submission

3.2.9.8.5 Category-specific recalculations (1.A.2.g vii)

As described above, the activity data for construction-sector transports are part of the primary data given in Energy Balance line 67. The provisional data provided for the year 2016, in the 2018 Submission, have been replaced with the corresponding figures from the final 2016 NEB. The quantities of consumed biofuels that were determined via the official admixture quotas have been recalculated as necessary. The 2016 admixture quota for biodiesel was corrected in the process.

Table 43: Revised primary activity data for 2016, in terajoules

	Diesel fuel	Gasoline	Biodiesel	Bioethanol
2019 Submission	105,895	7,991	5,562	347
2018 Submission	103,106	8,414	5,410	365
Absolute change	2,789	-423	152	-18
Relative change	2.70%	-5.03%	2.82%	-5.03%

Source: Energy Balance 2015 (AGEB, 2018), and own calculations on the basis of Knörr et al. (2018b)

In addition, the distribution key, based on TREMOD-MM data, was corrected with regard to the diesel-fuel sub-sectors subsumed under Energy Balance line 67. For 1.A.2.g vii, this revision led to minimal increases in the applicable percentage shares for the period as of 2011, as well as to increases in the sectoral activity data calculated on the basis of those shares.

Table 44: Revised annual fractions in CRF 1.A.2.g vii with respect to the diesel quantities given in EB line 67, in percent

	2010	2011	2012	2013	2014	2015	2016
				Diesel fuels			
2019 Submission	39.4127	39.7021	39.9757	40.1334	40.2911	39.8059	39.7044
2018 Submission	39.4127	39.7015	39.9751	40.1327	40.2904	39.8052	39.7037
Absolute change	0.0000	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006
Relative change	0.000%	0.002%	0.002%	0.002%	0.002%	0.002%	0.002%
				Gasoline			
2019 Submission	63.9942	63.8426	66.3062	66.4825	66.2296	65.9426	67.5736
2018 Submission	63.9942	63.8419	66.3056	66.4819	66.2290	65.9419	67.5730
Absolute change	0.0000	0.0007	0.0006	0.0006	0.0007	0.0007	0.0006
Relative change	0.000%	0.001%	0.001%	0.001%	0.001%	0.001%	0.001%

Source: Own calculations, based on , Knörr et al. (2018b)

The described effects lead to the following changes in the sectoral activity data used in the last report:

Table 45: Resulting revision of activity data, in terajoules

	2010	2011	2012	2013	2014	2015	2016
Diesel fuel							
2019 Submission	34,891	36,026	35,607	37,202	38,972	40,334	41,814
2018 Submission	34,891	36,025	35,607	37,201	38,972	40,334	40,706
Absolute change	0	0.57	0.57	0.59	0.62	0.64	1,108
Relative change	0.000%	0.002%	0.002%	0.002%	0.002%	0.002%	2.722%
Gasoline							
2019 Submission	2,779	2,516	784	775	825	3,288	3,366
2018 Submission	2,779	2,516	784	775	825	3,288	3,652
Absolute change	0.001	0.023	0.008	0.008	0.008	0.037	-286
Relative change	0.000%	0.001%	0.001%	0.001%	0.001%	0.001%	-7.826%
Biodiesel							
2019 Submission	2,263	2,361	2,325	2,154	2,363	2,180	2,196
2018 Submission	2,277	2,373	2,334	2,164	2,376	2,180	2,136
Absolute change	-14	-11	-9	-10	-12	0	61
Relative change	-0.599%	-0.477%	-0.395%	-0.444%	-0.525%	0.002%	2.835%
Bioethanol							
2019 Submission	107	103	35	33	36	143	146
2018 Submission	107	103	35	33	36	143	159
Absolute change	0.0000	0.0011	0.0003	0.0003	0.0004	0.0014	-12.4175
Relative change	0.000%	0.001%	0.001%	0.001%	0.001%	0.001%	-7.828%

Source: Own calculations, based on , Knörr et al. (2018b)

In addition, the year-specific CO_2 emission factors for fossil-based gasoline were revised for 2015 and 2016.

Table 46: Revised CO_2 emission factors for fossil-based gasoline, for 2015 and 2016, in kg/TJ

	2015	2016
2019 Submission	75,287	75,285
2018 Submission	75,289	75,286
Absolute change	-1.8	-1.8
Relative change	-0.002%	-0.002%

Source: Own calculations

The described corrections necessitated recalculations of the reported emissions quantities for the period as of 2010.

Table 47: Revised emissions figures for the period 2010 -2016, in kt and kt CO_2-eq

	2010	2011	2012	2013	2014	2015	2016
Carbon dioxide[a]							
2019 Submission	2,786	2,851	2,693	2,811	2,945	3,233	3,349
2018 Submission	2,786	2,851	2,693	2,811	2,945	3,233	3,288
Absolute change	0.00	0.04	0.04	0.04	0.05	0.04	60.50
Relative change	0.000%	0.002%	0.002%	0.002%	0.002%	0.001%	1.840%
Methane							
2019 Submission	0.11	0.11	0.07	0.07	0.07	0.12	0.11
2018 Submission	0.11	0.11	0.07	0.07	0.07	0.12	0.12
Absolute change	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Relative change	-0.018%	-0.014%	-0.017%	-0.017%	-0.021%	0.001%	-3.918%
Nitrous oxide							
2019 Submission	0.11	0.12	0.11	0.12	0.12	0.13	0.13
2018 Submission	0.11	0.12	0.11	0.12	0.12	0.13	0.13
Absolute change	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Relative change	-0.035%	-0.027%	-0.023%	-0.023%	-0.028%	0.002%	2.294%
Total GHG[a]							
2019 Submission	2,822	2,888	2,728	2,847	2,983	3,275	3,391
2018 Submission	2,822	2,888	2,728	2,847	2,983	3,275	3,330
Absolute change	0	0	0	0	0	0	61
Relative change	-0.0004%	0.0012%	0.0013%	0.0013%	0.0012%	0.0014%	1.8400%

[a] Not including CO_2 from use of biofuels; source: own calculations

3.2.9.8.6 Planned improvements (category-specific) (1.A.2.g vii)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

3.2.10 Transport (1.A.3)

3.2.10.1 Transport – Domestic aviation (1.A.3.a)

3.2.10.1.1 Category description (1.A.3.a)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
-/-	1.A.3.a Transport: Civil aviation	All fuels	CO_2	2,238.5	0.18%	2,056.2	0.23%	-8.1%
-/-	1.A.3.a Transport: Civil aviation	All fuels	N_2O	22.3	0.00%	20.5	0.00%	-8.4%
-/-	1.A.3.a Transport: Civil aviation	All fuels	CH_4	2.3	0.00%	1.7	0.00%	-24.2%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1 [a], CS (Tier 3a)	NS/IS/M	D [a], *CS* [b]
CH_4	CS (Tier 3a)	NS/IS/M	CS [c] (M)
N_2O	CS (Tier 3a)	NS/IS/M	CS [c] (M)
NO_X, CO	CS (Tier 3a)	NS/IS/M	CS [c] (M)
NMVOC	CS (Tier 3a)	NS/IS/M	CS [c] (M)
SO_2	Tier 1	NS/IS/M	D

[a] Avgas: pursuant to IPCC (2006), Chapter 3.6 – *Civil Aviation*, Table 3.6.4

[b] Derived from the default value of 3,150 kg/ t kerosene pursuant to IPCC et al. (1997) and from the specific net calorific value pursuant to AGEB (2018)

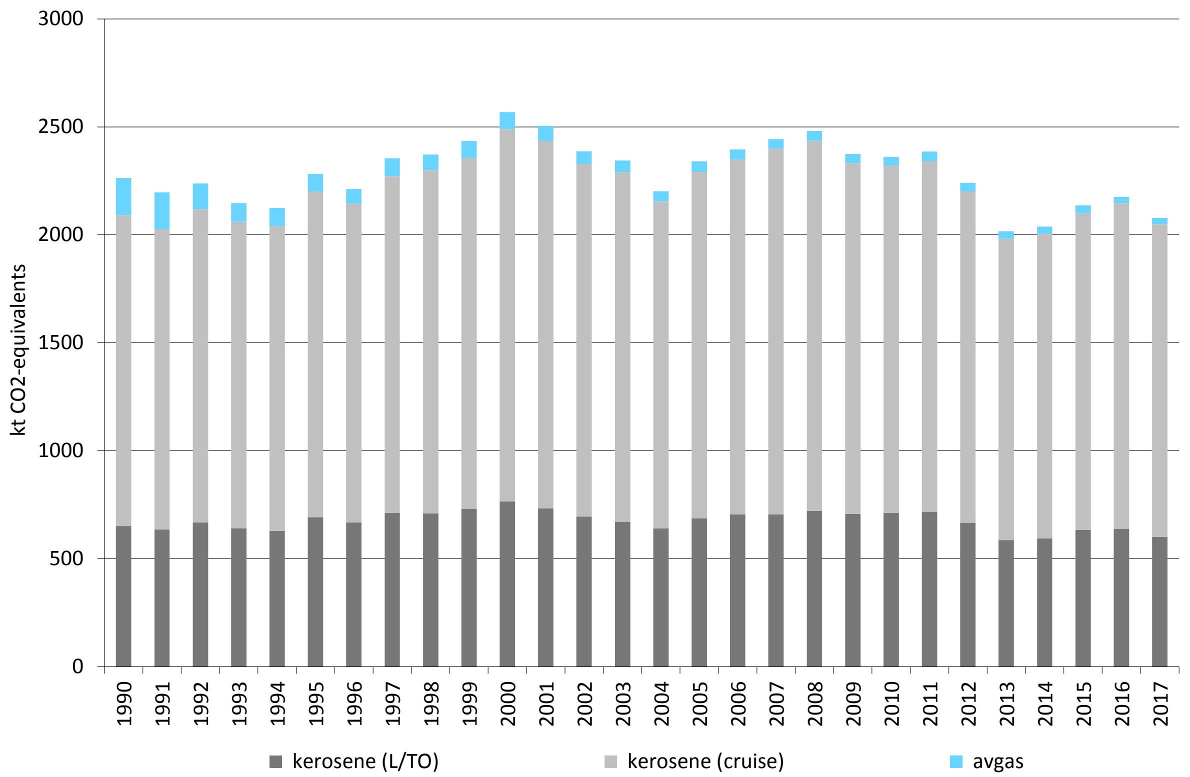
[c] Derived from Tier 3 default values pursuant to EMEP (2016)

The category *Civil aviation* is not a key category.

In terms of emissions origins, air transports differ considerably from land and water transports, since aircraft burn most of their fuel under atmospheric conditions that differ from those on the ground and that are not constant. The main factors that influence the combustion process in this sector include atmospheric pressure, environmental temperature and humidity – all of which are factors that vary considerably with flight altitude.

In addition to considering carbon dioxide, the debate on the climate effects and airborne-emissions-related environmental impacts of air transports focuses mainly on water vapour and nitrogen oxides and, secondarily, on hydrocarbons, particulates, carbon monoxide and sulphur dioxide. In the framework of national emissions reporting, figures for other emissions are also required, however. The following remarks thus refer to emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O, laughing gas), nitrogen oxides (NO_X, i.e. NO and NO_2), carbon monoxide (CO), non-methane volatile organic compounds (NMVOC) and sulphur dioxide (SO_2).

Figure 30: Development of GHG emissions in national civil air transports since 1990



3.2.10.1.2 Methodological issues (1.A.3.a)

Air-transport emissions are calculated in accordance with Tier 3a, i.e. taking account of the annual flight mileages logged by the relevant individual aircraft types, broken down by national and international flights, and taking account of the operational states LTO cycle (landing/take-off cycle, i.e. aircraft movements to an elevation of 3,000 feet / about 915 m) and cruise (cruising flight at elevations above 3,000 feet).

In general, emissions are determined on the basis of the National Energy Balance data for consumption of kerosene and aviation gasoline (AGEB, 2018). For years for which no data are yet available, data from the Federal Office of Economics and Export Control (BAFA, 2018a) are used. Within the TREMOD AV (TREMOD Aviation) (Knörr et al., 2015) model, flights are categorised as either intra-German or international flights. This breakdown plays a decisive role in reporting. The relevant flight data are collected by the Federal Statistical Office.

For reporting purposes, emissions are determined, in each case, by multiplying fuel consumption for the relevant flight phase by the pertinent specific emission factor. CO_2 and SO_2 emissions figures do not depend on what method is used; they depend solely on the quantities and characteristics of the fuel consumed. Emissions of NMVOC, CH_4, CO, NO_X and N_2O, on the other hand, depend on engines, flight altitudes, flight phases, etc., and thus they are described more precisely by higher-Tier methods. The emission factors for NOx and CO are thus taken from the results of the TREMOD-AV calculations.

In a departure from this approach, as proposed in (IPCC (2006): Volume 2, Chapter 3: Mobile Combustion), the emissions caused by use of avgas are calculated separately, in a Tier 1 approach, with adjusted emission factors and calorific values. In such calculation, there is no need for any breakdown into domestic and international transports; aviation gasoline is used only in smaller aircraft that fly mostly domestic routes.

The **activity data** (energy inputs) are in keeping with the aviation fuel sold in Germany pursuant to (AGEB (2018); currently, for the period through 2016) and the *Official mineral-oil data for the Federal Republic of Germany* (Amtliche Mineralöldaten für die Bundesrepublik Deutschland) that are published by the Federal Office of Economics and Export Control (BAFA, 2018a).

The calculations made within TREMOD-AV, with regard to **kerosene**, take account of the numbers of flights, for the various aircraft types and great-circle distances involved, and for national and international air transports. In the process, the commercial flights recorded by the Federal Statistical Office, for certain airports, are included. The Federal Statistical Office breaks down flights from "other airfields", and non-commercial flights, only by weight or aircraft classes, and not by destinations. The great majority of the flights concerned are flights by small aircraft fueled with aviation gasoline. Rough calculations pursuant to Knörr et al. (2010) indicate that it is appropriate to allocate such flights to (solely national) avgas consumption.

Table 48: Domestic flights' annual shares of domestic kerosene deliveries, in %

1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
14.6	12.7	11.3	9.0	8.8	8.7	8.7	8.6	8.7	9.1	8.0	7.1	7.5	7.8	7.5	6.5

Source: TREMOD AV (Knörr et al., 2018c)

Jet-kerosene consumption is broken down, in accordance with the two flight phases landing / take-off (LTO cycle) and cruise, on the basis of data of the Federal Statistical Office, and via TREMOD-AV calculations. Those results make it possible to extract kerosene consumption figures for the LTO flight phase for both domestic and international air traffic. Consumption in cruise flight is obtained as the difference in kerosene consumption, pursuant to the NEB, less the LTO consumption.

The activity data for ***avgas*** are in keeping with the avgas quantities sold in Germany pursuant to AGEB (2018) and BAFA (2018a). In a conservative approach, all relevant consumption is assumed to occur in national flight operations. Pursuant to (IPCC (2006): Volume 2, Chapter 3: Mobile Combustion) the data do not have to be broken down in terms of LTO and cruising flight phases.

The pertinent quantities of ***co-combusted lubricants*** are derived, pursuant to (VSI, 2014), from the relevant annual fuel quantities (cf. Chapter 19.1.4 in the Annex).

With regard to the **emission factors** used for carbon dioxide, we refer, in general, to Chapter 18.8.

The emission factor for *carbon dioxide* from use of ***kerosene*** was derived from the carbon content of kerosene; it is *3,150 g/kg*. That value, which has been substantiated by numerous published studies, is used for all air transports.

Nitrous oxide (laughing gas) is a product of nitrogen oxidation in the combustion chamber, and it can occur in traces. The available data for this substance are poor. Since the emission factors have to be broken down in accordance with the two flight phases, the emission factors for both nitrous oxide and *methane* have been taken from the IPCC emission factor database (EFDB) (cf. Table 530). For methane, it is assumed that emissions occur only during the LTO cycle (cf. IPCC (2006): Volume 2, Chapter 3.6, Tab. 3.6.5). On the other hand, N_2O emissions are also calculated for cruising flight.

The other emissions are calculated separately for each flight phase, on the basis of the relevant emission factors. In the process, different sources are used.

The implied emission factors used for NO_X, CO and NMVOC consist of quotients obtained by dividing the aircraft-type-specific emissions calculated and aggregated in TREMOD by the applicable annual kerosene consumption. The detailed emissions data used for this purpose are calculated in TREMOD with aircraft-type-specific emission factors from the EMEP/EEA database.

Figures relative to the air pollutants additionally considered are presented in Chapter 19.1.3.1 in the Annex.

The emission factors expressed in the units [g/kg] are converted into the units [g/TJ] on the basis of a net calorific value of 43,000 kJ/kg (AGEB, 2018).

For ***avgas***, emission factors do not have to be divided into LTO and cruise categories.

For calculation of *CO_2 emissions*, the standard value pursuant to (IPCC (2006): Volume 2, Chapter 3: Mobile Combustion) is used. In those guidelines (page 3-64), the emission factors for *methane* and *nitrous oxide* are explicitly defined as equal to the relevant values given for kerosene use. That assumption has been adopted here.

In a procedure similar to that described above for kerosene, the implied emission factors used for NO_X, and CO are derived from aircraft-type-specific emissions calculated and aggregated in TREMOD and from the applicable annual avgas consumption.

CO_2 emissions from unintentional co-incineration of lubricants are reported in CRF 2.D.1. With regard to releases of methane and nitrous oxide, it is assumed that such emissions are already taken into account in the pertinent emission factors for the fuels used and thus are to be reported as IE *(included elsewhere)*.

Table 49: Emission factors used for report year 2017, in kg/TJ

	CH_4	N_2O	Origin
Kerosene: LTO	8.21 (0.50)	2.74 (2.00)	pursuant to TREMOD AV; derived from EFDB defaults in kg/LTO
Kerosene: Cruise	0.00 (0.50)	2.33 (2.00)	pursuant to TREMOD AV; derived from EFDB defaults in kg/t kerosene
Avgas	8.21 (-)	2.33 (-)	equivalent to IEF for kerosene, CH_4: LTO; N_2O: Cruise
Lubricants	IE	IE	Included in the EF for fuels

Source: (Gores, 2018); in parentheses: Sector-specific defaults pursuant to IPCC (2006): Volume 2, Chapter 3.6, Tab. 3.6.5

3.2.10.1.3 Uncertainties and time-series consistency (1.A.3.a)

For determination of uncertainties, the individual components that enter into emissions calculation are identified, and their uncertainties (U_1 to U_n) are quantified. The total uncertainty U_{total} is obtained via additive linking of squared partial uncertainties, as explained in IPCC (2006): Volume 1, Chapter 3, page 3.28, formula 3.1:

$$U_{total} = \sqrt{U_1^2 + U_2^2 + \ldots + U_n^2}$$

For all time series and flight phases, uncertainties were estimated as mean values. The total uncertainties were calculated as is shown in Annex Chapter 19.1.3.1.2. The left column in that section contains the components that enter into the uncertainty calculation; the relevant partial uncertainties are listed in the neighbouring columns to the right. The columns that then follow to the right contain the values for the required total uncertainties. Some of these, in turn, are individual components of the uncertainties calculation for other values. For example, the uncertainty for national jet-kerosene consumption in the two relevant flight phases, LTO and cruise, is calculated from the partial uncertainties for total national jet-kerosene consumption and from the partial uncertainty for the LTO/cruise breakdown. The latter is based on the number of aircraft movements, as reported by the *Federal Statistical Office*, and on assumptions relative to the fleet composition. The total uncertainty for kerosene consumption during the LTO and cruise flight phases, in turn, serves as a partial uncertainty in determination of the uncertainties for emissions data.

3.2.10.1.4 Category-specific quality assurance / control and verification (1.A.3.a)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

For a growing share of aircraft types for which no specific data are available, emission factors have to be obtained via regressions carried out on the basis of take-off weight. Use of more current, and more complete, aircraft-type-specific data would further improve the quality of the calculations. Furthermore, expansion of the TREMOD calculations, to include differentiation in accordance with the different engines used, would also improve the quality of the calculations.

Except for the emission factors for sulphur dioxide, international standard values were used, taken from the IPCC emission-factors database, the EMEP-EEA database and EMEP (2016). Country-specific consumption and emissions data provided by Eurocontrol are currently being used only for verification purposes.

Table 50: Overview of relevant data comparisons

	Comparison with...	Remark
CO_2, CH_4, N_2O	Alternative emissions inventories for Germany	No comparable data sets
CO_2	Specific Tier 1 default EF pursuant to IPCC (2006): Volume 2, Chapter 3.6, Tab. 3.6.4	cf. Table 51
CH_4, N_2O	Specific Tier 1 default EF pursuant to IPCC (2006): Volume 2, Chapter 3.6, Tab. 3.6.5	cf. Table 49
CO_2, CH_4, N_2O	Specific IEF of other countries	cf. Table 52

Table 51: Comparison of the EF(CO_2) used in the inventory with default values [a], in kg/TJ

	Inventory value	Default[b]	*Lower bound*	*Upper bound*
Kerosene	73,256	71,500	*69,700*	*74,400*
Avgas	70,000		*67,500*	*73,000*

[a] pursuant to IPCC (2006): Volume 2, Chapter 2, Table 2.4

The following table provides a comparison with specific implied emission factors of other countries.

Table 52: International comparison of reported IEF, in kg/TJ

	Kerosene			Avgas		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Germany	73,256	2.40	2.45	70,000	8.21	2.33
Denmark	71,878	0.59	3.54	72,644	19.84	2.00
France	71,591	0.97	2.00	70,500	1.86	1.97
Netherlands	71,500	0.50	2.00	72,000	0.50	2.00
UK	71,706	0.94	2.28	69,467	49.36	2.22
EU (28)	72,081	1.32	2.17	70,348	11.83	4.49

Germany: current IEF for report year 2017; all other countries: IEF for 2016, pursuant to 2018 CRF Submission

3.2.10.1.5 Category-specific recalculations (1.A.3.a)

Recalculations with respect to the 2018 Submission were carried out for all years under consideration, to take account of adjustment of the specific LTO-consumption figures in the TREMOD AV model to circumstances prevailing at German airports.

Table 53: Revised mean LTO consumption, in kg kerosene / take-off

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
2019 Submission	671	637	635	574	631	616	609	582	578	631	626
2018 Submission	789	736	745	657	713	700	692	662	658	712	711
Absolute change	-118	-99	-110	-83	-82	-83	-83	-80	-80	-81	-85
Relative change	-15%	-13%	-15%	-13%	-11%	-12%	-12%	-12%	-12%	-11%	-12%

As a result of this revision, domestic flights' annual share of total domestic kerosene deliveries is also reduced, for all years under consideration.

Table 54: Domestic flights' annual shares of domestic kerosene deliveries, revised, in [%]

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
2019 Submission	14.60	12.73	11.31	9.00	8.66	9.14	8.02	7.14	7.48	7.83	7.45
2018 Submission	15.55	13.73	12.29	9.82	9.46	10.01	8.79	7.85	8.24	8.61	8.17
Absolute change	-0.95	-1.00	-0.98	-0.82	-0.80	-0.87	-0.76	-0.70	-0.76	-0.78	-0.72
Relative change	-6.13%	-7.26%	-7.96%	-8.34%	-8.47%	-8.74%	-8.69%	-8.98%	-9.24%	-9.04%	-8.80%

Source: TREMOD AV (Knörr et al., 2018c)

The quantities of kerosene consumed for domestic flights were downwardly corrected by the same amount.

Table 55: Resulting revision of kerosene consumed for domestic flights, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
2019 Submission	28,228	29,722	33,615	30,936	31,338	31,623	29,725	26,758	27,075	28,334	28,986
2018 Submission	30,071	32,049	36,521	33,753	34,237	34,651	32,554	29,399	29,830	31,151	31,783
Absolute change	-1,843	-2,327	-2,906	-2,816	-2,899	-3,028	-2,829	-2,640	-2,755	-2,817	-2,797
Relative change	-6.13%	-7.26%	-7.96%	-8.34%	-8.47%	-8.74%	-8.69%	-8.98%	-9.24%	-9.04%	-8.80%

The relative changes in the reported greenhouse-gas emissions are largely in keeping with the kerosene consumption data. Methane is the sole exception: Since it is assumed that no methane emissions occur during cruising flight, the reduction in the LTO-consumption figures has a disproportionately large effect in this area.

Table 56: Revised GHG emissions, in kt and kt CO_2 equivalents

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
Carbon dioxide – CO_2											
2019 Submission	2,239	2,257	2,541	2,315	2,335	2,360	2,217	1,995	2,016	2,114	2,152
2018 Submission	2,374	2,428	2,754	2,521	2,548	2,581	2,424	2,188	2,218	2,321	2,357
Absolute change.	-135	-170	-213	-206	-212	-222	-207	-193	-202	-206	-205
Relative change	-5.69%	-7.02%	-7.73%	-8.18%	-8.34%	-8.59%	-8.55%	-8.84%	-9.10%	-8.89%	-8.69%
Methane – CH_4											
2019 Submission	0.092	0.086	0.094	0.082	0.083	0.084	0.078	0.069	0.069	0.075	0.074
2018 Submission	0.104	0.096	0.105	0.092	0.093	0.094	0.088	0.078	0.078	0.083	0.083
Absolute change	-0.012	-0.010	-0.012	-0.010	-0.009	-0.010	-0.010	-0.009	-0.009	-0.009	-0.009
Relative change	-11.7%	-10.4%	-11.1%	-11.2%	-10.2%	-10.8%	-10.9%	-11.2%	-11.3%	-10.6%	-10.9%
Nitrous oxide – N_2O											
2019 Submission	0.075	0.076	0.085	0.077	0.078	0.079	0.074	0.067	0.067	0.071	0.072
2018 Submission	0.080	0.082	0.092	0.084	0.085	0.086	0.081	0.073	0.074	0.078	0.079
Absolute change.	-0.005	-0.006	-0.007	-0.007	-0.007	-0.008	-0.007	-0.007	-0.007	-0.007	-0.007
Relative change	-6.14%	-7.25%	-7.95%	-8.37%	-8.45%	-8.73%	-8.69%	-8.98%	-9.23%	-9.01%	-8.82%
Total for all greenhouse gases											
2019 Submission	2,263	2,282	2,569	2,340	2,361	2,385	2,241	2,016	2,038	2,137	2,175
2018 Submission	2,400	2,454	2,784	2,549	2,576	2,609	2,450	2,212	2,242	2,346	2,382
Absolute change	-137	-172	-215	-209	-215	-224	-210	-196	-204	-209	-207
Relative change	-5.70%	-7.03%	-7.74%	-8.19%	-8.34%	-8.60%	-8.55%	-8.84%	-9.10%	-8.90%	-8.70%

Source: Own calculations

3.2.10.1.6 Category-specific planned improvements (1.A.3.a)

Recently, the TREMOD AV model's specific LTO-consumption figures were updated in the framework of an ad hoc revision. Now, more-extensive revision of the TREMOD AV model is planned.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

3.2.10.2 Transport – Road transportation (1.A.3.b)

3.2.10.2.1 Category description (1.A.3.b)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
L/T	1.A.3.b Transport: Road transportation	All fuels	CO_2	151,880.6	12.41%	160,082.9	17.96%	5.4%
-/T	1.A.3.b Transport: Road transportation	All fuels	CH_4	1,316.8	0.11%	134.9	0.02%	-89.8%
-/T	1.A.3.b Transport: Road transportation	All fuels	N_2O	1,113.5	0.09%	1,601.2	0.18%	43.8%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1 [a], CS (Tier 2)	NS / M	D [a], CS
CH_4	Tier 1 [b], CS (Tier 3)	NS / M	D [b], CS (M)
N_2O	Tier 1 [b], CS (Tier 3)	NS / M	D [b], CS (M)
NO_X, CO, NMVOC, SO_2	CS (Tier 3)	NS / M	CS (M)

[a] Biodiesel, petroleum, lubricants co-combusted in two-stroke engines; [b] LP gas

The category *Road transportation* is a key category for CO_2 emissions in terms of level and trend. For CH_4 and N_2O emissions, it is a key category only in terms of trend.

Emissions from motorised road transport in Germany are reported under this category. It includes transport on public roads within Germany, except for agricultural, forestry and military transports. Calculations are made for the vehicle categories of passenger cars (PCs), motorcycles, light duty vehicles (LDVs), heavy duty vehicles (HDVs), buses and motorcycles. For calculation purposes, the vehicle categories are broken down into so-called *vehicle layers* with the same emissions behaviour. To that end, vehicle categories are also broken down by type of fuel used, vehicle size (trucks and buses by weight class; automobiles and motorcycles by engine displacement) and pollution control equipment used, as defined by EU directives for emissions control ("EURO norms"), and by regional traffic distribution (outside of cities, in cities and on autobahns).

3.2.10.2.2 Methodological issues (1.A.3.b)

- Cf. also Chapter 19.1.3.2 -

Since 1990, emissions of CH_4, NO_X, CO, NMVOC and SO_2 from road transports have decreased sharply, due to catalytic-converter use and engine improvements resulting from continual tightening of emissions laws, and due to improved fuel quality.

Between 1990 and 1993, the methane emission factor for gasoline dropped sharply, producing a corresponding sharp reduction in methane emissions. This was due especially to a massive reduction in the numbers of vehicles with two-stroke engines in the new German Länder. Further EF decreases have resulted via the aforementioned tightening of emissions standards.

For buses and heavy duty vehicles (over 3.5 t total permissible vehicle weight), maximum permissible levels of hydrocarbon (HC) emissions were lowered considerably (-40 %) via the introduction of the EURO3 standard in 2000. Since EURO3 vehicles were very quick to reach the market as of 2000, the emission factor for hydrocarbon emissions from diesel oil – and the relevant emissions themselves – decreased considerably after 2000. A similar trend occurred for methane, emissions of which are calculated as a fixed share of total HC emissions.

N_2O emissions result primarily from incomplete reduction of NO to N_2 in 3-way catalytic converters. They are not limited by law. Initially, growth in numbers of cars with catalytic converters caused increases in N_2O emissions in comparison to the 1990 level. Newer catalytic converters are optimised to produce only small amounts of N_2O, however. As a result, N_2O decreased during the period 2000-2006. Since then, such emissions have been increasing again. Those increases are due to increasing use of selective catalytic reduction (SCR) equipment in HDVs; under certain conditions, such equipment can produce N_2O as an undesired by-product.

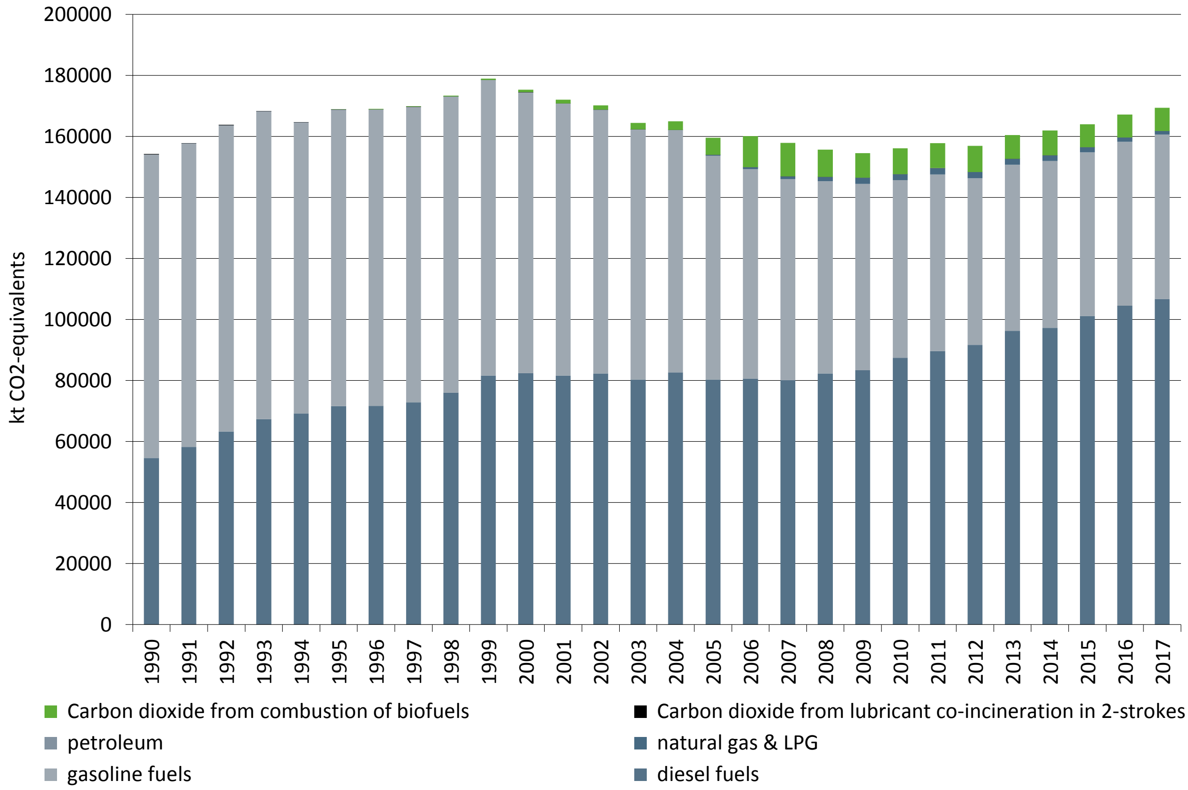
CO_2 emissions depend directly on fuel consumption. From 1990-1999, these emissions increased, since growth in mileage travelled outweighed improvements in vehicle fuel consumption. In the 2000-2009 period, road-transport emissions from consumption of fossil fuels decreased for the first time. The likely reasons for this trend include reductions in specific fuel consumption, the marked shift toward diesel vehicles in new registrations, continual increases in fuel prices, use of biofuels – and consumers' growing tendency to travel to other countries in order to make their fuel purchases (see the following paragraphs).

In the years 2010 and 2011, the CO_2 emissions increased again, as the aforementioned trends slowed and overall mileage increased. In 2012, they decreased by over 1.3 million t with respect to the previous year, however, because traffic volumes and mileage decreased. As a result of renewed growth in overall mileage traveled, of decreases in inputs of biofuels and of continual increases – over a period of years now – in the average engine power of newly registered automobiles[30], however, CO_2 emissions have increased again since then, by nearly 9 %. In 2017,

[30] According to the Federal Statistical Office, the average engine power of newly registered automobiles in 2013 was 137 hp. The corresponding figure eight years earlier was just under 123 hp.

https://www.destatis.de/DE/PresseService/Presse/Pressemitteilungen/2015/06/PD15_213_85pdf.pdf?__blob=publicationFile they amounted to 160.1 million t. That figure is 8.2 million t above the corresponding emissions level in 1990.

Figure 31: Development of GHG emissions in road transports, since 1990



CO_2 emissions from motorised road transports in Germany are calculated via a Tier-2 "*bottom-up*" approach pursuant to (IPCC (2006): Volume 2, Chapter 3.2, page 3.12): In the pertinent process, the fuels sold in Germany (gasoline, (bio-) ethanol fuel, diesel fuel, biodiesel, LP and natural gas, petroleum (until 2002), biogas) are allocated, within the TREMOD ("Transport Emission Model") model, to the various relevant vehicle layers (cf. Chapter 19.1.3.2) (Knörr et al., 2018a)[31]. The consumption data that enter into the model, for each type of fuel, are obtained from the *National Energy Balances* (NEBs). The actual emission calculation is carried out in the Central System of Emissions (CSE), after the pertinent specific fuel consumption data and emission factors have been imported.

The procedure for calculation of non-CO_2 emissions is based on a Tier-3 method, implemented in TREMOD, in which the mileage data for the relevant individual vehicle layers are multiplied by the applicable specific emission factors. For passenger cars and light duty vehicles, a "*cold start surplus*" is also added. The total consumption determined for each fuel type is cross-checked against consumption pursuant to the Energy Balance. Then, the relevant emissions as calculated in TREMOD are corrected with the help of correction factors obtained via such cross-checking. For gasoline-powered vehicles, the VOC-evaporation emissions are calculated as a function of the pollution-control technology used. From emissions and fuel consumption data for the individual TREMOD vehicle layers, implied emission factors (IEF) in [kg/TJ] are derived. The IEF, fuel-based, are differentiated by fuel type and road type (autobahn, country road, municipal streets) and,

[31] To make it possible to derive and assess reduction measures, energy consumption and CO_2 emissions for the various vehicle categories are also calculated with TREMOD. The resulting values are subsequently checked against total consumption and total CO_2 emissions.

within the individual vehicle categories, by "with/without" emissions-control equipment. After being derived, the IEF are entered into the Central System of Emissions (CSE). The following categories of emissions-control equipment are differentiated:

Table 57: Differentiation of emissions-control categories in road transports

Vehicle classes considered	Emissions-control system Without	 With
Automobiles / LDVs with gasoline engines	Without catalytic converter	With catalytic converter
Automobiles / LDVs with diesel engines, as well as buses, HDVs and motorcycles	Prior to the EURO 1 standard	as of EURO 1

The actual emission calculation is carried out in the CSE, after the pertinent specific fuel consumption data and IEF have been imported.

Table 58: Emissions from road transports, in kilotonnes

	CO_2 fossil [a]	 *biogenic* [b]	CH_4	N_2O	NO_X	CO	NMVOC [c]	SO_2
1990	151,881	0	52.67	3.74	1,342.66	6,658.25	1,168.55	90.20
1995	166,437	106	29.12	5.64	1,136.23	3,469.60	532.40	69.31
2000	172,494	869	18.60	5.20	1,034.23	2,157.98	290.93	19.67
2005	152,728	5,573	11.18	3.31	738.09	1,373.78	174.55	0.80
2006	148,706	10,176	10.15	3.25	721.12	1,247.05	169.97	0.80
2007	145,715	11,005	9.11	3.39	661.55	1,134.77	152.10	0.79
2008	145,491	8,914	7.92	3.55	584.49	1,030.47	133.49	0.78
2009	145,202	8,024	7.34	3.73	537.08	971.93	124.36	0.78
2010	146,258	8,483	6.70	4.03	523.16	907.01	115.39	0.78
2011	148,199	8,175	6.48	4.30	506.13	884.37	111.44	0.79
2012	146,860	8,536	5.98	4.55	495.61	826.04	103.89	0.79
2013	151,124	7,753	5.82	4.81	493.12	805.88	101.51	0.80
2014	152,257	8,084	5.77	4.89	476.47	787.83	100.23	0.81
2015	154,878	7,491	5.47	5.09	453.41	736.75	94.70	0.81
2016	157,992	7,522	5.42	5.25	430.50	719.78	94.15	0.83
2017	160,082	7,623	5.40	5.37	402.42	704.37	93.62	0.84

Source: Own calculations, based on , Knörr et al. (2018a)

[a] Including CO_2 from lubricants co-combusted in two-stroke engines

[b] CO_2 emissions from biofuels are listed here solely for informational purposes

[c] Including emissions from fuel evaporation

For calculation with TREMOD, extensive basic data from generally accessible statistics and special surveys are used, co-ordinated, and supplemented. The main data sources used, and key assumptions made, are outlined only briefly here. A detailed description of the databases, including information on the sources used, and the calculation methods used in TREMOD, is provided in Knörr et al. (2018a).

For western Germany from 1990 through 1993, and for Germany as a whole as of 1994, total-automobile-fleet data are calculated on the basis of the officially published fleet and new registration statistics of the Federal Motor Transport Authority (KBA). The car ownership analysis for East Germany in 1990 was based on a detailed analysis of the Adlershof car-emissions-testing agency in 1992 and the time series in the statistical annuals of the GDR. For the period between 1991 and 1993, it was necessary to estimate the figures with the aid of numerous assumptions.

The fleet data for base years as of 2001 are obtained for the TREMOD model by querying the database of the KBA. The supplied data include vehicle fleets for each reference year, broken down as required for emissions calculation, i.e. in accordance with the following characteristics: type of engine (gasoline, diesel, other), size class, vehicle age and emissions standard. For each reference year, the mid-year fleet is assumed to be representative of the fleet's composition for the year.

Mileage data are updated on the basis of the "2002 Mileage Survey" ("Fahrleistungserhebung 2002"; (Hautzinger et al., 2005)) and the 2010 road transport census (Straßenverkehrszählung 2010; (Lensing, 2013)). For heavy duty vehicles, the data are also cross-checked against road-toll statistics.

With regard to the **emission factors** used for carbon dioxide, we refer, in general, to Chapter 18.8.

For gasoline and natural gas, year-specific values, weighted in accordance with the fuel qualities produced in Germany, are available. For all other fuels, standardised values are used, throughout all relevant years. Further information – in particular, with regard to carbon dioxide from lubricant co-combustion – is also provided in Chapter 19.1.4.

All other emission factors are listed in the "Handbook Emission Factors for Road Transport 3.2" (HBEFA), which originated via a cooperative effort, involving Austria, Germany and Switzerland, aimed at deriving emission factors for road transports. In large part, the factors were obtained via measurement programmes of TÜV Rheinland and RWTÜV and via fundamentally oriented studies oriented to the reference years 1989/1990. In those studies, a new method was used, for both passenger cars and heavy duty vehicles, whereby emission factors were derived on the basis of driving habits and traffic situations. Emission factors for automobiles until the 1994 (automobile-)model year were updated with the help of field-monitoring data. Now, the Netherlands, Sweden and Norway also participate in the development of the HBEFA. HBEFA version 3.3 (Keller et al., 2017), which is used for the current emissions calculations, draws on findings of the EU working group COST 346, of measurement programmes of the participating countries and of the ARTEMIS research programme.

With regard to *unintentional co-incineration of lubricants*, it is assumed that the pertinent non-CO_2 emissions are already included in the emission factors for the relevant fuels and thus have to be reported here as IE *(included elsewhere)*. Carbon dioxide from *unintentional* co-incineration of lubricants is reported in 2.D.1, however, as emissions from product use. On the other hand, carbon dioxide from *intentional* co-incineration of lubricants, as part of the fuel mixtures used in road-vehicle two-stroke engines, is also assigned to road transports and, in the CRF tables, is reported in 1.A.3.b v.

Shifting of fuel purchases to other countries

Because fuel prices in Germany are higher – significantly, in some cases – than in several of Germany's neighbours, for some time the fuels used in Germany have included fuels purchased in other countries and brought into the country as "grey" imports.

At present, no precise data are available on this phenomenon, which is significant for truck and automobile traffic in Germany's border regions and which is referred to as "refueling tourism" ("Tanktourismus"). Although several detailed studies have been carried out, no reliable overall picture of the situation is available (Lenk et al., 2004).

The sources that have documented shifting of consumers' fuel purchases to other countries (along with the resulting negative impacts on neighbouring countries' own emissions inventories) have included a study published by the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management (Molitor et al., 2004). The relevant neighbouring countries profit, to a not-inconsiderable degree, from additional revenue from energy taxation of such fuels. Such revenue is likely to be significantly higher than the certificate costs for the pertinent CO_2 emissions would be.

3.2.10.2.3 Uncertainties and time-series consistency (1.A.3.b)

In the framework of a study (Knörr et al., 2009), uncertainties were calculated for the activity data entered into TREMOD, for the emission factors generated in TREMOD and for the emissions calculated in the Central System of Emissions (CSE).

3.2.10.2.4 Source-specific quality assurance / control and verification (1.A.3.b)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

Quality reports of the Working Group on Energy Balances (AGEB) have been submitted to the Federal Environment Agency, for purposes of quality assurance of the National Energy Balances. In addition, documentation on revision of Energy Balances as of 2003 has been published in the Internet[32].

Table 59: Overview of relevant data comparisons

	Comparison with...	Remark
CO_2, CH_4, N_2O	Alternative emissions inventories for Germany	No comparable data sets
CO_2	Specific Tier 1 defaults pursuant to IPCC (2006): Volume 2, Chapter 3, Table 3.2.1	No defaults for biofuels and petroleum
CO_2	Tier 1 default EF pursuant to IPCC (2006): Volume 2, Chapter 3, Tab. 2.4	cf. Table 60
CH_4, N_2O	Specific Tier 1 defaults pursuant to IPCC (2006): Volume 2, Chapter 3, Table 3.2.2	Results are inconclusive
CH_4, N_2O	Tier 1 default EF pursuant to IPCC (2006): Volume 2, Table 2.4	Results are inconclusive
CO_2, CH_4, N_2O	Specific IEF of other countries	cf. Table 61

Table 60: Comparison of a) the EF(CO_2) used and b) default values, in kg/TJ

	Inventory value [a]	Default [b]	Lower bound	Upper bound
Fossil diesel fuel	74,027	74,100	72,600	74,800
Fossil-based gasoline	75,285	69,300	67,500	73,000
Natural gas	55,827	56,100	54,300	58,300
LP gas	66,334	63,100	61,600	65,600
Petroleum	74,000	-	-	-
Co-combusted lubricants	73,300		71,900	75,200
Biodiesel	70,800		59,800	84,300
Bioethanol	71,607	70,800	59,800	84,300
Biogas	90,584	54,600	46,200	66,000

[a] used for reported year 2017; [b] pursuant to IPCC (2006): Chapter 2, Table 2.4

The following table provides a comparison with specific implied emission factors of other countries as well as with the relevant values resulting for the EU(28).

[32] AG Energiebilanzen (Working Group on Energy Balances): explanations relative to revision of the Energy Balances 2003 – 2009; URL: http://www.ag-energiebilanzen.de/index.php?article_id=7&clang=0#revision_der_energiebilanzen_2003_bis_2009_05 (last checked on 18 Sept. 2013)

Table 61: International comparison of reported IEF, in kg/TJ

	Gasoline			Diesel fuel			LPG			Natural gas		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Germany	75,285	6.80	0.56	74,027	0.19	3.29	66,334	1.92	1.32	55,827	6.51	0.87
Denmark	72,985	6.04	0.91	73,998	0.53	3.44	63,100	4.46	1.03	56,800	0.22	3.47
France	70,579	12.81	1.33	75,032	0.50	3.15	65,254	2.77	2.69	56,383	43.00	0.05
Netherlands	73,023	11.92	0.94	72,454	0.54	2.69	66,700	2.42	0.90	56,500	92.00	3.00
UK	69,998	6.93	0.67	72,930	0.43	3.08	63,979	1.25	0.72	IE	IE	IE
EU (28)	72,387	10.47	1.09	73,858	0.84	2.93	65,186	9.83	1.84	57,011	34.37	1.18

Germany: current IEF for 2015; otherwise: IEF for 2014, pursuant to 2016 CRF Submission

3.2.10.2.5 Category-specific recalculations (1.A.3.b)

Since the Submission 2018, recalculations have been carried out to take account of revised activity data and emission factors.

In addition, provisional energy-consumption figures in the 2016 Energy Balance have been replaced with final values.

Table 62: Revised energy inputs for 2016, in terajoules

	Diesel	Biodiesel	Gasoline	Bioeth.	Natural	LP gas	Biogas	Lubricants
2019 Submission	1,393,48	73,337	709,179	30,804	5,848	16,799	1,375	86.63
2018 Submission	1,398,27	73,507	708,672	30,783	7,468	19,462	1,201	87.13
Absolute change	-4,790	-171	507	21	-1,620	-2,663	174	-0.50
Relative change	-0.34%	-0.23%	0.07%	0.07%	-21.70%	-13.68%	14.45%	-0.57%

Source: TREMOD, (Knörr et al., 2018a) based on AGEB (2018) and MWV (2018)

Lubricants: as part of 1:50 two-stroke fuel mixtures; burned in two-stroke gasoline engines

Table 63: Revised EF(CO_2) for gasoline and LP gas, 2015 and 2016, in kg/TJ

	Gasoline		Natural gas	
	2015	2016	2015	2016
2019 Submission	75,287	75,285	55,889	55,840
2018 Submission	75,289	75,286	55,936	55,936
Absolute change	-2	-2	-47	-96
Relative change	0.00%	0.00%	-0.08%	-0.17%

Source: Own calculations

Changes in the specific Tier 3 emission factors for methane and nitrous oxide were made on a highly differentiated basis, in keeping with the motor-vehicle and road types concerned. They cannot be usefully presented here.

The following table presents a finalising comparison of the emissions quantities reported in the current submission and the 2018 Submission.

Table 64: Revised GHG emissions, in kt CO_2 equivalents

	2012	2013	2014	2015	2016
1.A.3.b i – automobiles					
2019 Submission	93,872	96,544	99,197	98,305	100,157
2018 Submission	93,873	96,545	99,198	98,309	100,312
Absolute change	-0.4	-1.2	-1.7	-3.8	-154.4
Relative change	0.000%	-0.001%	-0.002%	-0.004%	-0.154%
1.A.3.b ii – light duty vehicles					
2019 Submission	7,074	7,273	7,429	7,481	7,502
2018 Submission	7,074	7,273	7,429	7,481	7,565
Absolute change	0.0	-0.03	-0.1	-0.2	-63.1
Relative change	0.000%	-0.0004%	-0.001%	-0.002%	-0.834%

	2012	2013	2014	2015	2016
1.A.3.b iii – Heavy duty vehicles (including buses)					
2019 Submission	46,050	47,462	45,752	49,275	50,562
2018 Submission	46,050	47,461	45,751	49,273	50,927
Absolute change	0.5	1.2	1.5	2.0	-365.3
Relative change	0.001%	0.003%	0.003%	0.004%	-0.717%
1.A.3.b iv – Motorised two-wheelers (motorcycles and mopeds)					
2019 Submission	1,363	1,416	1,473	1,466	1,464
2018 Submission	1,363	1,416	1,473	1,466	1,472
Absolute change	0.0	0.0	0.0	0.0	-8.4
Relative change	0.000%	0.000%	0.000%	-0.002%	-0.571%
CO_2 from co-incineration of lubricants in two-stroke gasoline engines					
2019 Submission	6.427	6.449	6.573	6.314	6.386
2018 Submission	6.427	6.449	6.573	6.314	6.386
Absolute change	0.000	0.000	0.000	0.000	0.000
Relative change	0.000%	0.000%	0.000%	0.000%	0.000%
1.A.3.b – TOTAL					
2019 Submission	148,365	152,702	153,858	156,533	159,692
2018 Submission	148,365	152,702	153,858	156,535	160,283
Absolute change	0.01	0.02	-0.29	-1.98	-591.24
Relative change	0.0000%	0.00001%	-0.0002%	-0.0013%	-0.3689%

Source: Own calculations

3.2.10.2.6 Category-specific planned improvements (1.A.3.b)

Apart from annual regular revision of the TREMOD AV model, no source-specific improvements are planned.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

3.2.10.3 Transport – Railways (1.A.3.c)

3.2.10.3.1 Category description (1.A.3.c)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
L/T	**1.A.3.c Transport: Railways**	**All fuels**	**CO_2**	**2,900.52**	**0.24%**	**1,045.25**	**0.12%**	**-64.0%**
-/-	1.A.3.c Transport: Railways	All fuels	N_2O	6.68	0.00%	2.56	0.00%	-61.7%
-/-	1.A.3.c Transport: Railways	All fuels	CH_4	2.60	0.00%	0.36	0.00%	-86.0%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1 [a], CS (Tier 2)	NS	D [a], CS
CH_4	CS (Tier 2)	NS	D [b, c, d]
N_2O	CS (Tier 2)	NS	D [d], CS
NO_x, CO, NMVOC, SO_2	CS (Tier 2)	NS	CS

[a] Biodiesel: pursuant to (IPCC (2006): Tab. 2.4); [b] Diesel: pursuant to (EMEP (2016): 1.A.3.c – *Railways*; Tab. 3-2 through 3-4); [c] hard coal & hard-coal coke: pursuant to (IPCC (2006): Tab. 3.4.1); [d] Lignite: pursuant to (IPCC (2006): Tab. 2.5).

The category *Railway transports* is a key category for CO_2 emissions in terms of emissions level and trend.

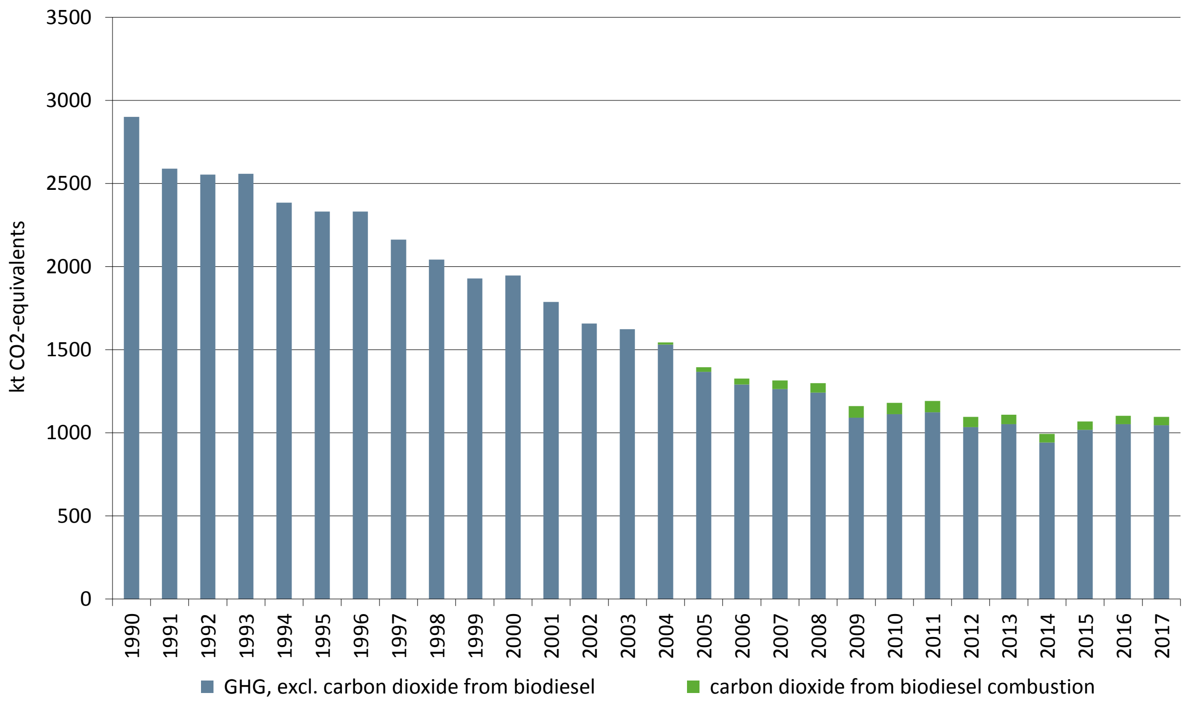
Germany's railway sector is undergoing a long-term modernisation process, aimed at making electricity the main energy source for rail transports. Its share of the energy used for traction is currently about 75 % (AGEB, 2018). Railways' power stations for generation of required traction current are allocated to the stationary component of electricity generation in public power stations (1.A.1.a) and are not included in the following section.

In energy input for trains operating in Germany, diesel oil is the only energy source that plays a significant role apart from electric power. Since 2004, biodiesel has also been used, as an additive.

In historic vehicles, very small quantities of solid fuels are also used.

Use of other fuels – such as vegetable oils or gas – in private narrow-gauge railway vehicles has not been included to date and may be considered negligible.

Figure 32: Development of greenhouse-gas emissions of railway transports, since 1990



* not including greenhouse gases from generation of traction current, and not including CO_2 from unintentional co-incineration of lubricants

3.2.10.3.2 Methodological issues (1.A.3.c)

The relevant emissions are thus calculated as the product of fuel consumption and the relevant country-specific emission factors. This procedure conforms to the general Tier 2 method and the basic calculation rule pursuant to Equation 3.4.2 of the 2006 IPCC Guidelines (Volume 2, page 3.42).

In general, the **activity data** (energy inputs) are taken from Energy Balance lines 74 (through 1994) and 64 (as of 1995) (AGEB, 2018). In a departure from this procedure, and for methodological reasons, the figures for the years 2005 through 2009 are based on sales figures of the Association of the German Petroleum Industry (MWV) that are published in the annual report

"Petroleum Data" ("Mineralöl-Zahlen"; the table "Sectoral consumption of diesel fuel" ("Sektoraler Verbrauch von Dieselkraftstoff")) (MWV, 2018).[33]

Due to inadequacies in the available statistical data, annual figures for biodiesel consumption continue to be calculated, for the time being, on the basis of the official mixture percentages.

In the official Energy Balances, evaluatable consumption data for relevant solid fuels are available as follows: for lignite, solely for the period until 2002; for hard coal, for the period until 2000. For the present purposes, those data have been supplemented with the results of two surveys, one carried out in 2012 and one dating from 2016 (Hedel & Kunze, 2012; Illichmann, 2016).

Table 65: Overview of the statistics and other sources used

Fuel	Source(s) used
Diesel	until 2004: AGEB; 2005-2009: MWV; as of 2010: AGEB
Biodiesel	Calculated in keeping with official admixture quotas
Hard coal	until 1994: AGEB; 1995-2004: Interpolation; as of 2005: survey; as of 2016: Updating
Hard-coal coke	until 1997: AGEB; 1998-2004: Interpolation; 2005-2010: survey; as of 2011: Extrapolation
Crude lignite & Lignite briquettes	1990-2002: AGEB; not used thereafter

With regard to the **emission factors** used for carbon dioxide, we refer, in general, to Chapter 18.8.

For methane and nitrous oxide, country-specific values pursuant to (Knörr et al. (2018a): liquid fuels) or default values pursuant to (IPCC (2006): solid fuels) are used. With regard to releases of methane and nitrous oxide from co-incineration of lubricants, it is assumed that such emissions are already taken into account in the pertinent emission factors for the fuels used and thus are to be reported as IE *(included elsewhere)*.

Table 66: Emission factors used for reported year 2017, in kg/TJ

	CH_4	N_2O	Origin
Diesel	0.97 (4.15)	0.56 (28.60)	CH_4: country-specific value pursuant to Knörr et al. (2018a); N_2O: Tier 2 default pursuant to EMEP (2016)
Biodiesel	0.97 (-)	0.56 (-)	In keeping with the factors for fossil diesel
Crude lignite & lignite briquettes	300 (-)	1.50 (-)	*Fuels not used in 2017*
Hard coal & Hard-coal coke	2.00 (2.00)	1.50 (1.50)	Use of sector-specific IPCC-prescribed values for "*sub-bituminous coal*"
Lubricants	IE	IE	Already included in the EF for liquid fuels

In parentheses: Sector-specific prescribed values pursuant to IPCC (2006), Volume 2, Chapter 3.4 - *Railways*

3.2.10.3.3 Uncertainties and time-series consistency (1.A.3.c)

In the framework of a study (Knörr et al., 2009), uncertainties were calculated for the activity data entered into TREMOD, for the emission factors generated in TREMOD and for the emissions calculated in the Central System of Emissions (CSE).

[33] AG Energiebilanzen (Working Group on Energy Balances): explanations relative to revision of the Energy Balances 2003 – 2009; URL: http://www.ag-energiebilanzen.de/index.php?article_id=7&clang=0#revision_der_energiebilanzen_2003_bis_2009_05 (last checked on 4 Oct. 2014)

The activity-rate time series for lignite briquettes, hard coal and hard-coal coke exhibit inconsistencies resulting from statistical conversion as of 1994/1995; these inconsistencies cannot be eliminated at present.

3.2.10.3.4 Category-specific quality assurance / control and verification (1.A.3.c)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

Quality reports of the Working Group on Energy Balances (AGEB) have been submitted to the Federal Environment Agency, for purposes of quality assurance of the National Energy Balances. In addition, documentation on revision of Energy Balances as of 2003 has been published in the Internet.

Table 67: Overview of relevant comparisons

	Comparison with...	Remark
CO_2, CH_4, N_2O	Alternative emissions inventories for Germany	No comparable data sets
CO_2	Specific Default EF pursuant to IPCC (2006): Volume 2, Chapter	not for all relevant fuels
CO_2	Default EF pursuant to IPCC (2006): Volume 2, Chapter 2,	cf. Table 60
CH_4, N_2O	Specific Default EF pursuant to IPCC (2006): Volume 2, Chapter	cf. Table 66
CH_4, N_2O	Default EF pursuant to IPCC (2006): Volume 2, Chapter 2,	Results are inconclusive
CO_2, CH_4, N_2O	IEF of other countries	cf. Table 69

Table 68: Comparison of a) the EF(CO_2) used and b) default values [a], in kg/TJ

	Inventory value [b]	Default[b]	*Lower bound*	*Upper bound*
Fossil diesel fuel	74,027	74,100	*72,600*	*74,800*
Lignite briquettes	99,518	97,500	*87,300*	*109,000*
Crude lignite	105,798	101,000	*90,900*	*115,000*
Hard coal	93,562	94,600	*89,500*	*99,700*
Hard-coal coke	108,130	107,000	*95,700*	*119,000*
Biodiesel	70,800		*59,800*	*84,300*

[a] for reported year 2017; [b] pursuant to IPCC (2006): Volume 2, Tab. 2.4

The following table provides a comparison with specific implied emission factors of other countries as well as with the relevant values resulting for the EU(28).

Table 69: International comparison of reported IEF, in kg/TJ

	Fossil liquid fuels			Fossil solid fuels		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Germany [a]	74,027	0.97	0.56	93,402	2.00	1.50
Denmark	74,000	1.48	2.04	NO	NO	NO
France	75,032	6.98	2.51	IE	IE	IE
Netherlands	72,454	4.26	0.56	NO	NO	NO
UK	74,938	2.99	2.37	95,018	99.76	0.80
EU (28)	74,584	3.33	10.53	94,383	52.68	1.17

Sources: [a] IEF for reported year 2017; otherwise: IEF for 2016, pursuant to 2018 CRF Submission

3.2.10.3.5 Category-specific recalculations (1.A.3.c)

Since the Submission 2018, recalculations have been carried out to take account of revised activity data and emission factors.

In the process, the energy inputs for diesel fuels, which had still been provisional, were replaced with final values for 2016. This led to a corresponding correction of the figure for biodiesel used as an admixture. At the same, the official admixture quota for biodiesel, for 2016, was corrected.

Table 70: Correction of fuel inputs for 2016, in terajoules

	Diesel	Biodiesel
2019 Submission	13,775	724
2018 Submission	12,381	650
Absolute change	1,394	74
Relative change	11.26%	11.38%

Sources: (AGEB, 2018); (Knörr et al., 2018a)

The figures for methane from diesel and biodiesel were corrected for the years 2014 through 2016. Otherwise, the emission factors have not been changed with respect to the 2018 report.

Table 71: Correction of the emission factors for methane from diesel fuel, for 2014 -2016, in kg/TJ

	2014	2015	2016
2019 Submission	1.06	1.02	1.01
2018 Submission	1.05	1.01	1.00
Absolute change	0.01	0.01	0.01
Relative change	0.73%	0.62%	0.73%

Source: (Knörr et al., 2018a)

The above-described adjustments lead to the following recalculated emissions quantities:

Table 72: Revised emissions quantities, in kt and kt CO_2 equivalents

	2014	2015	2016
		Carbon dioxide – CO_2 [a]	
2019 Submission	941	1,018	1,052
2018 Submission	941	1,018	948
Absolute change	0.0	0.0	103.2
Relative change	0.00%	0.00%	10.88%
		Methane – CH_4	
2019 Submission	0.0145	0.0150	0.0153
2018 Submission	0.0144	0.0149	0.0137
Absolute change	0.0001	0.0001	0.0016
Relative change	0.69%	0.59%	11.48%
		Nitrous oxide – N_2O	
2019 Submission	0.008	0.008	0.009
2018 Submission	0.008	0.008	0.008
Absolute change	0.000	0.000	0.001
Relative change	0.00%	0.00%	10.53%
		Total for all greenhouse gases [a]	
2019 Submission	944	1,021	1,055
2018 Submission	944	1,021	951
Absolute change	0.003	0.002	103.48
Relative change	0.0003%	0.0002%	10.88%

Source: Own calculations

3.2.10.3.6 Category-specific planned improvements (1.A.3.c)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

3.2.10.4 Transport – Water-borne navigation (1.A.3.d)

3.2.10.4.1 Category description (1.A.3.d)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
L/T	**1.A.3.d Transport: Navigation**	**All fuels**	**CO_2**	**3,644.53**	**0.30%**	**1,721.28**	**0.19%**	**-52.8%**
-/-	1.A.3.d Transport: Navigation	All fuels	N_2O	34.17	0.00%	17.89	0.00%	-47.6%
-/-	1.A.3.d Transport: Navigation	All fuels	CH_4	1.83	0.00%	0.61	0.00%	-66.8%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1 a, CS (Tier 2)	NS/IS/M	D a, CS
CH_4	CS (Tier 2)	NS/IS/M	CS (M)
N_2O	CS (Tier 2)	NS/IS/M	CS (M)
NOx, CO, NMVOC, SO_2	CS (Tier 2)	NS/IS/M	CS (M)

[a] Biodiesel

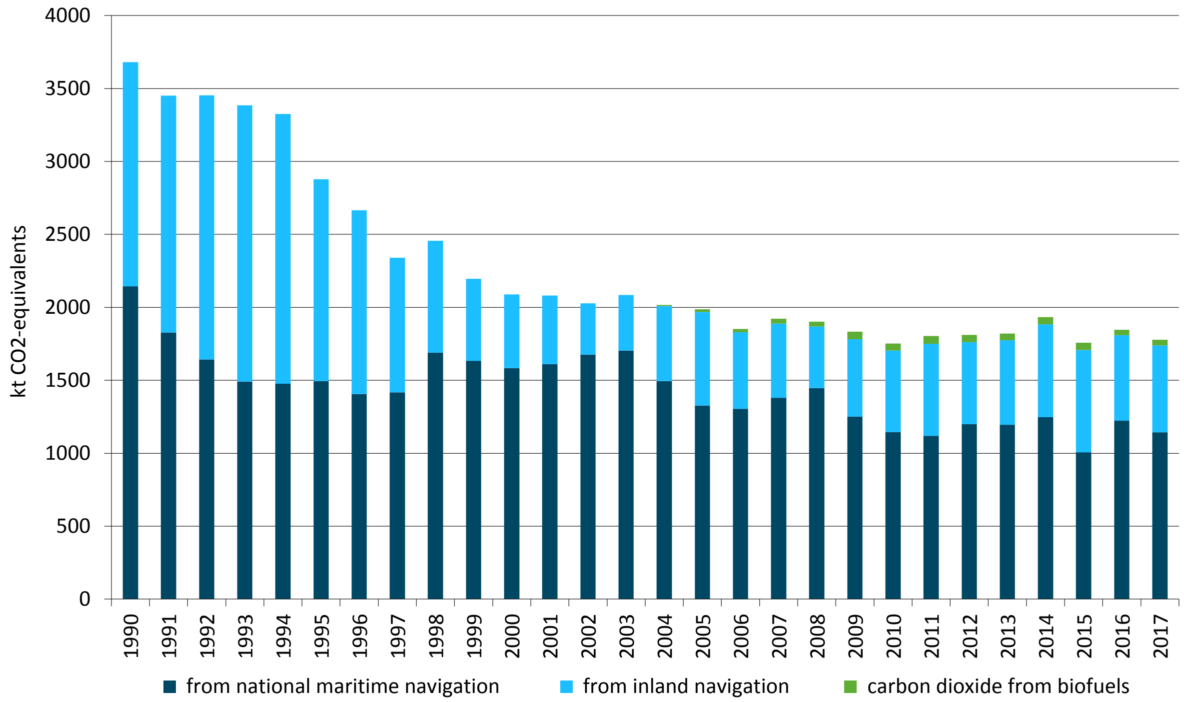
The category *Domestic water-borne navigation* is a key category for CO_2 emissions in terms of emissions level.

Water-borne navigation is broken down into the categories "domestic water-borne navigation," "inland navigation" and "international water-borne navigation." Emissions from international water-borne navigation are listed in the emissions inventories, as a memo item, but they are not included in total emissions.

In the CSE, both inland navigation and domestic water-borne navigation, i.e. travel between German ports, are assigned to category 1.A.3.d – domestic water-borne navigation.

The following figure shows the development of GHG emissions from domestic water-borne navigation, since 1990, broken down into inland navigation and domestic water-borne navigation.

Figure 33: Development of GHG emissions from domestic water-borne navigation, since 1990



3.2.10.4.2 Methodological issues (1.A.3.d)

For the area of *Domestic water-borne navigation*, all primary input data are combined in a model operated by the Federal Maritime and Hydrographic Agency (BSH), in keeping with the Tier 3 method pursuant to (EMEP (2016): Sectoral guidance chapters, 1.A.3.d Navigation (shipping)) (Deichnik, 2018). The underlying AIS data used in the process are currently available only as of the year 2010. For the period 1990 through 2009, the specific consumption fractions for national and military water-borne navigation, and for fisheries, have been derived on the basis of annual trends in relevant indicators (including data on traffic volumes in the Kiel Canal, and data on development of military and fishery fleets).

For the *Inland navigation* category, primary data are combined, via a Tier 2 method, in TREMOD (Knörr et al., 2018a). The model integrates emission values from test-bench measurements and data on specific energy consumption aspects. The latter data have been linked with a traffic-quantity model based on the Federal Statistical Office's statistics on inland water-borne navigation, and they can be broken down by ship types, sizes and loads, and by applicable water-body types.

In general, the source for the **activity data**, as for the entire sector 1.A, is (AGEB (2018), based on BAFA and MWV). The data for the years 2005 through 2009 are based on sales data of the MWV, which differ from the pertinent data in the NEB, and which are published in the annual report "Petroleum Data" (*"Mineralöl-Zahlen"*; in this case: page 52, Table *"Sectoral consumption of diesel fuel"* (*"Sektoraler Verbrauch von Dieselkraftstoff"*)) (MWV, 2018).

Both AGEB and BAFA divide the data into the categories *domestic* (AGEB: "Coastal and inland navigation" = BAFA: "an die Binnenschifffahrt" ("for inland shipping")) and *international* (AGEB: "high-seas bunkering" = BAFA: "Bunker int. Schifffahrt"), in keeping with the different taxation rates applied to different ship fuels.

With respect to ship transports, the NEB – as described, solely based taxation aspects – differentiates between international marine bunkers (Energy Balance line 6) and coastal and inland navigation (Energy Balance line 64). Energy Balance line 6 lists the fuel quantities bunkered by ocean-going ships registered with the *International Maritime Organization* (IMO), as "sea-going ships" (IMO number). This category includes cargo, fishing and military ships that can operate on both domestic (between two German seaports) and international routes (from Germany to international ports). Energy Balance line 64, on the other hand, lists the fuel quantities that were a) taken on by inland vessels or b) bunkered by ocean vessels that have *not* been certified by the IMO (a category that includes smaller ships that operate only on domestic routes). For the breakdown into national and international *sea* transports, therefore, the fuel quantities listed in Energy Balance line 6 have to be divided in accordance with the categories of domestically operating and internationally operating sea-going ships. In addition, those relevant specific quantities of fishing and military ships that are reported separately under 1.A.4.c iii and 1.A.5.b are deducted.

Table 73: Sources for the activity data used

Material	Source statistics	included therein, in lines as indicated	
Diesel fuel	NEB	77 (through 1994) and 64 (since 1995)	"Coastal and inland water-borne navigation"
Biodiesel	NEB	64 (since 2004)	
Heavy fuel oil	NEB	6	"International marine bunkers"

Domestic water-borne navigation

The activity data for *Domestic water-borne navigation* consists of the data for the *non*-IMO-certified seagoing vessels listed in Energy Balance line 64 and of the data for the nationally operating IMO-certified seagoing vessels listed in Energy Balance line 6 (in each case, less the figures for fisheries and military). To determine these fractions, the specific consumption figures of the domestically operating seagoing vessels are calculated – in the aforementioned BSH model – on the basis of their AIS signals (currently, as of 2010; see above) and then aggregated into annual total quantities. Since the model differentiates between IMO-certified and non-IMO-certified sea-going ships, the sub-quantities included in NEB lines 6 and 64 are available. By deducting the former of the two sub-quantities (fuel consumption in domestically operating IMO-certified sea-going vessels) from the bunkered quantities listed in NEB line 6, one obtains a remaining quantity, bunkered by internationally operating sea-going vessels in Germany, that serves as a basis for calculating the separately listed emissions for international water-borne navigation (departing from Germany) pursuant to Tier 1 (cf. Chapter 3.2.2.3).

The fuel quantities taken on annually by *inland vessels* in Germany are obtained by deducting the second sub-quantity (fuel consumption in domestically operating, non-IMO-certified sea-going vessels) from the total quantity listed in NEB line 64. As a result of variations in the navigability of inland waterways, the annual fuel consumption levels of inland ships vary widely. Since the mid-1990s, those levels have been tending to decrease, as many ships have been refueling abroad in order to take advance of lower prices. The abrupt decrease that occurred in 1994/1995 was due to a conversion in the National Energy Balance, however. Due to inadequacies in the available statistical data, annual figures for biodiesel consumption continue to be calculated, for the time being, on the basis of the official mixture percentages.

In the framework of the UNFCCC's review process, Germany has been repeatedly requested (most recently, during the 2016 In Country Review) to separately list emissions from fuels that inland vessels take on in Germany and then consume outside of Germany. For such separate listing, which the available statistics and models do not directly support, extremely involved regular surveys would have to be carried out, and then data for the period back to 1990 would have to be developed from their results. Presumably, inland vessels that operate internationally rarely refuel in Germany[34], and thus the value of such an effort seems questionable. Nonetheless, the review team's request is being duly considered, and a solution that is acceptable for all sides, and scientifically reliable, is being sought.

With regard to the **emission factors** used for carbon dioxide, we refer, in general, to Chapter 18.8. Further information – in particular, with regard to carbon dioxide from lubricant co-combustion – is also provided in Chapter 19.1.4.

With regard to releases of methane and nitrous oxide from co-incineration of lubricants, it is assumed that such emissions are already taken into account in the pertinent emission factors for the fuels used and thus are to be reported as IE *(included elsewhere)*.

All other emission factors for the sub-sector *Domestic water-borne navigation* have been taken from (Deichnik, 2018).

For the area of *inland navigation*, CH_4 emission factors from Knörr et al. (2018a) are used. They are calculated on the basis of test-bench measurements, and of data, relative to the required propulsion energy, broken down by ship types, sizes and loads, and by waterway types. The emission factors for N_2O are in keeping with Federal Environment Agency (UBA) experts' assessments based on the UBA study "Air Quality Control '88" ("Luftreinhaltung '88") and on analogies to heavy duty vehicles without emissions-control equipment.

Table 74: Emission factors used for reported year 2017, in kg/TJ

	CH_4	N_2O	Origin
Inland navigation			
Diesel	1.24 (-)	1.00 (-)	Country-specific value pursuant to Knörr et al. (2018a)
Domestic water-borne navigation			
Diesel	0.90	3.36 (2.00)	Pursuant to Deichnik (2018)
Heavy fuel oil	0.61 (7.00)	3.49 (2.00)	Pursuant to Deichnik (2018)
Overarching			
Lubricants	IE	IE	Included in the EF for the individual fuels

* listed in parentheses: Default values pursuant to IPCC (2006): Volume 2, Chapter 3.5, p. 3.50, Table 3.5.3

The EF for biodiesel are in keeping with the values for fossil-based diesel fuel

3.2.10.4.3 Uncertainties and time-series consistency (1.A.3.d)

For domestic inland water-borne navigation, the pertinent uncertainties were available in (IFEU & INFRAS, 2009). For the area of domestic water-borne navigation, the IPCC default uncertainties still have to be applied, however.

The activity-data time series for coastal and inland water-borne navigation exhibit inconsistencies, resulting from the Energy-Balances transition between 1994 and 1995, which cannot be eliminated at present.

The emission-factor time series exhibit no inconsistencies.

3.2.10.4.4 Category-specific quality assurance / control and verification (1.A.3.d)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

[34] Because fuel prices in other countries along the Rhine and Danube rivers are consistently lower than they are in Germany, and because large inland vessels can easily travel several thousand kilometers on one tankful of fuel, inland ships making international trips presumably refuel in Germany only in exceptional cases.

Quality reports of the Working Group on Energy Balances (AGEB) have been submitted to the Federal Environment Agency, for purposes of quality assurance of the Energy Balances. In addition, documentation on revision of Energy Balances as of 2003 has been published on the Internet[35].

Table 75: Overview of relevant data comparisons

	Comparison with...	Remark
CO_2, CH_4, N_2O	Alternative emissions inventories for Germany	No comparable data sets
CO_2	Specific Tier 1 default EF pursuant to IPCC (2006): Volume 2, Table 3.5.2	cf. Table 76
CH_4, N_2O	Sector-specific Tier 1 default EF pursuant to IPCC (2006): Volume 2, Table 3.5.3	Sea-going: cf. Table 74 Inland: no defaults
CH_4, N_2O	Tier 1 default EF pursuant to (IPCC (2006): Volume 2, Table 2.4	Inland: Results are inconclusive
CO_2, CH_4, N_2O	Specific IEF of other countries	cf. Table 77

Table 76: Comparison of a) EF(CO_2) used for reported year 2017 and b) IPCC default values

	Inventory value [a]	Default[b]	*Lower bound*	*Upper bound*
Fossil diesel fuel	74,027	74,100	*72,600*	*74,800*
Heavy fuel oil	80,834	77,400	*75,500*	*78,800*
Biodiesel	70,800		*59,800*	*84,300*

[a] pursuant to IPCC (2006): Volume 2, Table 2.4

The following table provides a comparison with specific implied emission factors of other countries and of the EU (28).

Table 77: International comparison of reported IEF, in kg/TJ

	Diesel fuel			Heavy fuel oil			Biomass		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Germany	74,027	1.02	2.54	80,834	0.61	3.49	70,800	1.16	1.61
Denmark	73,968	1.92	1.83	77,953	2.19	1.85	NO	NO	NO
France	75,032	7.14	1.90	78,000	7.50	2.00	67,527	68.38	2.24
Netherlands	72,454	7.00	2.00	NO	NO	NO	70,741	47.23	0.86
UK	75,124	0.80	3.23	76,469	1.27	3.64	NO	NO	NO
EU (28)	74,442	3.51	4.04	78,774	6.20	2.20	68,678	43.87	1.97

Germany: current IEF for report year 2017; all other countries: IEF for 2016, pursuant to 2018 CRF Submission

3.2.10.4.5 Category-specific recalculations (1.A.3.d)

Since the 2018 Submission, recalculations have been carried out to take account of revisions of consumption data and of emission factors.

The key changes with respect to consumed fuels were made in the area of diesel fuel used in inland navigation.

[35] AG Energiebilanzen (Working Group on Energy Balances): explanations relative to revision of the Energy Balances 2003 – 2009; URL: http://www.ag-energiebilanzen.de/index.php?article_id=7&clang=0#revision_der_energiebilanzen_2003_bis_2009_05 (last checked on 18 Sept. 2013)

Table 78: Revised energy inputs for 2015 and 2016, in terajoules

	2015				2016			
	Diesel	Biodiesel	Heavy	Σ	Diesel	Biodiesel	Heavy	Σ
2019 Submission	22,781	697	50	23,528	24,167	524	7	24,698
2018 Submission	22,277	697	50	23,024	26,102	629	7	26,738
Absolute change	504	0	0	504	-1,935	-105	0	-2,040
Relative change	2.26%	0.00%	0.00%	2.19%	-7.41%	-16.70%	0.00%	-7.63%

The methane emission factors for diesel fuel consumed by inland vessels were updated in TREMOD for the years 2010 through 2016, and the implied emission factors used in this context were correspondingly adjusted.

Table 79: Revised methane emission factors, in kg/TJ

	2010	2011	2012	2013	2014	2015	2016
2019 Submission	1.41	1.39	1.36	1.34	1.31	1.29	1.26
2018 Submission	1.44	1.41	1.38	1.35	1.33	1.30	1.28
Absolute change	-0.03	-0.02	-0.02	-0.02	-0.02	-0.02	-0.01
Relative change	-1.75%	-1.65%	-1.46%	-1.30%	-1.26%	-1.25%	-1.13%

Source: (Knörr et al., 2018a)

In the area of maritime transports, the only change was that the emission factors for methane and nitrous oxide from combustion of heavy fuel oil were updated for 2016.

Table 80: Revised emission factors, in kg/TJ

	Methane	Nitrous oxide
2019 Submission	0.74	3.39
2018 Submission	0.73	3.36
Absolute change	-0.02	-0.02
Relative change	-1.26%	-1.25%

Source: (Deichnik, 2018)

The above-described corrections lead to the following recalculated emissions quantities:

Table 81: Revised emissions, in kt and kt CO_2-eq

	2010	2011	2012	2013	2014	2015	2016
				Carbon dioxide			
2019 Submission	1,685	1,731	1,742	1,756	1,864	1,690	1,790
2018 Submission	1,685	1,731	1,742	1,756	1,864	1,653	1,933
Absolute change	0.0	0.0	0.0	0.0	0.0	37.3	-143.2
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	2.26%	-7.41%
				Methane			
2019 Submission	0.0244	0.0253	0.0246	0.0247	0.0262	0.0249	0.0251
2018 Submission	0.0246	0.0256	0.0248	0.0249	0.0264	0.0244	0.0278
Absolute change	-0.0002	-0.0002	-0.0002	-0.0001	-0.0002	0.0005	-0.0027
Relative change	-0.82%	-0.82%	-0.65%	-0.58%	-0.57%	2.02%	-9.77%
				Nitrous oxide			
2019 Submission	0.059	0.059	0.061	0.061	0.064	0.056	0.063
2018 Submission	0.059	0.059	0.061	0.061	0.064	0.055	0.065
Absolute change	0.000	0.000	0.000	0.000	0.000	0.001	-0.002
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.92%	-3.17%

	2010	2011	2012	2013	2014	2015	2016
	Total for all greenhouse gases						
2019 Submission	1,703	1,749	1,761	1,774	1,883	1,708	1,809
2018 Submission	1,703	1,749	1,761	1,774	1,883	1,670	1,953
Absolute change	0.0	0.0	0.0	0.0	0.0	37.5	-143.9
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	2.24%	-7.37%

Not including carbon dioxide from biofuels

Source: Own calculations

3.2.10.4.6 Category-specific planned improvements (1.A.3.d)

With regard to *Domestic water-borne navigation*, various types of maintenance work on the model are carried out, as necessary, in the framework of annual model updating. Such work cannot be described in detail at present, however.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

3.2.10.5 Transport – Other transportation (1.A.3.e)

3.2.10.5.1 Category description (1.A.3.e)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
-/-	1.A.3.e Transport: Other Transportation	All fuels	CO_2	1,083.27	0.09%	1,249.47	0.14%	15.3%
-/-	1.A.3.e Transport: Other Transportation	All fuels	N_2O	14.49	0.00%	10.84	0.00%	-25.2%
-/-	1.A.3.e Transport: Other Transportation	All fuels	CH_4	5.31	0.00%	6.11	0.00%	15.0%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	ETS	CS
CH_4	Tier 2	ETS	CS
N_2O	Tier 2	ETS	CS

The *category 1.A.3.e - Transport – other transportion* is not a key category

Reporting in category *1.A.3.e – Other transportation* includes only emissions from *gas turbines in natural-gas compressor stations of the transport network*. The emissions from gas turbines of pumping stations are reported in category 1.A.1.c. Fugitive emissions from compressors are reported under 1.B.2.b.iii & iv. Additional gas compressors are operated in the chemical industry. In keeping with the relevant statistical structure, they are reported in category 1.A.2.g Other.

3.2.10.5.2 Methodological issues (1.A.3.e)

Activity data:

Calculation of fuel inputs for natural gas compressors was completely revised for the NIR 2012. As of 2005, the fuel inputs reported for purposes of emissions trading, and aggregated by the emissions-trading authority, are being used directly, as a new data source. In this area, the only data used from that data set are the data for natural gas compressors that are allocated to the transport network. Natural gas compressors of pumping stations are identified via energy statistics and thus are already included in category 1.A.1.c. This allocation approach prevents double-counting in the inventory.

In light of the new data situation, it seemed likely that the fuel inputs used were too low, throughout the entire time series. Only the value shown in the 2002 Energy Balance seemed plausible. While fuel inputs for natural gas compressors in the period 1995-2002 were reported in the context of statistics, it may be assumed that the recorded levels were too low. To establish consistency in the relevant time series, therefore, recalculations back to 1990 were carried out. Since the relevant fuel inputs fluctuate annually, in keeping with primary energy consumption, simple interpolation would not have led to the desired consistency. For that reason, a mean for the pertinent relationship (fuel inputs / primary energy consumption) was calculated for the period 2005-2009, and then that mean was used for the calculations back to 1990. This procedure has produced a plausible and consistent time series.

Emission factors:

The emission factors for natural-gas use in **natural gas compressor stations** are based, for each specific gas, on the results of various Federal Environment Agency research projects and expert opinions:

- With regard to CO_2, the reader's attention is called to the pertinent documentation in Annex 2, the Chapter "CO_2 emission factors".
- The CH_4 and N_2O EF have been obtained from the report Fichtner et al. (2011). The procedure used in the studies is described in Chapter 3.2.6.2.

3.2.10.5.3 Uncertainties and time-series consistency (1.A.3.e)

Uncertainties for the activity data were determined for the first time in reporting year 2004 (Juhrich & Wachsmann, 2007). The method for determining the uncertainties is described in Annex 2, in the Chapter "Uncertainties in the activity data of stationary combustion plants", of the NIR 2007.

The procedure for determining uncertainties for the EF of natural gas compressor stations is described in Chapter 3.2.6.2. Results for N_2O are presented in Chapter 3.2.6.3.2, while those for CH_4 are presented in Chapter 3.2.6.3.3.

3.2.10.5.4 Category-specific quality assurance / control and verification (1.A.3.e)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The results of Chapter 3.2.6.2 apply mutatis mutandis.

3.2.10.5.5 Category-specific recalculations (1.A.3.e)

Table 82: Recalculations in CRF 1.A.3.e

Units [kt]	2018 NIR	2019 NIR	Difference, absolute		Difference, relative
Year	Total	Total	gas	Total	Total
2016	1,230	1,228	-2.10	2.10	0.17%

Minor recalculations were carried out for the year 2016, to take account of revision of the emission factor for natural gas.

3.2.10.5.6 Category-specific planned improvements (1.A.3.e)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

3.2.11 Other: Residential, commercial/institutional, agriculture, forestry and fisheries (1.A.4 Stationary)

3.2.11.1 Category description (1.A.4 Stationary)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
L/T	**1.A.4.a Other Sectors: Commercial/institutional**	**All fuels**	**CO_2**	**64,105.89**	**5.24%**	**38,110.99**	**4.28%**	**-40.5%**
-/T	**1.A.4.a Other Sectors: Commercial/institutional**	**All fuels**	**CH_4**	**1,461.53**	**0.12%**	**24.16**	**0.00%**	**-98.3%**
-/-	1.A.4.a Other Sectors: Commercial/institutional	All fuels	N_2O	145.05	0.01%	85.15	0.01%	-41.3%
L/T	**1.A.4.b Other Sectors: Residential**	**All fuels**	**CO_2**	**128,635.75**	**10.51%**	**91,807.53**	**10.30%**	**-28.6%**
-/T	**1.A.4.b Other Sectors: Residential**	**All fuels**	**CH_4**	**2,483.93**	**0.20%**	**777.25**	**0.09%**	**-68.7%**
-/-	1.A.4.b Other Sectors: Residential	All fuels	N_2O	768.86	0.06%	308.26	0.03%	-59.9%
L/T	**1.A.4.c Other Sectors: Agriculture/Forestry/Fisheries**	**All fuels**	**CO_2**	**10,270.09**	**0.84%**	**6,356.45**	**0.71%**	**-38.1%**
-/-	1.A.4.c Other Sectors: Agriculture/Forestry/Fisheries	All fuels	CH_4	240.02	0.02%	394.84	0.04%	64.5%
-/-	1.A.4.c Other Sectors: Agriculture/Forestry/Fisheries	All fuels	N_2O	61.89	0.01%	83.45	0.01%	34.8%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1*, CS	NS/M	CS, D*
CH_4	CS (Tier 2)	NS/M	CS (M)
N_2O	CS (Tier 2)	NS/M	CS (M)
NO_X, CO, NMVOC, SO_2	CS (Tier 2)	NS/M	CS (M)

* biodiesel and co-combusted lubricants

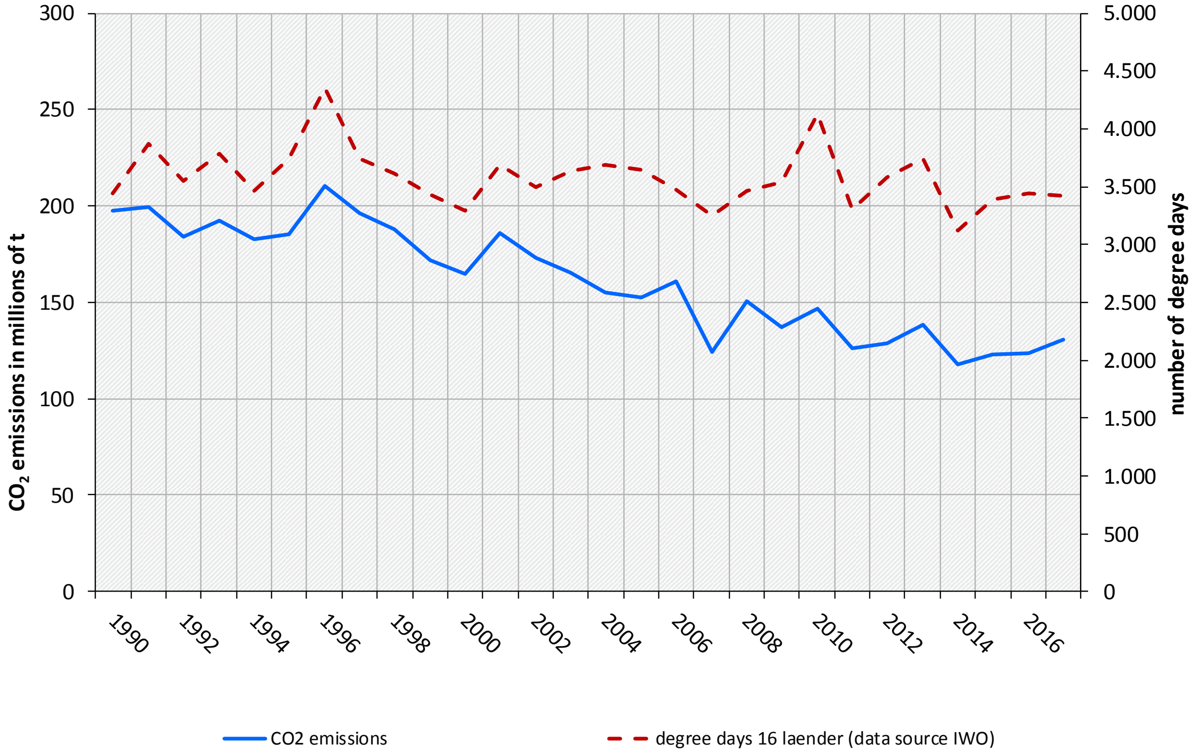
The stationary and mobile sources categories in 1.A.4 are placed in the relevant main categories together (for an overview, cf. Chapter 3.2.11.1). The category 1.A.4 *Other* is a key category for CO_2 emissions, in terms of both emissions level and trend, in all of its sub-categories. For CH_4 emissions, categories 1.A.4.a & b are a key category in terms of trend.

Category 1.A.4 Stationary comprises combustion systems in the areas *Commercial and Institutional, Residential* and *Agriculture*.

Heat-generation systems in small combustion systems of small commercial and institutional users are reported in sub-category 1.A.4.ai Commercial and institutional.

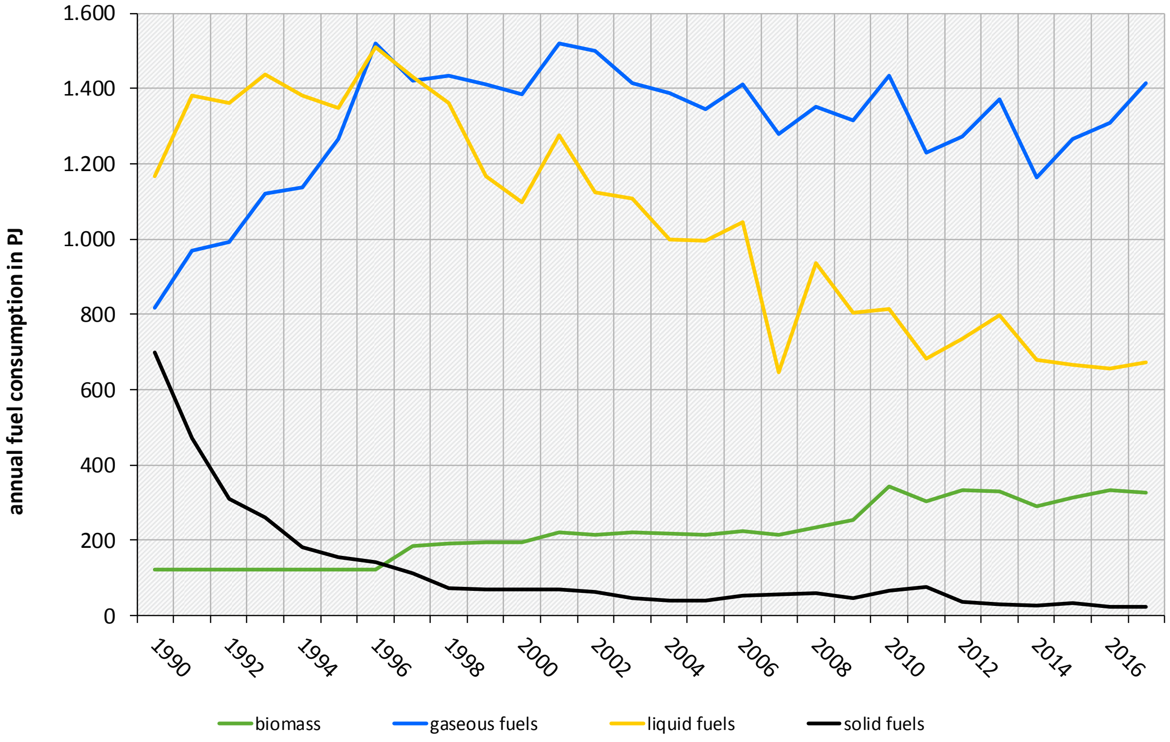
Emissions from residential combustion systems are reported in sub-category 1.A.4.bi. Sub-category 1.A.4.ci comprises the areas of agriculture, forestry and fisheries. Reporting under this category includes emissions from heat generation in small and medium-sized combustion systems.

Figure 34: Change in total emissions of 1.A.4, as a function of temperature



The main driver of CO_2 emissions in 1.A.4 is energy consumption for purposes of space heating. Consequently, fluctuations in consumption can plausibly be attributed to differences in periods of winter cold. The trend toward lower CO_2 emissions is a result of higher standards for new buildings, of successful energy-efficiency-oriented modernisations of existing buildings and of switching to fuels with low CO_2 emissions. CO_2 emissions from electrically driven heat pumps, which are being used more and more frequently in new buildings, are reported not here but under 1.A.1.a.

Figure 35: Trends in energy consumption in 1.A.4 (stationary), for 4 fuel categories



Shifting from liquid fuels (almost exclusively heating oil) and solid fuels (mainly coal) to gaseous fuels (natural gas) and biomass has brought about considerable CO_2-emissions reductions. In 2006 and 2007, a special phenomenon occurred whereby energy consumption was first above-average and then below-average, respectively, as a result of an increase in the value-added-tax (VAT) rate from 16 % to 19 %. Very high heating-oil sales in 2006 increased CO_2 emissions figures, since emissions data relative to heating oil are determined on the basis of sales, rather than consumption. In the years 2011 through 2016, trends in energy inputs, especially in the market for heat, were strongly influenced by weather conditions during winter heating periods, as well as by increased energy prices and costs. Over those years, these factors caused energy consumption – especially, consumption of light heating oil and natural gas – to fluctuate sharply.

In 2017, CO_2 emissions increased, primarily as a result of increased use of natural gas in the heat market. The increase in consumption was not due to lower air temperatures; those temperatures were actually lower, on average, than they had been in the previous year. The primary factors driving the increase were population growth and an increase in the number of residences with natural gas heating.

As a result, natural gas consumption increased by 8.1 %, over the previous year, in the residential, institutional and commercial (small consumers) sector. Petroleum consumption increased by 1.9 %. Consumption of lignite and hard coal also increased, although those fuels' share of final energy consumption in the residential, institutional and commercial (small consumers) sector is less than 1 %. Consumption of renewable energy sources – especially solid biomass – decreased by 1.4 % with respect to the previous year.

The group of combustion systems in the residential and commercial/institutional sectors is very diverse with regard to installation design and size. It covers a spectrum that includes individual room furnaces for solid fuels with a rated thermal output of approximately 4 kW (e.g. fireplaces, ovens), oil and gas furnaces used for space heating and water heating (e.g. central heating boilers), hand-fed and automatically fed wood-burning furnaces in the commercial sector and commercial/institutional users' licensable combustion systems with a rated thermal output of several megawatts, to name but a few examples. In total in 2010, more than 36.3 million combustion systems were installed (i.e. were in place) in Germany in the Residential and Commercial and Institutional sectors (Tebert et al., 2016). Gas-fired combustion systems accounted for a majority of these systems, or some 16.2 million, while combustion systems using solid fuels accounted for some 14.2 million systems and oil-fired furnaces accounted for some 5.9 million systems.

Of the wood fuels used in households and in commerce and trade, large quantities are purchased privately or obtained from system owners' own forest parcels. For this reason, in the Energy Balance, the relevant data from the Federal Statistical Office are supplemented with data from a survey of firewood consumption in private households. No official data are available on use of firewood in the categories commercial and institutional [commerce, trade and services]. As a result, data are taken from a pertinent study from the year 2000 (Kolmetz et al., 1995). The consumption-level figures determined in that study have been adopted for subsequent years since then. A research project entitled "Development of methods for determination of consumption of biogenic solid fuels in the commercial and institutional sector" ("Methodenentwicklung zur Ermittlung des Verbrauchs biogener Festbrennstoffe im GHD-Sektor") was carried out to determine activity data on use of firewood in the commercial and institutional sector more precisely. Since the project yielded sample results for individual areas, a complete data set on the sector's firewood use – a data set that would support an update – is still lacking. The initial aim of the project was to develop a method that would lead to a general approach. Currently, a follow-on project is underway that is aimed at producing comprehensive data on wood inputs in the Commercial and Institutional sector. No findings from that project are yet available, however. The Energy Balance fuel category "Waste and other biomass" is specified in greater detail in the Satellite Balance. The information in that Balance indicates that only firewood is used in the residential sector, while only sewage gas and biogas are used in the sector "Commercial and Institutional (commerce/trade/services) and other consumers".

3.2.11.2 Methodological issues (1.A.4, stationary)

Activity data

The **activity data** in category 1.A.4 are based on the Energy Balances for the Federal Republic of Germany, as prepared by the Working Group on Energy Balances (AGEB). For years prior to 1995 separate Energy Balances are used for the a) old German Länder and b) new German Länder. For years as of 1995, lines 66 (residential) and 67 (commercial and institutional and other consumers) are the standard.

Since the data in Energy Balance line 67 – commercial and institutional and other consumers – also include military consumption, such military consumption must be deducted from the relevant positions in line 67 (cf. Chapter 3.2.13.2 with regard to stationary and mobile sources in the military sector).

For energy inputs in *Agricultural combustion systems (1.A.4.ci*), which are also included in line 67 of the Energy Balance, relevant data are available, in a study (Kolmetz et al., 1995), for 1995. That study provides an estimate of agricultural combustion systems' share of total energy inputs in line 67. That share is assumed to have remained constant since then.

Emission factors

A detailed description of the relevant procedures, and a list of the CO_2 emission factors used, is presented in the Annex, Chapter 18.8.

The underlying data for the emission factors used for N_2O and CH_4 emissions of stationary combustion systems is the research report "Ermittlung und Aktualisierung von Emissionsfaktoren für das nationale Emissionsinventar bezüglich kleiner und mittlerer Feuerungsanlagen der Haushalte und Kleinverbraucher" ("Determination and updating of emission factors for the national emissions inventory, with regard to small- and medium-sized combustion systems in the residential and commercial/institutional sectors") (Tebert et al., 2016). Within the context of that project, device-related and category-specific emission factors for combustion systems in the residential and commercial/institutional sectors were calculated, with a high level of detail, for all important emissions components for the reference years 2010 and 2015.

Determination of emission factors is based on a category-specific "bottom-up" approach that, in addition, to differentiating (sub-)categories and fuels, also differentiates system technologies in detail. In the process, several system-specific emission factors are aggregated in order to obtain mean emission factors for all systems within the categories in question. Use of system-specific / category-specific emission factors ensures that all significant combustion-related characteristics of typical systems for the various categories are taken into account. The procedure is in keeping with the Tier 2/3 method described in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006).

The emission factors are structured in accordance with the relevant fuels involved in final energy consumption in Germany:

- Fuel oil EL
- Natural gas,
- Lignite (briquettes from the Rhine (Rheinisch) and Lusatian (Lausitz) coal fields; imported briquettes),
- Hard coal (coke, briquettes, anthracite) and
- Wood (unprocessed wood, wood pellets, residual wood).

In addition, emission factors for combustion systems are determined in accordance with device design, age level, output category and typical mode of operation. The emissions behaviour of combustion systems was documented via an extensive evaluation of the pertinent literature. Transfer factors were used to take account of the fact that emissions in a test-bench environment tend to be lower than those of corresponding installed systems.

The breakdown of the overall pool of installed combustion systems, by system types, was obtained by carrying forward data in Struschka et al. (2008), and drawing on sales statistics for the relevant industrial associations. Those data were used to estimate the energy inputs for various system types, to make it possible to determine sectoral emission factors weighted by energy inputs. Table 83 shows the sectoral emission factors used.

Table 83: Sectoral emission factors for combustion systems in the residential and commercial/institutional sectors for reference year 2010

	CH_4	N_2O
1.A.4.bi – Residential	**[kg/TJ]**	
Hard coal	134	11.5
Briquettes	368	9.7
Hard-coal coke	13	0.9
Lignite briquettes	237	5.2
Unprocessed wood	97	1.6
Heating oil EL	0.03	0.55
Natural gas	3	0.25
1.A.4.ai & ci – Commercial and Institutional		
Hard coal	100	8.5
Briquettes	-	-
Hard-coal coke	20	0.8
Lignite briquettes	-	-
Wood fuels	43	0.53
Heating oil EL	0.03	0.56
Natural gas	0.16	0.33

The emission factors for 2010 were used, without change, for subsequent years.

3.2.11.3 Uncertainties and time-series consistency (1.A.4, stationary)

Annex 2, Chapter 13.6 in the NIR 2007 describes the method used to determine the uncertainties for the **activity data**.

A complex procedure is required to calculate reliable emission factors in the installation sector. Apart from emission figures, it is also necessary to obtain other information; for example, one must make allowance for the relevant mode of operation (loads), installation structure and device-specific final energy consumption. In data surveys during the aforementioned research and development project, this approach was for the most part followed; nevertheless, given the sheer number of facilities concerned and the wide range of combustion systems and fuels used, the data must be assumed to have a fairly large "basic uncertainty".

For some installation types, moreover, only inadequate data or no data at all were available on emissions behaviour in connection with certain fuels. It is important to remember that the law does not require the greenhouse-gas emissions of combustion systems of residential and commercial/institutional users to be measured. When calculating the emission factors, therefore, in most cases (with the exception of CO_2, which is largely independent from furnace design) the researchers only had recourse to a few results from individual measurements on selected installations. Gaps in the data were closed via adoption of emission factors of comparable combustion systems.

The uncertainties listed for the emission factors for CH_4 and N_2O, for stationary combustion systems, were determined via expert estimation pursuant to IPCC-GPG (Penman et al. (2000): Chapter 6). That assessment, which is based on the emissions data obtained for the aforementioned research project, was carried out in the framework of that project by experts of the University of Stuttgart's Institute of Process Engineering and Power Facility Technology (Institut für Verfahrenstechnik und Dampfkesselwesen). Uncertainties were estimated separately for all combustion technologies and fuels. The following sources of error entered into the estimates for N_2O and CH_4:

- Measuring errors in determination of pollutant concentrations;

- Uncertainties in estimating transfer factors (systematic differences between test-bench and field measurements);
- Uncertainties resulting from having too little emissions data;
- Uncertainties resulting from use of different measuring procedures;
- Uncertainties in the installation data used (overall group structure in terms of type, age and performance and fuel consumption)

In gas-fired systems, another error occurs in determination of start-up / shut-down emissions. During start-up/shutdown processes, some unburned CH_4 is emitted from natural gas. These emissions, which occur upstream and downstream from the actual combustion process, cf. Chapter 3.3.2.2 (natural gas), are a significant reason why CH_4 emission factors for gas-combustion systems are subject to high levels of uncertainties.

As to the distribution of uncertainties, a log-normal distribution is assumed for N_2O emission factors. In all likelihood, the deviations are considerably more pronounced in the vicinity of larger values than they are in the vicinity of smaller values. The emission factors for CH_4 and N_2O were determined for the year 2005, in the framework of the aforementioned research project, and are assumed to have remained constant since then.

3.2.11.4 Category-specific QA/QC and verification (1.A.4, stationary)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts (except for 1.A.4.c.iii) and the Single National Entity.

Information on quality assurance for **activity data** is provided in Chapter 3.2.6.4. For further information on quality assurance, cf. Chapter 18.4.1.

For the purposes of quality assurance for data relative to *stationary combustion systems*, in the context of the aforementioned research and development project, all the input data used from literature and from the research contractor's own investigations were reviewed for validity. As a general principle, in description of the emissions behaviour of combustion systems, emissions data were included in subsequent calculations only if the relevant literature sources contained complete, undisputed data on the fuel used, the design of the furnace, and the furnace's operating mode during measurements. All resources of significance for inventory preparation were substantiated by the research company.

In the framework of a quality review carried out by Federal Environment Agency experts, the country-specific emission factors for CH_4 and N_2O, determined in accordance with the Tier 2 standard, were compared with the IPCC Tier 2 default factors in the IPCC Guidelines for emissions inventories (IPCC, 2006). For most fuels, the values agreed well (discrepancies within one order of magnitude), although the default values for CH_4 tended to be higher than the country-specific values.

In the framework of quality assurance, calculation with the Tier 1 default values was carried out, in addition to emissions determination pursuant to Tier 2/3, for the residential and commercial/institutional sectors for the year 2015. The results are shown in Table 84.

Table 84: Emissions calculation with country-specific Tier 2/3 emission factors and with the Tier 1 default emission factors pursuant to (IPCC 2006) IPCC (2006)

Emission factors	CH_4 [t]				N_2O [t]			
	Residential		Commercial and institutional		Residential		Commercial and institutional	
	Tier 1 default	Country-specific EF	Tier 1 default	Country-specific EF	Tier 1 default	Country-specific EF	Tier 1 default	Country-specific EF
Heating oil EL	4,694	76	1,723	6	277	256	101	97
Fuel gases	4,223	2,534	1,763	55	84	212	35	115
Coal fuels	7,388	5,776	44	85	37	177	2	7
Wood	66,780	21,074	9,011	1,465	890	352	120	25
Total	**83,085**	**29,459**	**12,541**	**1,611**	**1,289**	**997**	**258**	**244**

The emissions of the commercial and institutional sector include the emissions of the areas of agriculture, forestry and fisheries.

For N_2O, the emissions-calculation results obtained with both methods showed good agreement. Larger discrepancies were seen in determination of CH_4 emissions. Presumably, this is due to the fact that methane emissions of combustion systems depend strongly on the combustion technology used. Country-specific differences in installation structures (i.e. in sector composition) thus manifest themselves much more strongly in total emissions (as determined) than they do in nitrous-oxide emissions. The default emission factor for heating oil, in particular, is very high. The technology-specific emission factor given in IPCC 2006 for boilers shows considerably better agreement with the pertinent country-specific factor for Germany.

No data sources are known that would support a comparison with the data reported here for mobile sources in the residential, agricultural and fisheries sectors. In addition, the country-specific IEF were compared with those of other countries. Due to the heterogeneous composition of the sub-categories involved, however, that comparison is largely inconclusive – especially with regard to methane and nitrous oxide.

3.2.11.5 Category-specific recalculations (1.A.4, stationary)

Table 85: Recalculations in CRF 1.A.4 (stationary)

Units [kt]	2018 NIR	2019 NIR	Difference, absolute				Difference, relative
Year	**Total**	**Total**	gas	liquid	solid	**Total**	**Total**
2015	122,937	122,877	-60	0	0	-60	-0.05%
2016	128,312	123,502	-5,291	1,340	-859	-4,810	-3.75%

For the year 2016, major recalculations were carried out, since the provisional figures in the 2018 Submission have been replaced with final figures from the Energy Balance. In addition, revision of the emission factor for natural gas led to minor recalculations for the year 2015.

3.2.11.6 Planned improvements, category-specific (1.A.4, stationary)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

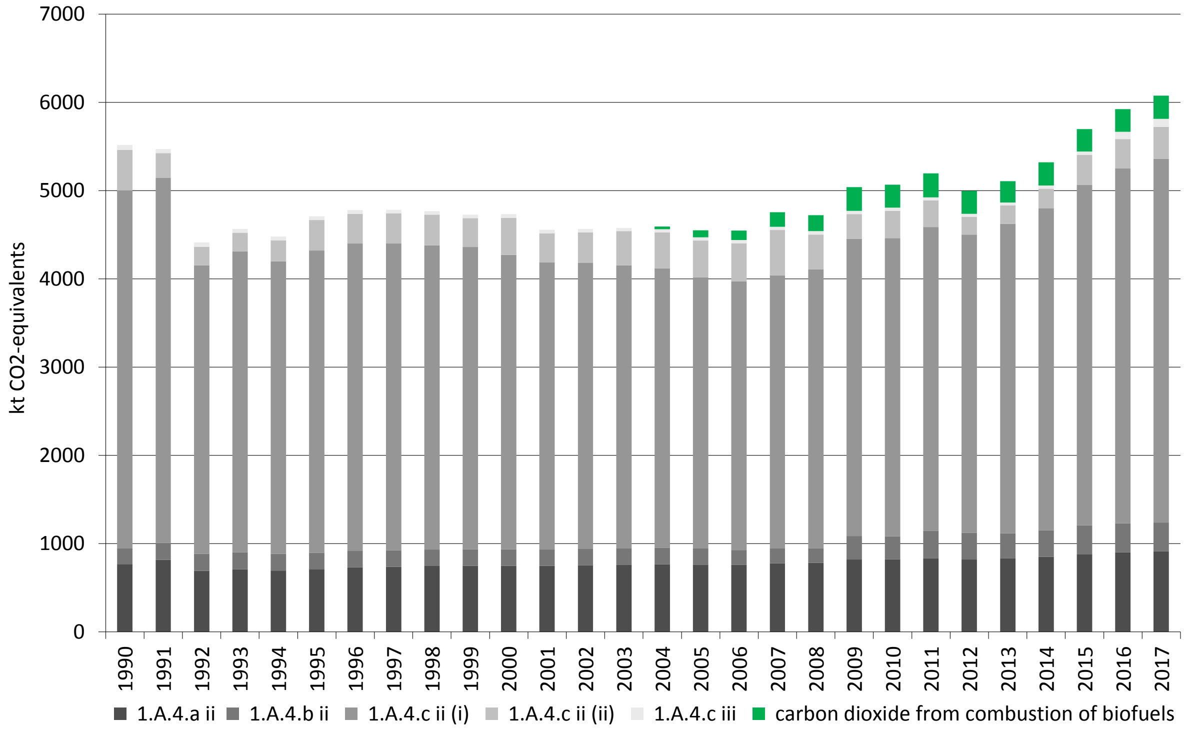
3.2.12 Other: Residential, commercial/institutional, agriculture, forestry and fisheries (1.A.4 Mobile)

3.2.12.1 Category description (1.A.4, Mobile)

The stationary and mobile sources categories in 1.A.4 are grouped together for purposes of determination of key-category status (for an overview, cf. Chapter 3.2.11.1). The category 1.A.4 *Other* is a key category for CO_2 emissions, in terms of both emissions level and trend, in all of its sub-categories. For CH_4 emissions, categories 1.A.4.a & b are a key category in terms of trend.

Category 1.A.4 – mobile comprises various mobile sources in sub-categories 1.A.4.a ii – Commercial and Institutional (commerce, trade and services), 1.A.4.b ii – Residential, 1.A.4.c ii – Agriculture and forestry and 1.A.4.c iii – Fisheries.

Figure 36: Development of GHG emissions in the various considered sub-sectors since 1990



3.2.12.2 Methodological issues (1.A.4, mobile)

The **activity data** in category 1.A.4 mobile, like those for stationary combustion systems, are taken from (AGEB, 2017a).

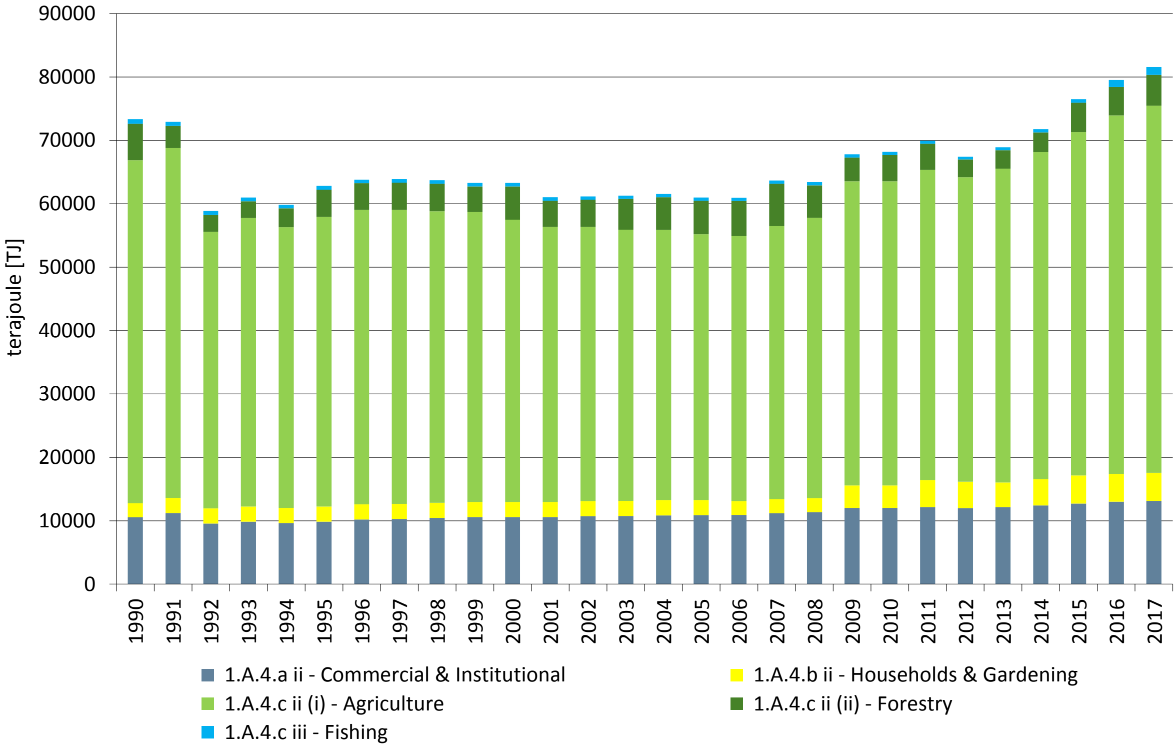
The quantities of gasoline fuels listed in Energy Balance line 66 – Residential are all allocated to *Mobile sources* (*1.A.4.b ii*).

NEB line 67 – Commercial and Institutional also includes fuel consumption areas of the military sector that are that are separately recorded in statistics of BAFA (2018a); those areas can thus be deducted here (cf. Chapter 3.2.14 regarding mobile sources in the military sector). The additional breakdown into mobile sources in *Agriculture (1.A.4.c ii (i) and Forestry (1.A.4.c ii (ii), Construction vehicles and machinery (1.A.2.g vii),* and mobile sources in *1.A.4.a ii* (primarily forklifts), is carried out on the basis of an annual distribution key generated in Knörr et al. (2018b).

In general, the activity data for the coastal and high-seas fisheries included under *1.A.4.c (iii) – Fisheries* are prepared, in the context of the BSH model described under 1.A.3.d, on the basis of AIS data (data of the IMO's Automatic Identification System) and of annual European Commission data on fleet development. For the reporting years 2015 and 2016, however, the data were carried forward, in the manner described in Chapter 3.2.10.4.

In general, the pertinent quantities of *unintentionally* co-combusted lubricants are derived, pursuant to Wallfarth (2014), from the relevant annual fuel quantities. For two-stroke gasoline engines (in the residential and forestry sectors), on the other hand, those quantities, as part of the lubricants co-combusted with fuel mixtures, are obtained as a two-percent addition to the quantities of gasoline used for refueling of (cf. also Chapter 19.1.4).

Figure 37: Development of fuel consumption within the various considered sub-categories since 1990



With regard to the **emission factors** used for carbon dioxide, we refer, in general, to Chapter 18.8. Further information – in particular, with regard to carbon dioxide from lubricant co-combustion – is also provided in Chapter 19.1.4.

For methane and nitrous oxide, country-specific values pursuant to Knörr et al. (2018b) and Deichnik (2018) are used. With regard to releases of methane and nitrous oxide from co-incineration of lubricants, it is assumed that such emissions are already taken into account in the pertinent emission factors for the fuels used and thus are to be reported as IE *(included elsewhere)*.

Table 86: Emission factors used for report year 2017, in kg/TJ

	CH_4	N_2O	Origin
1.A.4.a ii – Mobile sources in the Commercial and Institutional (commerce, trade and services) sector			
Diesel	1.32 (4.15)	2.89 (28.60)	Pursuant to Knörr et al. (2018b)
LPG	5.22 (-)	0.69 (-)	Pursuant to Knörr et al. (2018b)
1.A.4.b ii – Mobile sources of the residential sector			
Gasoline (two-stroke engines)	214 (180)	0.44 (0.40)	Pursuant to Knörr et al. (2018b)
Gasoline (four-stroke engines)	26.9 (120)	1.32 (2)	Pursuant to Knörr et al. (2018b)
1.A.4.c ii (i) – Mobile sources of the agricultural sector			
Diesel	2.35 (4.15)	2.87 (28.6)	Pursuant to Knörr et al. (2018b)
1.A.4.c ii (ii) – Mobile sources of the forestry sector			
Diesel	0.63 (4.15)	3.11 (28.6)	Pursuant to Knörr et al. (2018b)
Gasoline (two-stroke engines)	205 (170)	0.46 (0.40)	Pursuant to Knörr et al. (2018b)
1.A.4.c (iii) – Fisheries (here: *high-seas fisheries)*			
Diesel	1.03 (-)	3.33 (-)	Pursuant to Deichnik (2018)
Heavy fuel oil	NA	NA	Use of heavy fuel oil ended in 2014
Overarching			
Lubricants	IE	IE	Included in the EF for the individual fuels

In parentheses: Default values pursuant to IPCC (2006): Volume 2 Chapter 3.3 – *Off-road transportation*, p. 3.36, Table 3.3.1

The EF for biodiesel and bio-ethanol are in keeping with the values for their fossil-based counterparts.

3.2.12.3 Uncertainties and time-series consistency (1.A.4, mobile)

The uncertainty figures for the specific energy inputs, which are shaped primarily by the mathematical uncertainty in the distribution key developed in TREMOD MM (cf. above: Methodological aspects), are based on experts' assessments. The same holds for the carbon-dioxide emission factors used. While the emission factors for methane are based on results from Knörr et al. (2009), the emission factors for nitrous oxide – for the time being – have to be oriented to guideline values pursuant to the IPCC.

3.2.12.4 Category-specific QA/QC and verification (1.A.4, mobile)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

Table 87: Overview of relevant data comparisons

	Comparison with...	Remark
CO_2, CH_4, N_2O	Alternative emissions inventories for Germany	No comparable data sets
CO_2	Specific Tier 1 default EF pursuant to IPCC (2006): Volume 2, Chapter 3, Tables 3.3.1 and 3.5.2 (1.A.4.c iii)	cf. Table 88
CH_4, N_2O	Specific Tier 1 default EF pursuant to IPCC (2006): Volume 2, Chapter 3, Tables 3.3.1 and 3.5.3 (1.A.4.c iii)	cf. Table 86
CO_2, CH_4, N_2O	Specific IEF of other countries	cf. Table 89

Table 88: Comparison of the EF(CO_2) used in the inventory with default values*

	Inventory values[a]	Default [b]	*Lower bound*	*Upper bound*
Diesel fuel	74,027	74,100	*72,600*	*74,800*
Gasoline		69,300	*67,500*	*73,000*
Two-stroke engines [b]	*75,245*			
4-stroke engines	*75,285*			
LP gas	66,334	63,100	*61,600*	*65,600*
Heavy fuel oil	80,834	77,400	*75,500*	*78,800*
Lubricants	73,300		*71,900*	*75,200*
Biodiesel	70,800		*59,800*	*84,300*
Bioethanol		70,800	*59,800*	*84,300*
Two-stroke engines [c]	*71,641*			
4-stroke engines	*71,607*			

[a] Inventory values for 2017; [b] pursuant to IPCC (2006): Volume 2, Chapter 2, Table 2.4

[c] including 2 % lubricants (EF = 73,300 kg/TJ) in 1:50 two-stroke fuel mixtures

The following table provides a comparison with specific implied emission factors of other countries as well as with the relevant values resulting for the EU(28). It should be noted that the comparison is hampered by the fact that the factors involved represent an extremely heterogeneous group of categories.

Table 89: International comparison of IEF reported for liquid fossil fuels, in kg/TJ

	1.A.4.a ii			**1.A.4.b ii**			**1.A.4.c ii**		
	Liquid fuels			**Liquid fuels**			**Diesel**		
	CO_2	**CH_4**	**N_2O**	**CO_2**	**CH_4**	**N_2O**	**CO_2**	**CH_4**	**N_2O**
Germany	70,730	2.94	1.97	75,276	69.3	1.11	74,027	1.30	2.88
Denmark	73,230	24.8	1.86	73,000	48.7	1.19	73,999	0.96	3.51
France							75,032	4.15	28.6
Netherlands	72,492	3.15	0.60	73,023	57.1	0.63	72,454	1.33	0.60
UK				70,253	9.71	3.24	74,938	3.61	31.0
EU (28)							74,021	3.21	18.7
	1.A.4.c ii						**1.A.4.c iii**		
	Gasoline			**Heavy fuel oil**			**Diesel**		
	CO_2	**CH_4**	**N_2O**	**CO_2**	**CH_4**	**N_2O**	**CO_2**	**CH_4**	**N_2O**
Germany	75,245	204	0.46	NA	NA	NA	74,027	1.03	3.33
Denmark	72,996	156	1.46	77,880	2.54	1.69	73,844	2.29	1.68
France	70,579	163	0.45	78,000	7.50	2.00	75,032	7.14	1.90
Netherlands	73,023	294	0.63	77,400	7.00	2.00	72,454	7.00	2.00
UK	69,998	48.6	0.34	76,469	1.53	3.82	75,313	1.03	3.41
EU (28)	72,802	120	1.65	77,331	6.58	2.14	74,143	5.65	2.06

Germany: Current IEF for report year 2017; all other countries: IEF for 2016, pursuant to 2018 CRF Submission

3.2.12.5 Category-specific recalculations (1.A.4, mobile)

As described above, the activity data for construction-sector transports are part of the primary data given in Energy Balance line 67. The provisional data provided for the year 2016, in the 2018 Submission, have been replaced with the corresponding final figures. The quantities of consumed biofuels that were determined via the official admixture quotas have been recalculated as necessary. The 2016 admixture quota for biodiesel was corrected in the process.

Table 90: Revised primary activity data for 2016, in terajoules

	Diesel	Gasoline	Biodiesel	Bioethanol	LP gas
2019 Submission	105,895	7,991	5,562	347	23,260
2018 Submission	103,106	8,414	5,410	365	20,460
Absolute change	2,789	-423	152	-18	2,800
Relative change	2.70%	-5.03%	2.82%	-5.03%	13.69%

Source: Revised NEB 2016 (AGEB, 2018) and own calculations

In addition, the distribution key, based on TREMOD-MM data, was corrected with regard to the diesel-fuel sub-sectors subsumed under Energy Balance line 67. The distribution key for gasoline has not been changed, however.

Table 91: Revised applicable annual shares of the diesel-fuel quantities given in Energy Balance line 67, in percent

	2011	2012	2013	2014	2015	2016
			1.A.2.g vii			
2019 Submission	39.702	39.976	40.133	40.291	39.806	39.704
2018 Submission	39.702	39.975	40.133	40.290	39.805	39.704
Absolute change	0.001	0.001	0.001	0.001	0.001	0.001
Relative change	0.002%	0.002%	0.002%	0.002%	0.002%	0.002%
			1.A.4.a ii			
2019 Submission	6.9581	6.9130	6.8481	6.7839	6.7942	6.7918
2018 Submission	6.9582	6.9131	6.8482	6.7839	6.7943	6.7918
Absolute change	-0.0001	-0.0001	-0.0001	-0.0001	-0.0001	-0.0001
Relative change	-0.001%	-0.001%	-0.001%	-0.001%	-0.001%	-0.001%
			1.A.4.c ii (i)			
2019 Submission	50.6040	50.5739	50.4592	50.3299	50.7350	50.9979
2018 Submission	50.6045	50.5744	50.4597	50.3304	50.7355	50.9984
Absolute change	-0.0005	-0.0005	-0.0005	-0.0005	-0.0005	-0.0005
Relative change	-0.001%	-0.001%	-0.001%	-0.001%	-0.001%	-0.001%
			1.A.4.c ii (ii)			
2019 Submission	2.73574	2.53735	2.55933	2.59521	2.66493	2.50593
2018 Submission	2.73577	2.53739	2.55936	2.59524	2.66496	2.50597
Absolute change	-0.00004	-0.00003	-0.00003	-0.00003	-0.00004	-0.00003
Relative change	-0.001%	-0.001%	-0.001%	-0.001%	-0.001%	-0.001%

Source: Own calculations, based on , Knörr et al. (2018b)

The described effects lead to the following changes in the sectoral activity data used in the last report:

Table 92: Revised energy inputs for sub-sectors, in terajoules

	2010	2011	2012	2013	2014	2015	2016
				1.A.4.a ii			
2019 Submission	12,047	12,169	12,009	12,172	12,422	12,724	12,999
2018 Submission	12,049	12,171	12,011	12,174	12,424	12,724	12,800
Absolute change	-2	-2	-2	-2	-2	0	200
Relative change	-0.02%	-0.02%	-0.01%	-0.01%	-0.02%	0.00%	1.56%
				1.A.4.b ii			
2019 Submission	3,510	4,236	4,172	3,879	4,118	4,411	4,412
2018 Submission	3,510	4,236	4,172	3,879	4,118	4,411	4,500
Absolute change	0	0	0	0	0	0	-89
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-1.97%

	2010	2011	2012	2013	2014	2015	2016
				1.A.4.c ii (i)			
2019 Submission	47,980	48,928	47,989	49,482	51,634	54,188	56,529
2018 Submission	47,998	48,943	48,001	49,495	51,650	54,188	55,029
Absolute change	-18	-15	-12	-13	-16	-1	1,500
Relative change	-0.04%	-0.03%	-0.03%	-0.03%	-0.03%	0.00%	2.72%
				1.A.4.c ii (ii)			
2019 Submission	4,143	4,129	2,824	2,917	3,102	4,618	4,463
2018 Submission	4,144	4,130	2,825	2,918	3,103	4,618	4,533
Absolute change	-1	-1	-1	-1	-1	0	-69
Relative change	-0.02%	-0.02%	-0.02%	-0.02%	-0.03%	0.00%	-1.53%
				1.A.4.c iii			
2019 Submission	500	467	456	452	496	565	1,125
2018 Submission	500	467	456	452	496	565	1,126
Absolute change	0	0	0	0	0	0	-1
Relative change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.08%

Source: Own calculations, based on AGEB (2018), Knörr et al. (2018b) and Deichnik (2018)

In addition, the emission factors for methane from use of LP gas were adjusted in TREMOD MM.

Table 93: Revised EF(CH_4) for LP gas, in kg / TJ

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
2019 Submission	5.30	5.28	5.21	5.21	5.21	5.21	5.21	5.21	5.21	5.21	5.21
2018 Submission	5.28	5.26	5.20	5.20	5.20	5.20	5.20	5.20	5.20	5.20	5.20
Absolute change	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Relative change	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%	0.30%

Source: TREMOD MM (Knörr et al., 2018b)

The numerous corrections lead to the following recalculated emissions quantities:

Table 94: Revised emissions quantities, in kilotonnes of CO_2-eq[a]

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
						1.A.4.a ii					
Subm. 2019	766.6	707.50	749.50	759.97	822.61	831.19	820.02	834.76	851.43	880.71	900.99
Subm. 2018	767.2	707.50	749.50	759.97	822.61	831.20	820.03	834.77	851.44	880.72	886.79
Abs. change	-0.6	0.001	0.002	0.002	0.000	-0.006	-0.005	-0.006	-0.006	-0.005	14.197
Rel. change	-0.1%	0.0002%	0.0002%	0.0003%	-0.00002%	-0.001%	-0.001%	-0.001%	-0.001%	-0.001%	1.60%
						1.A.4.b ii					
Subm. 2019	177.4	189.4	185.3	184.7	259.6	311.0	303.3	281.1	297.8	328.0	327.6
Subm. 2018	177.4	189.4	185.3	184.7	259.6	311.0	303.3	281.1	297.8	328.0	334.2
Abs. change	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-6.6
Rel. change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-1.97%
						1.A.4.c ii (i)					
Subm. 2019	4,060	3,425	3,338	3,075	3,380	3,445	3,379	3,508	3,651	3,855	4,028
Subm. 2018	4,060	3,425	3,338	3,075	3,380	3,445	3,379	3,508	3,652	3,856	3,921
Abs. change	0	0	0	0	0	0	0	0	0	0	107
Rel. change	0.00%	0.00%	0.00%	0.00%	-0.001%	-0.001%	-0.001%	-0.001%	-0.001%	-0.001%	2.72%
						1.A.4.c ii (ii)					
Subm. 2019	458	346	420	414	308	303	201	209	221	340	328
Subm. 2018	458	346	420	414	308	303	201	209	221	340	334
Abs. change	0	0	0	0	0	0	0	0	0	0	-6
Rel. change	0.00%	0.00%	0.00%	0.00%	-0.0003%	-0.002%	-0.002%	-0.002%	-0.002%	-0.002%	-1.75%

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
						1.A.4.c iii					
Subm. 2019	55.3	42.66	41.32	37.93	36.77	34.33	33.50	33.32	36.52	41.65	83.85
Subm. 2018	55.0	42.66	41.32	37.93	36.77	34.33	33.50	33.32	36.52	41.65	83.85
Abs. change	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rel. change	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

[a] Not including CO_2 from use of biofuels; source: own calculations

3.2.12.6 Category-specific planned improvements (1.A.4, mobile)

No concrete improvements are currently planned, apart from ongoing routine review and revision of the models used.

3.2.13 Other sectors (1.A.5.a stationary)

Category 1.A.5 comprises the combustion-related emissions of the military sector. It is divided into the categories 1.A.5.a *"Stationary"* and 1.A.5.b *"Mobile"*.

3.2.13.1 Category description (1.A.5.a Stationary)

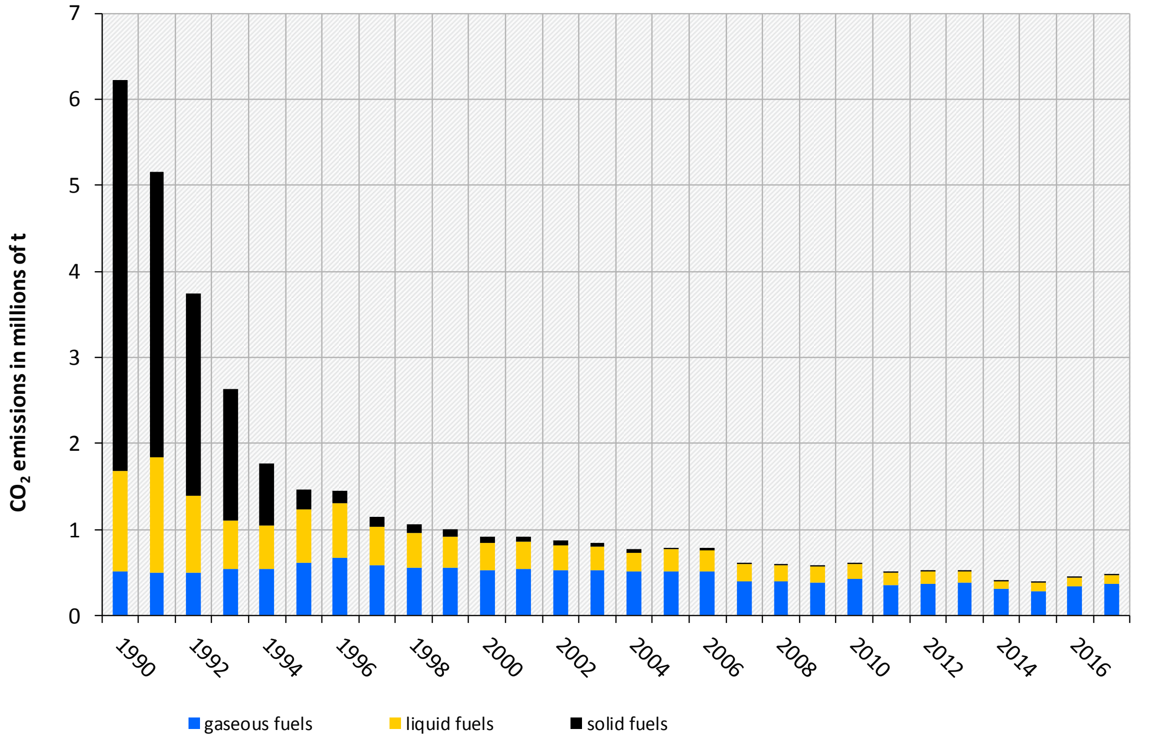
KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
L/T	**1.A.5 Other: Include Military fuel use under this category**	**All fuels**	**CO_2**	**11,797.50**	**0.96%**	**848.42**	**0.10%**	**-92.8%**
-/-	1.A.5. Other: Include Military fuel use under this category	All fuels	CH_4	279.43	0.02%	1.51	0.00%	-99.5%
-/-	1.A.5. Other: Include Military fuel use under this category	All fuels	N_2O	61.33	0.01%	3.10	0.00%	-94.9%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS, Tier 1	NS	CS/D
CH_4	CS, Tier 1, Tier 3	NS/M	CS/D/M
N_2O	CS, Tier 1, Tier 3	NS/M	CS/D/M

The stationary and mobile sources categories in 1.A.5 are placed in the relevant main categories together. The category *Other* is a key category for CO_2 emissions in terms of both emissions level and trend.

The following figure shows the emissions trend since 1990.

Figure 38: Development of CO_2 emissions in category 1.A.5.a



The especially large emissions reduction is the result of closure of many military agency locations, as well as of considerable shifting from use of solid fuels to use of gaseous and liquid fuels.

3.2.13.2 Methodological issues (1.A.5.a, stationary)

Activity data

The National Energy Balance (NEB) (AGEB) provides the basis for the **activity data** used. As of 1995, the NEB no longer lists the final energy consumption of military agencies separately, and instead includes that consumption in line 67, under "Commercial and Institutional" (commerce, trade, services and other consumers). As a result, figures of the Federal office for infrastructure, environmental protection and services of the German Armed Forces (Bundesamt für Infrastruktur, Umweltschutz und Dienstleistungen der Bundeswehr) (BAIUDBw, 2018) are used. That office reports "energy inputs for heat generation in the German Armed Forces" ("Energieeinsatz zur Wärmeerzeugung in der Bundeswehr"), broken down by fuels, to the Federal Environment Agency (most recently, this was done for the period 2000-2016). Those figures are deducted from the figures in Energy Balance line 67 (commercial, institutional) and are reported in 1.A.5, rather than in 1.A.4. As of report year 2008, use of wood in category 1.A.5.a is also reported.

Emission factors

A detailed description of the relevant procedures, and a list of the CO_2 emission factors used, is presented in the Annex, Chapter 18.8.

The database for the emission factors used for all other **pollutants** consists of the results of a research project carried out by the University of Stuttgart, under commission to the Federal Environment Agency (Struschka et al., 2008). Within that project, device-related and category-specific emission factors for combustion systems in military agencies were calculated, with a high level of detail, for all important emissions components for the reference year 2005. The method used to determine the factors conforms to the procedure described for category 1.A.4. Table 95 shows the sectoral emission factors used.

Table 95: Sectoral emission factors for the military sector

	CH_4	N_2O
	[kg/TJ]	
Stationary combustion in military agency locations		
Hard coal	2.0	4.8
Lignite briquettes	242	0.37
Heating oil EL	0.017	0.56
Natural gas	0.042	0.29

3.2.13.3 Uncertainties and time-series consistency (1.A.5.a, stationary)

Information regarding the uncertainties for the emission factors is provided in the description for category 1.A.4. Annex 2 Chapter 13.6 in the NIR 2007 describes how the uncertainties for the activity data were determined.

3.2.13.4 Category-specific QA/QC and verification (1.A.5.a, stationary)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

Since no other sources of data for Germany are known, it is currently not possible to verify the emissions reported here via comparison.

3.2.13.5 Category-specific recalculations (1.A.5.a, stationary)

Table 96: Recalculations in CRF 1.A.5.a

Units [kt]	2018 NIR	2019 NIR	Difference, absolute				Difference, relative
Year	Total	Total	gas	liquid	solid	Total	Total
2016	438	439	-1	1	0	0	0.09%

Minor recalculations were carried out for the year 2016, to take account of updating of calorific values.

3.2.13.6 Planned improvements, category-specific (1.A.5.a, stationary)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

3.2.14 Other (1.A.5.b Mobile)

3.2.14.1 Category description (1.A.5.b, Mobile)

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1 [a], CS	NS/M [b]	D [a], CS
CH_4	CS, Tier 1, Tier 3	NS/M [b]	CS (M)
N_2O	CS, Tier 1, Tier 3	NS/M [b]	CS (M)
NO_X, CO, NMVOC, SO_2	CS, Tier 1, Tier 3	NS/M [b]	CS (M)

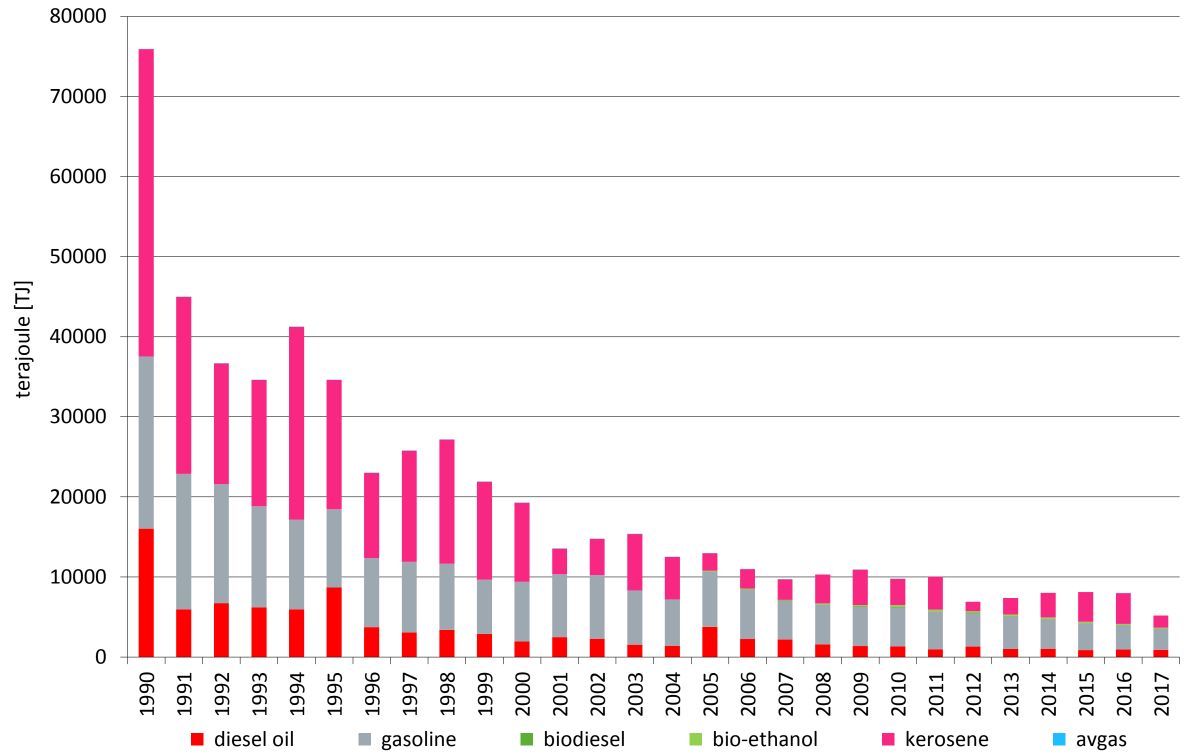
[a] Biodiesel and avgas: Default EF pursuant to IPCC (2006): Volume 2, Chapter 2, Table 2.4

[b] Military Ship transports: calculated in Deichnik (2018)

Key category analysis for *1.A.5 – Other* focuses primarily on stationary and mobile sources (for an overview, cf. Chapter 3.2.13.1). The analysis shows that category *1.A.5* is a key category for CO_2 emissions in terms of both emissions level and trend.

The following figure shows the development of GHG emissions since 1990.

Figure 39: Development of GHG emissions of mobile sources in the military sector since 1990



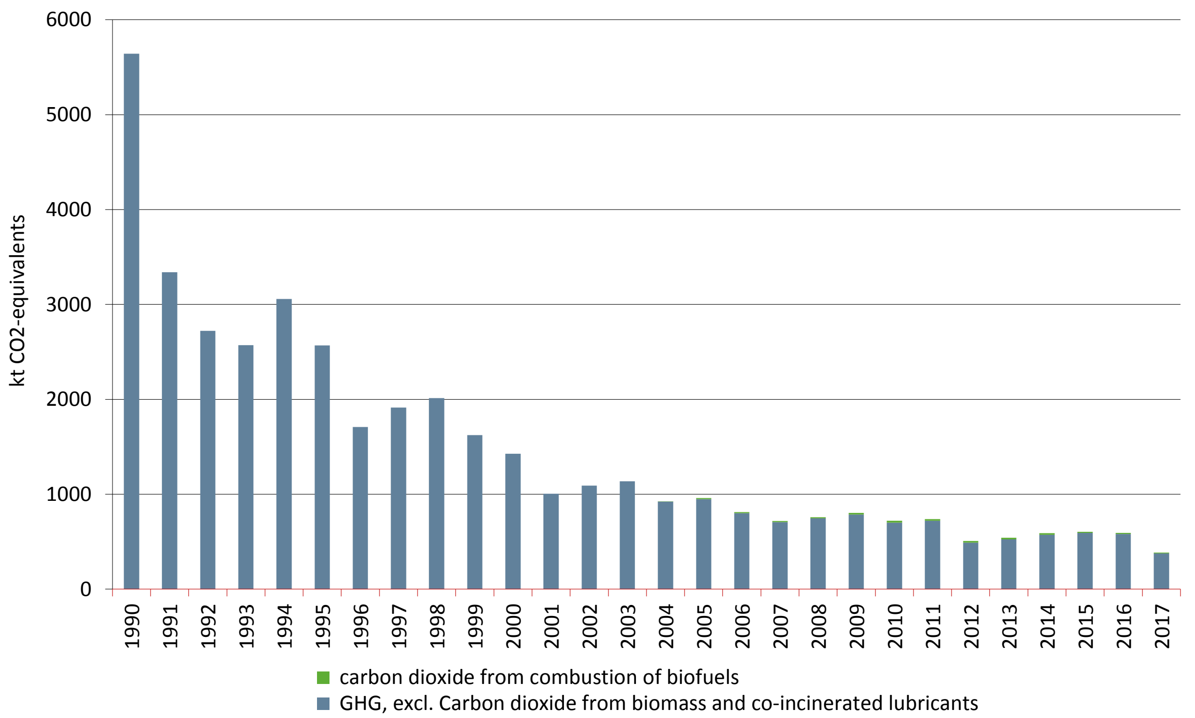
3.2.14.2 Methodological issues (1.A.5.b, mobile)

Activity data

The **activity data** used are based on the Energy Balance of the Federal Republic of Germany (AGEB), which provides directly usable fuel-input data for military air and ground transports (diesel fuel and gasoline – including any biogenic admixtures – and kerosene and avgas) only for the period until 1993. As of 1994, data of BAFA (2018a) are used. The consumption figures in that source, which are given in units of 1000 t, are converted into terajoules on the basis of the pertinent listed net calorific values (AGEB, 2018). On the other hand, the fuel inputs in the naval sector are only a sub-quantity of the quantities listed in *Energy Balance line 6 – International marine bunkers*. They are thus calculated separately, as described in Chapter 3.2.10.4.

In addition, the quantities of co-combusted lubricants are derived via co-combustion rates, pursuant to {Wallfarth, 2014 #28}, from the total quantities of the fuels used in sub-categories 1.A.5.b i through iii (cf. also Chapter 19.1.4).

Figure 40: Development of fuel inputs since 1990



Emission factors

With regard to the **emission factors** used for carbon dioxide, we refer, in general, to Chapter 18.8. Both country-specific and default values (biodiesel, avgas) are used. Further information regarding co-incineration of lubricants in particular is provided in Chapter 19.1.4.

For methane and nitrous oxide, country-specific values are also used for ground transports and for use of avgas. For jet kerosene, IPCC default figures are used, in light of the fact that the aircraft used by the sector differ strongly from those used in civil aviation. The emission factors used for the naval sector are taken from Deichnik (2018). With regard to releases of methane and nitrous oxide from co-incineration of lubricants, it is assumed that such emissions are already taken into account in the pertinent emission factors for the fuels used and thus are to be reported as IE *(included elsewhere)*.

Table 97: Emission factors used for reported year 2016, in kg/TJ

	CH_4	N_2O	Origin
1.A.5.b i – Military ground vehicles and machinery			
Diesel	2.97 (-)	0.81 (-)	IEF derived from 1.A.3.b: heavy duty vehicles
Gasoline	7.04 (-)	0.72 (-)	IEF derived from 1.A.3.b
1.A.5.b ii – Military air transports[a]			
Kerosene	0.50 (0.50)	2.00 (2.00)	Tier 1 Default value pursuant to IPCC (2006)
Avgas	8.21 (-)	2.33 (-)	cf. 1.A.3.a
1.A.5.b iii – Military maritime transports / naval transports [b]			
Diesel	0.75 (7.00)	3.40 (2.00)	Pursuant to Deichnik (2018)
Overarching			
Lubricants	IE	IE	Included in the EF for fuels

In parentheses: Default values pursuant to IPCC (2006): Volume 2, Chapter 3: [a] Tab. 3.6.5; [b] Tab. 3.5.3

The EF for biodiesel and bio-ethanol are in keeping with the values used for their fossil-based counterparts.

3.2.14.3 Uncertainties and time-series consistency (1.A.5.b, mobile)

Within sub-sectors 1.A.5.b i and ii, default uncertainties pursuant to IPCC are used. In a departure from that procedure, specific uncertainties for activity data and emission factors for military maritime transports were derived in (BSH, 2015).

3.2.14.4 Category-specific QA/QC and verification (1.A.5.b, mobile)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the Single National Entity.

Table 98: Overview of relevant data comparisons

	Comparison with...	Remark
CO_2	Alternative emissions inventories for Germany	No comparable data sets
CO_2	Specific Tier 1 default EF pursuant to IPCC (2006): Volume 2, Chapter	for 1.A.5.b ii & iii: cf. Table 99
CO_2	Tier 1 default EF pursuant to IPCC (2006): Volume 2, Chapter 2, Table	for 1.A.5.b i: cf. Table 99
CH_4, N_2O	Specific Tier 1 default EF pursuant to IPCC (2006)	for 1.A.5.b ii & iii: cf. Table 95
CH_4, N_2O	Tier 1 default EF pursuant to IPCC (2006): Volume 2, Chapter 2, Table	1.A.5.b i: cf. Table 95
CO_2	Specific IEF of other countries	cf. Table 89

Table 99: Comparison of the EF(CO_2) used with default values, in kg/TJ

	Inventory values[a]	Default[b]	*Lower bound*	*Upper bound*
Diesel fuel	74,027	74,100	*72,600*	*74,800*
Gasoline	75,286	69,300	*67,500*	*73,000*
Kerosene	73,256	71,500	*69,800*	*74,400*
Avgas	70,000		*67,500*	*73,000*
Biodiesel	70,800		*59,800*	*84,300*
Bioethanol	71,607	70,800	*59,800*	*84,300*

[a] for reported year 2017; [b] pursuant to IPCC (2006): Volume 2, Chapter 2, Table 2.4

The following table provides a comparison with specific implied emission factors of other countries.

Table 100: International comparison of IEF for liquid fossil fuels, in kg/TJ

	CO_2	CH_4	N_2O
Germany	72,519	3.28	1.47
Denmark	72,893	2.10	2.57
France			
Netherlands	74,100	6.24	3.79
UK	72,372	2.02	2.16
EU (28)			

Germany: current IEF for 1.A.5.b for reporting year 2017; all other countries: IEF for 2016, pursuant to 2018 CRF Submission

3.2.14.5 Category-specific recalculations (1.A.5.b, mobile)

Since the 2018 Submission, recalculations have been carried out to take account of revised activity data and emission factors.

While the consumption figures for military land and air transports did not change, the consumption data for military maritime transports for the years 2014 through 2016 were changed (corrected) slightly.

The only considerable correction was that with regard to the quantity of biodiesel used for military maritime transports in 2016.

Table 101: Revised activity data, 2014-2016, in terajoules

	2014	2015	2016
Military land transports			
2019 Submission	4,580	4,102	3,752
2018 Submission	4,580	4,102	3,752
Absolute change	0.00	0.00	0.00
Relative change	0.00%	0.00%	0.00%
Military air transports			
2019 Submission	3,060	3,726	3,845
2018 Submission	3,060	3,726	3,845
Absolute change	0.00	0.00	0.00
Relative change	0.00%	0.00%	0.00%
Military maritime transports			
2019 Submission	351.287	286.327	370.087
2018 Submission	351.283	286.323	371.301
Absolute change	0.004	0.004	-1.214
Relative change	0.0013%	0.0013%	-0.33%
Military transports, total			
2019 Submission	7,990.880	8,114.945	7,967.668
2018 Submission	7,990.875	8,114.941	7,968.884
Absolute change	0.005	0.004	-1.216
Relative change	0.00005%	0.00004%	-0.02%

Source: Own calculations, based on BAFA (2018a), and Deichnik (2018)

Table 102: Revised CO_2 emission factors for fossil-based gasoline, 2015 & 2016, in kg/TJ

	2015	2016
2019 Submission	75,286.77	75,284.61
2018 Submission	75,288.55	75,286.39
Absolute change	-1.78	-1.78
Relative change	-0.002%	-0.002%

Source: Own calculations

In the interest of clarity, the revised emission factors for methane and nitrous oxide are not presented here.

The above-described adjustments led to only marginal changes in the reported greenhouse-gas emissions.

Table 103: Revised emissions data, in kt CO_2 equivalents [a]

	2014	2015	2016
Military land transports			
2019 Submission	322.35	296.37	271.04
2018 Submission	322.35	296.38	271.05
Absolute change	0.00	-0.01	-0.01
Relative change	0.00%	-0.002%	-0.003%
Military air transports			
2019 Submission	226.01	275.25	284.03
2018 Submission	226.01	275.25	284.03
Absolute change	0.00	0.00	0.00
Relative change	0.00%	0.00%	0.00%
Military maritime transports			
2019 Submission	24.9509	20.4822	26.9650
2018 Submission	24.9505	20.4820	26.9659
Absolute change	0.0003	0.0003	-0.0009
Relative change	0.001%	0.001%	-0.003%

	2014	2015	2016
		Military transports, total	
2019 Submission	573.3044	592.10	582.03
2018 Submission	573.3041	592.11	582.04
Absolute change	0.0003	-0.01	-0.01
Relative change	0.0001%	-0.001%	-0.001%

[a] Not including CO_2 from use of biofuels; source: own calculations

3.2.14.6 Category-specific planned improvements (1.A.5.b, mobile)

No specific improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

3.2.15 Military

The German emissions inventories do not record emissions from international missions of the German Armed Forces, under NATO or UN mandates; instead, they list them as "not estimated" (NE) memo items. The reason for this is a lack of information regarding the fuel quantities (activity data) required/used in the framework of such mandates.

Emissions from stationary combustion systems of military agencies, and from *domestic* operation of military vehicles and machinery, are recorded and described in the German emissions inventories, however – under category *1.A.5 – Other*.

3.3 Fugitive emissions from fuels (1.B)

During all stages of fuel production and use, from extraction of fossil fuels to their final use, fuel components can escape or be released as fugitive emissions. While methane emissions are the most important emissions within the source category areas of fugitive emissions from solid fuels and fugitive emissions from natural gas, fugitive emissions of oil and natural gas also include substantial amounts of NMVOC. In category 1.B, carbon dioxide plays only a minor role in connection with processing of solid fuels, processing of hydrogen sulfide and flaring. Source category 1.B. is not a source for fluorinated gases.

3.3.1 Solid fuels – coal mining and handling (1.B.1)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
L/T	**1.B.1 Fugitive Emissions from Fuels**	**Solid fuels**	**CH_4**	**25,553.44**	**2.09%**	**2,484.45**	**0.28%**	**-90.3%**
-/-	1.B.1. Fugitive Emissions from Fuels	Solid fuels	CO_2	1,832.80	0.15%	693.40	0.08%	-62.2%

The category *Coal mining and handling* is a key category for CH_4 emissions in terms of emissions level and trend.

In mining, a distinction is made between surface mining, in which deposits are extracted from pits open to the surface, and underground mining, in which deposits are extracted from sites underground. All hard coal mining in Germany is underground mining, while (since 2003) all lignite mining is open-pit mining.

This category is subdivided as follows:

Source category			Included emissions
1.B.1.a. Coal mining			
	i.	**Underground mining**	
		Mining activities	Total emissions from active hard-coal mines, consisting of emissions from a) mine ventilation and b) mine-gas extraction, less the quantity of mine gas recovered and utilised
		Follow-up mining activities	Emissions from processing, storage and transport of hard coal
		Decommissioned coal mines	Emissions from decommissioned hard-coal mines and emissions from flaring
	ii.	**Open-pit mining**	
		Mining activities	Emissions from active open-pit lignite mining. Here, the entire potential methane content of German lignite is used as the basis – this methane is assumed to be emitted, in its entirety, during mining. Any later emissions of methane, during further processing, are thus already taken into account. No pit-gas collection or use takes place in open-pit mining.
		Follow-up mining activities	No separate listing – the emissions are already included in "mining activities"
1.B.1.b. Solid fuel transformation – coal processing and charcoal production			Emissions from coal processing and charcoal production. This area takes account of specific emissions that occur in hard-coal processing. Methane emissions from lignite processing are already included in 1.B.1.a.ii "Mining activities". The assumed activity data cover the total for all processed products from hard coal and lignite.
1.B.1.c. Other			No emissions are currently being reported in this category.

Emissions and trend (1.B.1)

Table 104: Calculation of methane emissions from coal mining for 2016

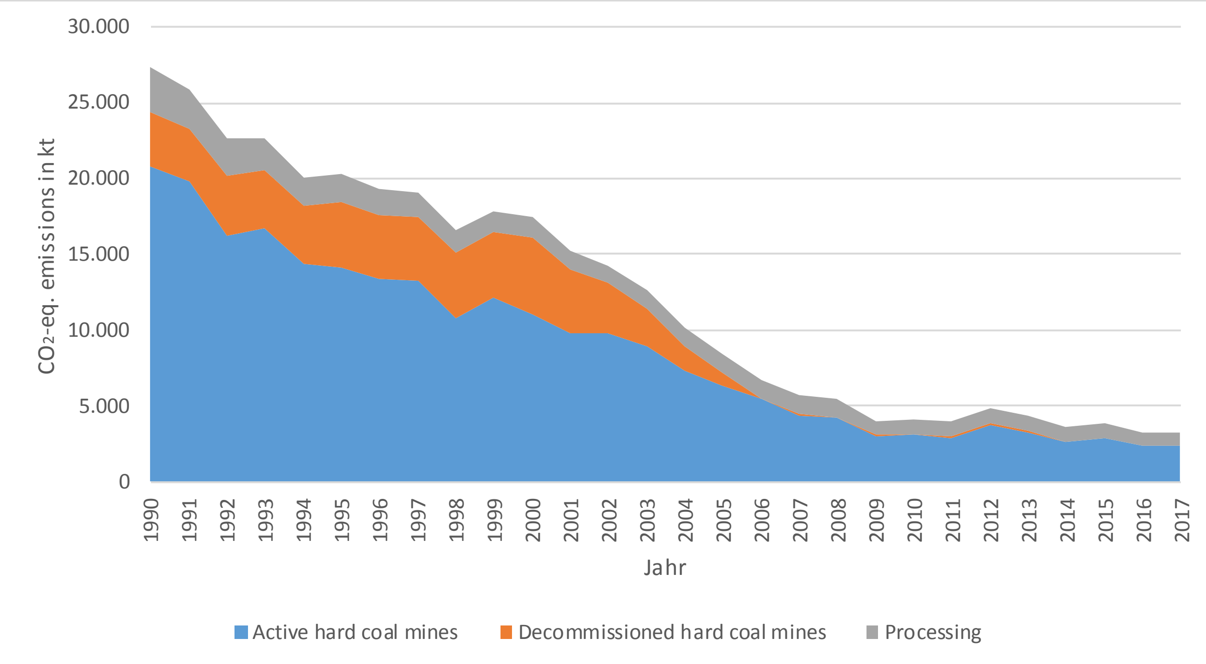
			Activity data [Mt]	CH_4 emissions [kt]
1.B.1.a. Coal mining			(= 1.B.1.a.i + 1.B.1.a.ii) = 3.7 + 171.3 **= 175.0**	(= 1.B.1.a.i + 1.B.1.a.ii) = 95.3 + 1.9 **= 97.2**
	i.	**Underground mining**		**= mining and post-mining activities** = 92.5 + 2.1 + 0.7 **= 95.3**
		Mining activities Hard-coal extraction [1)]	**3.7**	= AD * EF = 3.7*25.0 **= 92.5**
		Follow-up mining activities		**= 2.1**
		Decommissioned coal mines		Potential emissions, minus gas usage **= 0.7**
	ii.	**Open-pit mining**		**= mining activities** **= 1.9**
		Mining activities Lignite extraction [1)]	**171.3**	= AD * EF = 171.3 * 0.011 **= 1.9**
		Follow-up mining activities		(included in 1.B.1.a.ii "mining activities") **IE**

		Activity data [Mt]	CH_4 emissions [kt]
1.B.1.b Solid fuel transformation			**= 0.5**
	Coal processing Total for processed products [2) 1)]		$AD_{hard\text{-}coal\ prod.} * EF_{hard\text{-}coal\ prod.} + AD_{lignite\ prod.} * EF_{lignite\ prod.}$ = 9.3 * 0.049 + 6.7 * 0 **= 0.5**

1) Pursuant to (Statistik der Kohlenwirtschaft, 2018)

2) Hard-coal coke, hard-coal briquettes, lignite coke, coal dust, dry coal, fluidised-bed coal, lignite briquettes, lignite granulate

Figure 41: CO_2-equivalent emissions in category 1.B.1



3.3.1.1 Underground mining – hard coal

3.3.1.1.1 Category description (underground mining – hard coal)

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier 3	AS	CS
CO_2	M	AS	CS

Activity data

Table 105: Usable output of hard coal, in millions of t.

1990	1995	2000	2005	2010	2015	2016	2017
70.2	53.6	33.6	24.9	12.9	6.2	3.8	3.7

(Statistik der Kohlenwirtschaft, 2018)

Table 106: Number of active hard-coal mines

1990	1995	2000	2005	2010	2015	2016	2017
27	19	12	9	5	3	2	2

(Statistik der Kohlenwirtschaft, 2018)

Emission factors

An implied emission factor (IEF) can be derived from the figures for total methane emissions and from the relevant activity data for hard-coal mining. This calculation takes mine-gas usage into account. The measurements cover only actually emitted quantities of methane.

With this approach, the annual emissions change in keeping with the gas content in the hard coal, the quantity of gas extracted and the share of methane that is used.

For calculation of CH_4 emissions from hard-coal storage, the activity data for hard-coal production is used as a basis and then multiplied by the emission factor of 0.576 kg/t. That emission factor has been taken from a study of the Fraunhofer Institute for Systems and Innovation Research (FhG-ISI) (Schön et al., 1993).

Table 107: Methane emission factors for the area of hard-coal extraction and storage, for the year 2017

Emission factors	m^3 CH_4/t	kg/t
CH_4 from extraction	56.03	37.54
CH_4 from extraction, less mine gas utilised	37.31	24.99
CH_4 from storage	0.87	0.58
CH_4 from mining (extraction and storage, less mine gas utilised)	38.18	25.57

(Ilse, 2018)

No emission factor can be provided for decommissioned coal mines, since there are no pertinent activity data.

Emissions and trend

Table 108: Emissions in category 1.B.1.a.i – underground mining

Gas	Total emissions			Trend		Remark
	1990	2015	2016	Since 1990	With respect to the previous year	
Methane	975 kt	116 kt	93 kt	- 90 %	-20 %	The emissions have been decreasing as a result of decreases in utilisable extracted quantities and of increases in pit-gas utilisation since 2001.

3.3.1.1.2 Methods (Underground mining – hard coal)

Emissions from underground hard-coal mining are calculated pursuant to the Tier 3 method, in a procedure that meets requirements pertaining to mine-specific emissions determination. For safety reasons, gas compositions and air flows are measured continuously in all pit systems. The resulting data is used to determine levels of methane emissions. The Gesamtverband Steinkohle (GVSt) association of the German hard-coal-mining industry determines the total methane quantity by aggregating the relevant individual measurements. Expert review is carried out by the competent state supervisory authority (the mining authority – Bergamt).

3.3.1.1.3 Uncertainties and time-series consistency (underground mining – hard coal)

The uncertainties in the activity data result primarily from inaccuracies in weighing of extracted coal. Via surveys of experts carried out during the NaSE workshop of 2004 (NaSE-Workshop, 2004), the relevant error has been quantified as <3 %.

Uncertainties in calculation of methane releases result from inaccuracies in measurements. As a result of the facts that underground measurements of methane concentrations are carried out primarily for safety reasons, and that their most precise measurement range does not fall within the range of common gas-release concentrations, the available measuring equipment can be expected to have a technical measurement inaccuracy of about 10 % (Böttcher et al., 2009).

Methane releases from hard coal, during storage and transport, fluctuate considerably in keeping with storage duration and grain-size distribution. An uncertainty of 15 % must be assumed (Lange (1988) / Batz (1995) and information obtained via personal communication NaSE-Workshop (2004)).

The methane potential has been estimated on the basis of experts' knowledge. In this area, an uncertainty of 60 % has been assumed.

For the activity data, a consistent source is used throughout the entire time series.

3.3.1.1.4 Category-specific quality assurance/control and verification (underground mining – hard coal)

General and category-specific quality control, and quality assurance in conformance with the requirements of the QSE manual and its associated applicable documents, have been carried out by the Single National Entity. Quality control of the activity data was carried out by the data supplier, on the basis of the supplier's own QMS.

For underground hard-coal mining, the 2006 IPCC Guidelines recommend emission factors on the order of 10 to 25 m^3/t. Conversion of the German emission factors, using a conversion factor of 0.67 Gg/10^6 m^3 (2006 IPCC Guidelines, Chapter 4: at 20° C, 1 atmosphere) yields the individual values listed in Table 107. When production, storage and deductable mine-gas use are combined in one emission factor, the resulting value per tonne of coal (marketable production) lies within the recommended range.

The emissions from decommissioned hard-coal mines, as determined by the Gesamtverband Steinkohle (GVSt) association of the German hard-coal-mining industry, have been verified via the research project "Potential for release and utilisation of mine gas" ("Potential zur Freisetzung und Verwertung von Grubengas") (Meiners, 2014). The relevant calculations were carried out for all deposit regions in Germany.

The relevant figures for 2012, as reported in the 2014 Submission, have been compared with the corresponding figures of neighbouring countries.

Table 109: IEF for underground hard-coal mining: Germany as compared with neighbouring countries (NIR 2014)

	Hard coal extracted	Reported emissions	IEF
Germany	**10.8 million t**	**151.1 kt**	**14.0 kg/t**
Czech Republic	11.4 million t	100.1 kt	8.8 kg/t
UK	6.2 million t	65.4 kt	10.5 kg/t
Poland	71.3 million t	324.7 kt	4.6 kg/t
IPCC GL 2006			6.7 – 15.5 kg/t

3.3.1.2 Open-pit mining – lignite

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier 2	AS	CS

3.3.1.2.1 Category description (open-pit mining – lignite)

Activity data

Table 110: Usable output of lignite, in millions of t.

1990	1995	2000	2005	2010	2015	2016	2017
356.5	192.7	167.7	177.9	169.4	178.1	171.5	171.3

(Statistik der Kohlenwirtschaft, 2018)

Emission factors

In keeping with figures of the DEBRIV German lignite-industry association (DEBRIV, 2004), an average emission factor of 0.015 m^3 CH_4/t (corresponds to 0.011 kg CH_4/t) is assumed for German lignite. This emission factor is based on a 1989 study of RWE Rheinbraun AG (DEBRIV, 2004) and has been substantiated by publications of the Öko-Institut e.V. Institute for Applied Ecology and of the DGMK (German Society for Petroleum and Coal Science and Technology) (DGMK, 1992).

No lignite storage takes place; usage is "mine-mouth", i.e. extracted coal is moved directly to processing and to power stations.

Table 111: Emissions in category 1.B.1.a.ii – open-pit mining

Emission factors	m^3 CH_4/t	kg/t
CH_4 from extraction	0.016	0.011

Emissions and trend

Table 112: Emissions in category 1.B.1.a.ii – open-pit mining

Gas	Total emissions			Trend		Remark
	1990	2015	2016	Since 1990	With respect to the previous year	
Methane	3.9 kt	2.0 kt	1.9 kt	-51 %	-4 %	The emissions have been decreasing as a result of reductions in lignite production.

3.3.1.2.2 Methods (open-pit mining – lignite)

The emissions from open-pit lignite mining are calculated with the Tier 2 method.

3.3.1.2.3 Uncertainties and time-series consistency (open-pit mining – lignite)

The emission factor used for calculating methane emissions from lignite production is based on maximum methane content levels and thus represents the upper limit of possible methane emissions. It thus already includes possible emissions from transport and storage. Numerous studies have shown that a negative uncertainty of - 33 % must be assumed (DEBRIV / DGMK research report / Forschungsbericht 448-2, DGMK (1992)).

For the emission factor and the activity data, a consistent source is used throughout the entire time series.

3.3.1.2.4 Category-specific quality assurance/control and verification (open-pit mining – lignite)

General and category-specific quality control, and quality assurance in conformance with the requirements of the QSE manual and its associated applicable documents, have been carried out by the Single National Entity. Quality control of the activity data was carried out by the data supplier, on the basis of the supplier's own QMS.

In the framework of verification for the current report, various data sources for activity data in coal mining, and the relevant EF used, were compared with the corresponding sources and EF of other countries (cf. Table 113). A by-country comparison of specific emission factors for open-pit mining shows a broad range, with Germany in the lower part of the range, in a position comparable to that of Poland. The 2011 NIR (p. 103) noted that the Czech Republic uses the average IPCC default factor, in keeping with the fact that the coal mined in that country, in comparison to the coal mined in Poland and Germany, consists to a larger extent of sub-bituminous coal. The degree of coalification (rank) – and, thus, the methane content – of such coal is higher than that of the lignite found in Poland and Germany (sources: NaSE-Workshop (2004), personal communication of DEBRIV (2004)). This conclusion was also reached by a report prepared by VERICO (Betzenbichler et al., 2016).

Table 113: IEF for open-pit lignite mining: Germany as compared with neighbouring countries (NIR 2014)

	Extracted lignite	Reported emissions	IEF
Germany	**185.4 million t**	**2.0 kt**	**0.011 kg/t**
Poland	64.3 million t	0.8 kt	0.012 kg/t
Czech Republic	43.5 million t	33.5 kt	0.770 kg/t
IPCC GL 2006			0.2 – 1.3 kg/t

The IPCC emission factors have been derived from figures for American bituminous coal and thus, according to national experts, cannot be applied to German lignite, which did not exceed a temperature of 50°C during the coalification process. Significant methane releases occur only at temperatures above 80°C (DGMK, 1992).

3.3.1.3 Decommissioned hard-coal mines

Emissions from decommissioned hard-coal mines play a significant role in this sub- source category. As well as active mines, decommissioned hard coal mines represent another relevant source of fugitive CH_4 emissions.

When a hard-coal mine is decommissioned, methane can escape from neighbouring rock, and from coal remaining in the mine, into the mine's network of shafts and passageways. Since the mine is no longer artificially ventilated, the methane collects and can then reach the surface via gas pathways in the overlying rock or via the mine's own shafts and passageways.

Such mine gas was long seen primarily as a negative environmental factor. Recently, increasing attention has been given to the gas' positive characteristics as a fuel (use for energy recovery). In the past, use of mine gas was rarely cost-effective. This situation changed fundamentally in 2000 with the Renewable Energy Sources Act (EEG). Although mine gas is a fossil fuel in finite supply, its use supports climate protection, and thus the gas was included in the EEG. The Act requires network operators to accept, and provide specified compensation for, electricity generated with mine gas and fed into the grid.

3.3.1.4 Solid fuel transformation

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier 2	AS	CS
CO_2	Tier 2	AS	CS
NMVOC	Tier 2	AS	CS
CO	Tier 2	AS	CS
SO_2	Tier 2	AS	CS

The 2006 IPCC Guidelines do not specify this category, and thus no pertinent decision tree is available.

3.3.1.4.1 Category description (solid fuel transformation)

Activity data

Table 114: activity data for processed products [figures in tonnes]

	1990	1995	2000	2005	2010	2015	2016	2017
Lignite briquettes	40,045,000	5,010,829	1,819,263	1,489,922	2,024,103	1,709,000	1,545,000	1,681,000
Lignite granulate	59,000	0	0	0	0	0	0	0
Lignite coke	3,355,937	191,883	179,453	173,443	175,932	170,000	159,000	155,000
Lignite dust	3,791,431	2,700,110	2,678,926	2,923,620	3,632,333	4,398,000	4,247,000	4,440,000
Dried lignite	694,693	569,973	0	0	0	0	0	0
Fluidised-bed lignite	265,000	470,692	560,822	659,906	414,855	450,000	467,000	430,000
Hard-coal briquettes	756,000	379,000	146,000	91,625	0	0	0	0
Hard-coal coke	17,580,000	11,102,000	9,115,000	8,397,000	8,171,000	8,800,000	9,387,000	9,337,983

(Statistik der Kohlenwirtschaft, 2018)

Emission factors

The methane emission factor used for calculation of CH_4 emissions from hard-coal-coke production (coking plants) is 0.049 kg methane per tonne of hard-coal coke (Meiners, 2005). It is used for the entire time series. The CO_2-emission factor is determined on the basis of the conservative assumption that about 1% of the coke is lost, in the form of fugitive emissions, between the time the blast-furnace door is opened and the coke is quenched. The activity data used consists of the total relevant quantities of hard-coal and lignite coke.

The emission factors for the non-greenhouse gases have been obtained from the research project "Emission factors for the iron and steel industry, for purposes of emissions reporting" ("Emissionsfaktoren zur Eisen- und Stahlindustrie für die Emissionsberichterstattung") (Hensmann et al., 2011).

Table 115: Emission factors for the production of hard-coal coke

Gas	Emission factor	Units
CH_4	0.049	kg/t
CO_2	2,777[36]	kg/t
CO	0.015	kg/t
NH_3	243.3	mg/t
NMVOC	0.310	kg/t
SO_2	0.076	kg/t

No methane emissions are to be expected from processing of lignite products, since the EF used for 1.B.1.a.ii corresponds to the gas content of the lignite occurring in Germany. The other identified emissions are based on measurements made by the sole (at present) German producer of lignite coke at the Fortuna-Nord hearth-furnace plant.

36 The emission factor covers the area of production of hard-coal and lignite coke

Small quantities of charcoal are produced in Germany – by one major charcoal-factory operator and in a number of demonstration charcoal kilns. The pertinent quantities are determined by the Federal Statistical Office and are subject to confidentiality requirements. The emission factors were obtained from US_EPA 1995 (Neulicht, 1995). Use of charcoal is reported under 2.G.4.

Emissions and trend

Table 116: Emissions in category 1.B.1.b – solid fuel transformation

Gas	Total emissions			Trend		Remark
	1990	**2015**	**2016**	**Since 1990**	**With respect to the previous year**	
Methane	2.4 kt	2.4 kt	2.2 kt	-8 %	-8 %	The methane emissions are affected primarily by charcoal production. The emissions from coking plants have fallen since 1990, as a result of reductions in coke production.
Carbon dioxide	1,819 kt	701 kt	706 kt	-61 %	1 %	The emissions have fallen since 1990, as a result of reductions on coke production.

CO_2 emissions from charcoal production are considered "biogenic" and are reported within the memo-items section.

3.3.1.4.2 Methodological aspects (solid fuel transformation)

Emissions from hard-coal-coke production have been calculated via the Tier 2 method, in a manner similar to that of the IPCC Reference Manual's equation for CH_4 emissions from coal mining:

$$\text{Emissions [kt } CH_4\text{]} = \text{EF [m}^3\ CH_4\text{ /t]} * AR_{\text{transformation product}} * \text{conversion factor [kt/}10^6\text{m}^3\text{]}$$

3.3.1.4.3 Uncertainties and time-series consistency (solid fuel transformation)

The uncertainties for the emission factors for processing of coal have been estimated by experts as 10% to 25%.

For the activity data, a consistent source is used throughout the entire time series.

3.3.1.4.4 Category-specific quality assurance / control and verification (solid fuel transformation)

General and category-specific quality control, and quality assurance in conformance with the requirements of the QSE manual and its associated applicable documents, have been carried out by the Single National Entity. Quality control of the activity data was carried out by the data supplier, on the basis of the supplier's own QMS.

In consideration of emission factors, the IPCC conversion factor of 0.67 Gg/10^6m^3 at 20°C and 1 atmosphere should be applied to the units used in Germany: normal cubic metres at 1.01325 bar and 0°C (DIN 2004, DIN No. 1343). The German practice of using normal cubic metres should also be noted in consideration of the IPCC default EF, and of figures from other published sources. In use of EF data published in Germany, it is assumed that the relevant figures use normal cubic metres (substantiated via survey of experts at the NaSE-Workshop (2004)).

The guideline figures are oriented to 20°C and 1,013 mbar. In keeping with methane's isobaric proportionality, the factor 1.07 can be used to convert Nm^3 into m^3.

Conversion factor, normal cubic metres ⇔ kilogrammes:

0.717 Nm^3/kg (1.01325 bar, 0°C) **= 0.67 Gg/10^6m^3** (20°C, 1 atmosphere) *** 1.07 Nm^3/m^3**

No comparisons with the corresponding data of other countries are possible in this category, since the pertinent CRF tables do not yield the required precise quantities and compositions of the transformed coal products involved. What is more, the IPCC Guidelines provide neither methods nor default emission factors for such a comparison in this category.

3.3.1.5 Category-specific recalculations (1.B.1 all)

Otherwise, no recalculations were required.

3.3.1.6 Planned improvements, category-specific (1.B.1 all)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

3.3.2 Oil and natural gas and fugitive emissions from energy production (1.B.2)

This category is subdivided as follows:

Source category				Included emissions
1.B.2. Oil, natural gas and fugitive emissions from energy production				
	a	**Oil**		
		i)	**Exploration**	Total emissions from exploratory drilling for oil and gas
		ii)	**Production**	Fugitive emissions from oil production and from oil processing (separation of water and accompanying gases)
		iii)	**Transport**	Emissions from transport of crude oil via pipelines and inland-waterway tankers
		iv)	**Refining / storage**	Emissions from oil desulphurisation and refining, from storage of crude oil and of petroleum products and from cleaning of storage tanks
		v)	**Distribution of oil products**	Emissions from distribution of petroleum products, from refuelling processes and drip losses and from cleaning of tanks of transport vehicles
		vi)	**Other**	No emissions in this category
	b	**Gas**		
		i)	**Exploration**	The emissions are assigned to category 1.B.2.a.i, since no differentiation is possible
		ii)	**Production**	Fugitive emissions from natural gas production
		iii)	**Processing**	Emissions from desulphurisation and processing of sour gas and from processing of town gas
		iv)	**Transport**	Emissions from long-distance high-pressure pipelines and from underground gas storage (caverns and porous-rock reservoirs)
		v)	**Distribution**	Emissions from natural-gas distribution lines, and from above-ground storage facilities, and fugitive leaks from tanks of vehicles for natural-gas transport
		vi)	**Other**	Fugitive emissions from installations in the residential, institutional and commercial (small consumers) and industry sectors

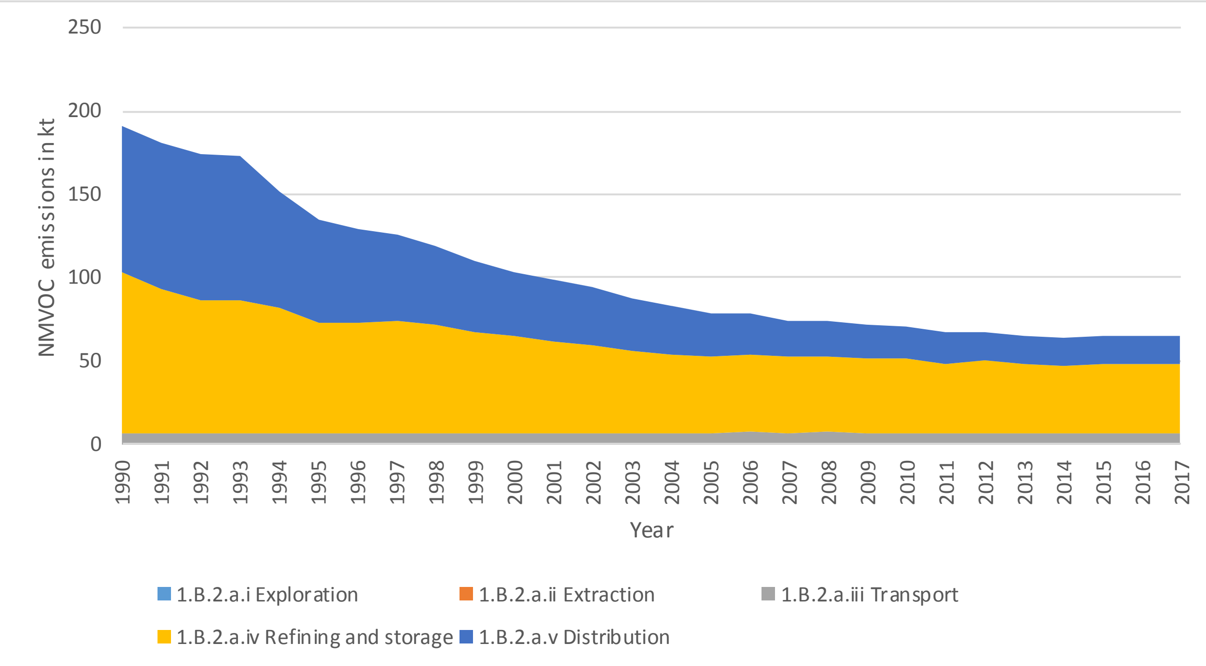
Source category				Included emissions
	c	Venting and flaring		
		i) Venting		
			Oil	The emissions are included in the categories 1.B.2.a.iii and 1.B.2.a.v
			Gas	The emissions are included in the categories 1.B.2.b.iv and 1.B.2.b.v
			Combined	No emissions in this category
		ii) Flaring		
			Oil	Flaring emissions related to oil production and refining
			Gas	Flaring emissions related to natural gas production and to processing of sour gas
			Combined	No emissions in this category
	d	Other		
		i) Geothermal energy		No fugitive CO_2, CH_4 or N_2O emissions occur in ongoing operations. Fugitive F-gas emissions are assigned to the category 2.F.9
1.C CO_2 – transport and storage				No emissions are being reported at present in this category, since no CCS measures are currently taking place in Germany.

3.3.2.1 Oil (1.B.2.a)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
-/-	1.B.2.a Fugitive Emissions from Fuels: Oil	Liquid fuels	CH_4	404.31	0.03%	217.40	0.02%	-46.2%
-/-	1.B.2.a Fugitive Emissions from Fuels: Oil	Liquid fuels	CO_2	282.70	0.02%	309.78	0.03%	9.6%

The category 1.B.2.a. "Oil" is not a key category.

Figure 42: NMVOC emissions in category 1.B.2.a



3.3.2.1.1 "Oil, Exploration" (1.B.2.a.i)

Gas	Method used	Source for the activity data	Emission factors used
CO_2, CH_4	Tier 1	AS	D
NMVOC	Tier 2	AS	CS

3.3.2.1.1.1 Category description, "Oil, exploration" (1.B.2.a.i)

This category's emissions consist of emissions from activities of drilling companies and of other participants in the exploration sector. Gas and oil exploration takes place in Germany. The pertinent statistics do not differentiate between drilling solely for oil and drilling solely for natural gas.

Activity data

Table 117: Number of exploratory wells (sum total for oil and natural gas)

1990	1995	2000	2005	2010	2015	2016	2017
12	17	15	23	16	18	20	30

(BVEG, 2018)

Table 118: Total length of all exploratory wells, in m (sum total for oil and natural gas)

1990	1995	2000	2005	2010	2015	2016	2017
50,140	109,187	41,378	63,994	51,411	32,773	37,127	32,301

(BVEG, 2018)

Emission factors

Table 119: Emission factors used for category 1.B.2.a.i

Gas	Emission factor	Method	source
CO_2	0.48 kg / No	Tier 1	IPCC GPG 2000
CH_4	64 kg / No	Tier 1	IPCC GPG 2000
NMVOC	576 kg / No	Tier 2	Expert estimate

The emission factors given in IPCC GL 2006 (Table 4.2.4) refer to production quantities and not to exploratory wells. Therefore, those factors cannot be used in the present context.

Emissions and trend

Table 120: Emissions in category 1.B.2.a.i

Gas	Total emissions			Trend		Remark
	1990	2016	2017	Since 1990	With respect to the previous year	
Methane	768 kg	1,280 kg	1,920 kg	250 %	50 %	The emissions have increased with respect to their level in 1990, as a result of increased drilling.
Carbon dioxide	5.76 kg	9.60 kg	14.40 kg	250 %	50 %	
NMVOC	6,912 kg	11,520 kg	17,280 kg	250 %	50 %	

3.3.2.1.1.2 Methodological aspects of the category "Oil, exploration" (1.B.2.a.i)

According to the WEG, virtually no fugitive emissions occur in connection with drilling operations, since relevant measurements are regularly carried out at well sites (with use of methane sensors in wellhead-protection structures, ultrasound measurements and annulus manometers), and since old / decommissioned wells are backfilled and normally covered with concrete caps.

Since pertinent measurements are not available for the individual wells involved, a conservative approach is used whereby well emissions are calculated on the basis of the default factor pursuant to IPCC GPG 2000 (Penman et al., 2000) for carbon dioxide and methane, using the Tier 1 method.

3.3.2.1.1.3 Uncertainties and time-series consistency, category "Oil, exploration" (1.B.2.a.i)

The uncertainties in the activity data for oil and gas exploration have been quantified as +/- 5 %. The emission factors are assigned the default uncertainties from the Good Practice Guidance 2000, +/- 25 %.

For the activity data and the emission factors, a consistent source is used throughout the entire time series.

3.3.2.1.1.4 Category-specific quality assurance / control and verification, category "Oil, exploration" (1.B.2.a.i)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

Due to a lack of country-specific data, an external assessment (Bender, 2009b) was commissioned. In its source-category analysis, that assessment found that the default factors are applicable to Germany. It was not possible to carry out a comparison with the results for other countries, because the relevant data lack basic comparability – for example, they use a range of units that are not mutually convertible.

3.3.2.1.2 "Oil, production and preprocessing" (1.B.2.a.ii)

Gas	Method used	Source for the activity data	Emission factors used
CO_2, CH_4	Tier 2	AS	CS
NMVOC	Tier 2	AS	CS

3.3.2.1.2.1 Category description, "Oil, production and preprocessing" (1.B.2.a.ii)

This category's emissions are produced in the petroleum industry's extraction (crude oil) and pre-treatment of raw materials (petroleum). Because Germany's oil fields are old, oil production in Germany is highly energy-intensive (thermal extraction, operation of pumps to inject water into oil-bearing layers).

The first treatment that extracted petroleum (crude oil) undergoes in processing facilities serves the purposes of removing gases, water and salt from the oil. Crude oil in the form in which it appears at wellheads contains impurities, gases and water, and thus does not conform to requirements for safe, easy transport in pipelines. No substance transformations take place. Impurities – especially gases (petroleum gas), salts and water – are removed, in order to yield crude oil of suitable quality for transport in pipelines.

Activity data

Table 121: Extracted quantity of petroleum, in kt

1990	1995	2000	2005	2010	2015	2016	2017
3,606	2,959	3,113	3,573	2,516	2,414	2,357	2,217

(BVEG, 2018)

Emission factors

Table 122: Emission factors used for production and processing

Gas	Emission factor	Method	source
CO_2	98.7 g/m³	Tier 2	Expert estimate
CH_4	118.0 g/m³	Tier 2	Expert estimate
NMVOC	19.5 g/m³	Tier 2	Expert estimate

Emissions and trend

Table 123: Emissions in category 1.B.2.a.ii

Gas	Total emissions			Trend		Remark
	1990	2016	2017	Since 1990	With respect to the previous year	
Methane	1,081 t	48 t	30 t	-93 %	-38 %	The emissions have decreased with respect to 1990, as a result of decreasing production and improved emissions-reduction technologies in the areas of production and processing.
Carbon dioxide	460 t	254 t	254 t	-45 %	0 %	
NMVOC	108 t	71 t	50 t	-54 %	-30 %	

3.3.2.1.2.2 Methodological aspects of the category "Oil, production and preprocessing" (1.B.2.a.ii)

The emissions from production and processing are measured, or calculated, by the operators, and the pertinent data are published in the annual reports of the Federal association of the natural gas, oil and geothermal energy industries (BVEG). The emission factors are determined from the reported emissions and the activity data shown in Table 121.

The emissions are calculated in keeping with the Tier 2 method.

3.3.2.1.2.3 Uncertainties and time-series consistency in the category "Oil, production and preprocessing" (1.B.2.a.ii)

In this category, the uncertainty for the activity data is given as 5 to 10 %. The figures are based on estimates of BVEG experts and national experts.

The uncertainties for the emission factors in the category amount to 25 %.

3.3.2.1.2.4 Category-specific quality assurance / control and verification for the category "Oil, production and preprocessing" (1.B.2.a.ii)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The emission factors that have been used are of the same order of magnitude as those given in the 2006 IPCC Guidelines (IPCC, 2006).

Table 124: Comparison of IEF with the relevant IPCC default values

Gas	CS emission factor used	IPCC GL 2006 (Table 4.2.4)	
	Units in [g/m³]	Units in [Gg/1000m³]	Units in [g/m³]
CO_2	98.7 g/m³	$1.1*10^{-07}$ to $2.6*10^{-04}$	0.11– 260.00
CH_4	118.0 g/m³	$1.5*10^{-06}$ to $6.0*10^{-02}$	1.50– 60,000
NMVOC	19.5 g/m³	$1.8*10^{-06}$ to $4.5*10^{-03}$	1.80– 4500.0

3.3.2.1.3 "Oil, transport" (1.B.2.a.iii)

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier 2	AS	CS
NMVOC	Tier 2	AS	CS

3.3.2.1.3.1 Category description, "Oil, transport" (1.B.2.a.iii)

This category's emissions are tied to activities of logistics companies and of operators of pipelines and pipeline networks. Following first treatment, crude oil is transported to refineries.

Almost all transports of crude oil take place via pipelines. Pipelines are stationary and, normally, run underground. In contrast to other types of transports, petroleum transports are not interrupted by handling processes.

Activity data

Table 125: Transports of domestically produced crude oil, in kt

1990	1995	2000	2005	2010	2015	2016	2017
3,606	2,959	3,113	3,573	2,516	2,414	2,357	2,217

(BVEG, 2018)

Table 126: Transports of imported crude oil, in kt

1990	1995	2000	2005	2010	2015	2016	2017
84,043	86,063	89,280	97,474	93,270	91,275	91,244	90,743

(BAFA, 2018b; BVEG, 2018)

Table 127: Crude-oil transports via inland-waterway tankers, in kt

1990	1995	2000	2005	2010	2015	2016	2017
88.9	66.6	111.8	176.4	5.6	43.1	75	50.7

(Statistisches Bundesamt (FS 8, R 4), Table 2.1, line for petroleum), for 2017: DESTATIS (2018)

Emission factors

Table 128: Activity data and emission factors used for category 1.B.2.a.iii, "Transport of crude oil"

Category	Activity data	Units	Gas	Emission factor (EF)	Units
Transports of imported crude oil	90.743	Millions of t/a	NMVOC	0.0064	kg/t
			CH_4	0.0064	
Transports of domestically produced crude oil	2.22		NMVOC	0.13	
			CH4	0.013	

Emissions and trend

Table 129: Emissions in category 1.B.2.a.iii

Gas	Total emissions			Trend		Remark
	1990	2016	2017	Since 1990	With respect to the previous year	
NMVOC	5,885 t	6,171 t	6,113 t	4 %	-1 %	The increasing trend is driven primarily by increases in the quantities of transported oil.
CH_4	588 t	617 t	611 t	4 %	-1%	

3.3.2.1.3.2 Methodological aspects of the category "Oil, transport" (1.B.2.a.iii)

The emissions are calculated in keeping with the Tier 2 method.

For pipelines, the emission factor for methane has been taken from the 2006 IPCC Guidelines (IPCC, 2006), while for inland-waterway tankers that factor has been estimated by experts. The pertinent emission factors have been confirmed by the research project "Determination of emission factors and activity data in areas 1.B.2.a.i through vi" ("Ermittlung von Emissionsfaktoren und Aktivitätsraten im Bereich 1.B.2.a.i bis vi" (Theloke et al., 2013)). Since long-distance pipelines are continually monitored, and since disruptive incidents in such pipelines are very rare (CONCAWE – "Performance of European cross country oil pipelines" (Cech et al., 2017)), emissions occur – in small quantities – only at their transfer points. The emission factor is thus highly conservative.

The emission factor covers the areas of transfer / injection into pipelines at pumping stations, all infrastructure (connections, control units, measuring devices) along pipelines and transfer at refineries, and it has been determined on the basis of conservative assumptions. For imported quantities, only one transfer point (only the withdrawal station) is assumed, since the station for input into the pipeline network does not lie on Germany's national territory.

3.3.2.1.3.3 Uncertainties and time-series consistency in the category "Oil, transport" (1.B.2.a.iii)

The uncertainties for the emission factors have been quantified as +/- 20 %, while those for the activity data have been determined to be +/- 10 %. The emission factors and the activity data are consistent throughout the entire time series.

3.3.2.1.3.4 Category-specific quality assurance / control and verification for the category "Oil, transport" (1.B.2.a.iii)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The emission factors that have been used are of the same order of magnitude as those given in the 2006 IPCC Guidelines.

In the 2016 ESD Review, it was noted that Germany reports no CO_2 emissions in this category, although the 2006 IPCC Guidelines give a pertinent Tier 1 default value. In a telephone conversation involving experts of the Federal Environment Agency and experts of the Association of the German Petroleum Industry (MWV) (Bittkau, 2017), the MWV experts confirmed that no CO_2 emissions from transport pipelines occur.

Table 130: Comparison of IEF with the relevant IPCC default values

Gas	CS emission factor used	IPCC GL 2006 (Table 4.2.4)	
	Units in [g/m³]	Units in [Gg/1000m³]	Units in [g/m³]
CH_4	6 g/m³	$5.4*10^{-06}$	5.4
NMVOC	55 g/m³	$5.4*10^{-05}$	54.0

3.3.2.1.4 "Oil, refining and storage" (1.B.2.a.iv)

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 2	AS	CS
CH_4	Tier 2	AS	CS
SO_2	Tier 2	AS	CS
CO	Tier 2	AS	CS
NO_x	Tier 2	AS	CS
NMVOC	Tier 2	AS	CS

3.3.2.1.4.1 Category description, "Oil, refining and storage" (1.B.2.a.iv)

This category's emissions consist of emissions from activities of refineries and of refining companies in the petroleum industry. Crude oil and intermediate petroleum products are processed in Germany. For the most part, the companies concerned receive crude oil for refining and processing. Such processing takes place in state-of-the-art plants.

Refinery tank storage systems are used to store both crude oil and intermediate and finished petroleum products. They thus differ from non-refinery tank storage systems in terms of both the products they store and the quantities they handle. Tank-storage facilities outside of refineries are used especially for interim storage of heating oil, gasoline and diesel fuel.

Tanks are emptied and cleaned for purposes of tank inspections and repairs. In tank cleaning, a distinction is made between crude-oil tanks and product tanks. Because of the sediment deposits involved, cleaning of crude-oil tanks, in comparison to cleaning of product tanks, is a considerably more involved process. Product tanks contain no sedimentable substances and thus are cleaned only when the products they contain are changed. In keeping with an assessment of Bender (2009a), the emission factors for storage of crude oil and of petroleum products may be assumed to take cleaning processes into account.

Activity data

Table 131: Quantity of crude oil refined, in kt

1990	1995	2000	2005	2010	2015	2016	2017
107,058	96,475	107,632	114,589	95,378	93,391	94,220	93,104

(MWV, 2018)

Table 132: Capacity utilisation in refineries, in percent

1990	1995	2000	2005	2010	2015	2016	2017
106.2	92.1	95.3	99.5	81.1	91	92.3	91.1

(MWV, 2018)

Table 133: Crude-oil-refining capacity in refineries, in kt

1990	1995	2000	2005	2010	2015	2016	2017
100,765	104,750	112,940	115,630	117,630	103,080	102,055	102,155

(MWV, 2018)

Table 134: Tank-storage capacity in refineries and pipeline terminals, in millions of m^3

1990	1995	2000	2005	2010	2015	2016	2017
27.2	28.4	24.9	24.0	22.5	22.1	20.9	20.9

(BAFA, 2018a)

Table 135: Storage capacity of tank-storage facilities outside of refineries, in millions of m^3

1990	1995	2000	2005	2010	2015	2016	2017
41.9	41.2	46.0	44.2	43.2	40.8	41.1	41.1

(BAFA, 2018a)

Emission factors

Table 136: Emission factors used for category 1.B.2.a.vi, "Fugitive emissions at refineries"

Gas	Emission factor	Method	source
CH_4	0.647 g/t	Tier 2	Expert estimate
CO	0.598 g/t	Tier 2	Expert estimate
CO_2	594.001 g/t	Tier 2	Expert estimate
SO_2	0.439 g/t	Tier 2	Expert estimate
NMVOC	24.647 g/t	Tier 2	Expert estimate
NO_x	0.001 g/t	Tier 2	Expert estimate

Table 137: Emission factor used for category 1.B.2.a.vi, "Anode production at refineries"

Gas	Emission factor	Method	source
CO_2	202.4 kg/t	Tier 2	Expert estimate

Table 138: Emission factors used for category 1.B.2.a.vi, "Storage and cleaning of crude oil in tank-storage facilities of refineries"

Gas	Emission factor	Method	source
CH_4	0.016 kg/t	Tier 2	Expert estimate
NMVOC	0.144 kg/t	Tier 2	Expert estimate

Table 139: Emission factors used for category 1.B.2.a.vi, "Storage of liquid petroleum products in tank-storage facilities outside of refineries"

Gas	Emission factor	Method	source
CH_4	5 g/m³	Tier 2	Expert estimate
NMVOC	100 g/m³	Tier 2	Expert estimate

Table 140: Emission factors used for category 1.B.2.a.vi, "Storage of gaseous petroleum products in tank-storage facilities outside of refineries"

Gas	Emission factor	Method	source
CH_4	150 g/m³	Tier 2	Expert estimate
NMVOC	500 g/m³	Tier 2	Expert estimate

Emissions and trend

Table 141: Emissions in category 1.B.2.a.iv

Gas	Total emissions			Trend		Remark
	1990	2016	2017	Since 1990	With respect to the previous year	
Carbon dioxide	282,240 t	249,046 t	309,527 t	10 %	-21 %	The trend for CO_2 is influenced by calcining and anode production. The falling trend for methane and NMVOC is driven by improved emissions-reduction technologies in refineries and in storage of refinery products.
Methane	14,502 t	8,057 t	8,052 t	- 44 %	0 %	
NMVOC	97,183 t	41,651 t	41,616 t	- 57 %	0 %	

3.3.2.1.4.2 Methodological aspects of the category "Oil, refining and storage" (1.B.2.a.iv)

The emissions for all sub-areas are calculated in keeping with the Tier 2 method.

Refining

The emission factors used for NMVOC, CH_4, CO_2, CO, NO_x and SO_2 were obtained from evaluations, carried out by Theloke et. al. (2013), of the 2004 and 2008 emissions declarations.

Anode production

The activity data are calculated from the relevant quantity of petroleum coke, minus the own consumption (coke burn-off in catalyst regeneration – cf. 1.A.1.b). The data have been obtained from the Official Mineral Oil Statistics. This "green coke" is processed via calcining. The emission factor is calculated from the pertinent activity data and from the emissions data of the EU Emissions Trading System (ETS).

Tank-storage facilities in refineries

In keeping with the results of the research project "Processing of data of emissions declarations pursuant to the 11th Ordinance Implementing the Federal Immission Control Act – the area of storage facilities" ("Aufbereitung von Daten der Emissionserklärungen gemäß 11. BImSchV - Bereich Lageranlagen") (Bender, 2009a), the crude-oil-distillation capacity is used as the activity data for estimation of emissions from storage in refineries. The fugitive-VOC-emissions value specified in VDI Guideline 2440 (VDI, 2000), 0.16 kg/t, may be used as the emission factor. The EF for methane was derived from it (5-10 % of 0.16 kg) and then suitably deducted.

Tank-storage facilities outside of refineries

According to Müller-BBM (Bender, 2009a), no emission factors can be derived, via evaluation of emissions declarations for storage systems, that would be representative of individual systems. This is due, so the same source, to the clearly widely differing emissions behaviour of different individual systems. It was possible, however, to form aggregated emission factors. For each relevant group of data, this was done by correlating the sums of all emissions with the sums of all capacities. For non-refinery tank-storage systems, storage of liquid petroleum products can be differentiated from storage of gaseous petroleum products, since the relevant data are suitably differentiated.

3.3.2.1.4.3 Uncertainties and time-series consistency in the category "Oil, refining and storage" (1.B.2.a.iv)

Uncertainties of +/- 20 % are assumed for the emission factors for refining of crude oil. The uncertainties for the activity data are assumed to be +/- 10 %. The total uncertainties for the emissions from the area of storage and cleaning are estimated at +/- 40 %. These figures are based on estimates of national experts, and on the research report of Müller-BBM (Bender, 2009a) and Theloke et al. (2013).

The emission factors and the activity data are consistent throughout the entire time series.

3.3.2.1.4.4 Category-specific quality assurance / control and verification for the category "Oil, refining and storage" (1.B.2.a.iv)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

Due to the complexity of the category, the data cannot be cross-checked against those of other countries. This was also confirmed at the 2014 EU Workshop (Harthan et al., 2017). To permit comparison with the IPCC Guidelines, only the factors for refining and crude oil storage were summed. It was not possible to take the emissions from anode production and from storage of refinery products into account, since the default value does not include those processes.

Table 142: Comparison of IEF with the relevant IPCC default values

Source	Gas	CS emission factor used	IPCC GL 2006 (Table 4.2.4)	
		Units in [g/m³]	Units in [Gg/1000m³]	Units in [g/m³]
Storage	CH_4	13.8		
Refining	CH_4	0.56		
Total	**CH_4**	**14.4**	**$2.6*10^{-06}$ - $41.0*10^{-06}$**	**2.6 – 41.0**
Storage	NMVOC	124.1		
Refining	NMVOC	21.5		
Total	**NMVOC**	**145.6**	**0.0013**	**1,300**

The emission factor for methane lies within the range of the default value given in the IPCC Guidelines. While the factor for NMVOC is an order of magnitude lower, the relevant default value has an uncertainty of +/- 100%. The factor in the EMEP Guidebook (Table 3-1) (EMEP, 2016) is 0.2 kg/t, which corresponds to 172 g/m^3 and thus is of the same order of magnitude as the German emission factor.

3.3.2.1.5 "Oil, distribution of oil products" (1.B.2.a.v)

Gas	Method used	Source for the activity data	Emission factors used
NMVOC	Tier 2	AS	CS

3.3.2.1.5.1 Category description, "Oil, distribution of oil products" (1.B.2.a.v)

The category comprises transports and handling of petroleum products, via inland-waterway tankers, pipelines, railway tank cars and road tankers, as well as cleaning of transport vehicles.

Activity data

Table 143: Service stations in Germany (number)

1990	1995	2000	2005	2010	2015	2016	2017
19,317	17,957	16,324	15,187	14,744	14,531	14,510	14,478

(MWV, 2018)

Table 144: Distributed quantities of petroleum products, in kt

	1990	1995	2000	2005	2010	2015	2016	2017
Diesel fuel	21,817	26,208	28,922	28,531	32,128	36,756	37,901	38,703
Jet fuel	4,584	5,455	6,939	8,049	8,465	8,550	9,189	9,978
Light heating oil	31,803	34,785	27,875	25,380	21,005	16,127	15,812	15,836
Gasoline	31,257	30,333	28,833	23,431	19,634	18,226	18,238	18,296

(MWV, 2018)

Table 145: Petroleum transports via inland-waterway tankers, in kt

1990	1995	2000	2005	2010	2015	2016	2017
3,000	3,000	3,000	2,783	6,358	4,756	5,241	5,784

(DESTATIS, 2018) Data prior to 2001 are from UBA estimates

Emission factors

The emission factors listed below have been verified by the study (Theloke et al., 2013). The model used for calculation of gasoline emissions is described in Chapter 3.3.2.1.5.2.

Petroleum products are transported by inland-waterway tanker ships, product pipelines, railway tank cars and road tankers, and they are transferred from tanks to other tanks. Experts consider the emissions from refueling of aircraft to be non-existent, since the equipment used for such refueling is fitted with dry couplings. The emissions from filling of private heating-oil tanks are also very low, thanks to high safety standards.

In this category, petroleum products are handled and distributed that have undergone fractional distillation in refineries, i.e. processes in which gaseous products are separated out. For this reason, no significant methane emissions are expected. Only in storage of certain petroleum products can small quantities of methane escape.

Table 146: NMVOC emission factors used for category 1.B.2.a.v "Distribution of gasoline“

Process responsible for emissions	Emission factor [kg/t]	Method	Source
Drip losses in refuelling at filling stations	0.117 kg/t	Tier 2	Expert estimate
Transfers from road tankers to filling stations (20th Ordinance Implementing the Federal Immission Control Act – vapour displacement)	1.4[37] kg/t	M (Tier 2)	Expert estimate
Ventilation in connection with transports with inland-waterway tankers	0.025 kg/t	Tier 2	Expert estimate
Transfers from filling station tanks to vehicle tanks (21st Ordinance Implementing the Federal Immission Control Act – vapour recovery)	1.4 kg/t	M (Tier 2)	Expert estimate

Table 147: NMVOC emission factors used for category 1.B.2.a.v "Distribution of diesel fuels"

Process responsible for emissions	Emission factor [kg/t]	Method	Source
Drip losses in refuelling at filling stations	0.1 kg/t	Tier 2	Expert estimate
Transports from refineries to transport vehicles	0.008 kg/t	Tier 2	Expert estimate
Transfers from service station tanks to vehicle tanks	0.003 kg/t	Tier 2	Expert estimate

37 The factor does not include reduction measures – cf. Table 151

Table 148: NMVOC emission factors used for category 1.B.2.a.v "Distribution of light heating oil"

Process responsible for emissions	Emission factor [kg/t]	Method	Source
Drip losses in refuelling at transfer stations	0.0011 kg/t	Tier 2	Expert estimate
Transports from refineries to transport vehicles	0.0053 kg/t	Tier 2	Expert estimate
Transfers from service station tanks to vehicle tanks	0.0063 kg/t	Tier 2	Expert estimate

Table 149: NMVOC emission factors used for category 1.B.2.a.v "Distribution of jet fuels"

Process responsible for emissions	Emission factor [kg/t]	Method	Source
Drip losses in refuelling at transfer stations	0 kg/t	Tier 2	Expert estimate
Transports from refineries to transport vehicles	0.055 kg/t	Tier 2	Expert estimate
Transfers from service station tanks to vehicle tanks	0.02 kg/t	Tier 2	Expert estimate

Emissions and trend

Table 150: Emissions in category 1.B.2.a.v

Gas	Total emissions			Trend		Remark
	1990	2016	2017	Since 1990	With respect to the previous year	
NMVOC	87.8 kt	17.1 kt	17.2 kt	- 80 %	1 %	The emissions decreases are due primarily to the introduction of the 20th and 21st Ordinances Implementing the Federal Immission Control Act (BImSchV), which phased in requirements for vapour-balancing and vapour-recovery systems.

3.3.2.1.5.2 Methodological aspects of the category "Oil, distribution of oil products" (1.B.2.a.v)

Transport

Inland-waterway tankers that transport gasoline retain considerable quantities of gasoline vapours in their tanks after their gasoline has been unloaded. When the ships change loads or spend time in port, their tanks have to be ventilated. With such ships averaging 277 instances of ventilation per year, the quantity of NMVOC emitted in such operations amounts to 336 - 650 t (S. Bauer; Dr. A. Polcher, 2010). The highest value in the range is used for calculation of the relevant emissions.

About 13 million m^3 of gasoline fuels are transported annually in Germany via ***railway tank cars***. Transfer/handling (filling/unloading) and tank losses result in annual emissions of only 1,400 t VOC (Joas; et al., 2004). The emissions situation points to the high technical standards that have been attained in railway tank cars and pertinent handling facilities.

Filling stations

Significant quantities of fugitive VOC emissions are released into the environment during transfers from tanker vehicles to storage facilities and during refuelling of vehicles. For emissions determination, a standardised emission factor of 1.4 kg/t is used. This refers to the saturation concentration for hydrocarbon vapours – and, thus, corresponds to the maximum possible emissions level in the absence of reduction measures.

The immission-control regulations issued in 1992 and 1993 (20. BImSchV, 2017; 21. BImSchV, 2017) that required filling stations to limit such emissions promoted a range of reduction measures. The relevant reductions affect both the area of transfer and storage of gasoline (20. BImSchV, 2017) and the area of fuelling of vehicles, with gasoline, at filling stations (21. BImSchV).

Use of required emissions-control equipment, such as vapour-balancing (20th BImSchV) and vapour-recovery (21st BImSchV) systems, along with use of automatic monitoring systems (via the amendment of the 21st BImSchV on 6 May 2002), have brought about continual reductions of

VOC emissions; the relevant high levels of use of such equipment are shown in the table below (Table 151).

In emissions calculation, the two ordinances' degrees of application to the service stations in service, and their efficiencies, are taken into account. The following assumptions, based on the technical options currently available, are applied:

Table 151: Effectiveness of the 20th and 21st Ordinances Implementing the Federal Immission Control Act (BImSchV), and their resulting effects on service stations

Ordinance		Factor	
20th BImSchV	Vapour balancing	Level of use	98 %
		Efficiency	98 %
21. BImSchV	Vapour recovery	Level of use	98 %
		Efficiency	85 %

The emissions are calculated with the following formula:

Emissions = activity data * unreduced emission factor (from Table 146) * (level of use * (1 - efficiency) + (1 - level of use))

In addition, permeation of hydrocarbons occurs in tank hoses. The DIN EN 1360 standard sets a limit of 12 ml / hose meter per day for such permeation. From analysis of measurements, UBA experts have adopted a conservative factor of 10ml/m per day. That factor is used to determine the NMVOC emissions. The calculation is carried out in accordance with the pertinent formula of the University of Stuttgart's Institute for Machine Components (Haas, 2015):

Number of service stations * number of fuel pumps per service station * number of hoses per fuel pump * hose length * emission factor.

Cleaning of transport vehicles

Tank interiors are cleaned prior to tank repairs, prior to safety inspections, in connection with product changes and with lease changes.

The inventory currently covers cleaning of railway tank cars. The residual amounts remaining in railway tank cars' tanks after the tanks have been emptied – normally, between 0 and 30 litres (up to several hundred litres in exceptional cases) – are not normally able to evaporate completely. They thus produce emissions when the insides of tanks are cleaned.

Each year, some 2,500 cleaning operations are carried out on railway tank cars that transport gasoline. The emissions released, via exhaust air, in connection with cleaning of tank cars' interiors amount to about 40,000 kg/a VOC (Joas; et al., 2004), p. 34.

Any additional prevention and reduction measures could affect emissions in this category only slightly. At the same time, emissions can be somewhat further reduced from their current levels via a combination of various technical and organizational measures. Emissions during handling – for example, during transfer to railway tank cars – are produced especially by residual amounts of gasoline that remain after tanks have been emptied. Such left-over quantities in tanks can release emissions via manholes the next time the tanks are filled. Study is thus underway to determine the extent to which "best practice" is being followed at all handling stations, and whether this extent has to be taken into account in emissions determination. In addition, improvements of fill nozzles enhance efficiency in prevention of VOC emissions during refueling.

Pursuant to the UBA text (Joas; et al., 2004), a total of 1/3 of all relevant transports are carried out with railway tank cars. The remaining 2/3 of all transports are carried out by other means – primarily with road tankers.

The 1/3 to 2/3 relationship given by the report is assumed to be also applicable to the emissions occurring in connection with cleaning. Currently, the inventory includes 36,000 kg of NMVOC emissions from cleaning of railway tank cars. Emissions from cleaning of other transport equipment – primarily road tankers – are derived from that figure; they amount to about 70,000 kg NMVOC.

More thorough emissions collection upon opening of manholes of railway tank cars (a volume of about 14.6 m^3 escapes), along with more thorough treatment of exhaust from cleaning of tanks' interiors, could further reduce VOC emissions. Exhaust cleansing is assumed to be carried out via one-stage active-charcoal adsorption. For an initial load of 1 kg/m^3, exhaust concentration levels can be reduced by 99.5 %, to less than 5 g/m^3. As a result, the remaining emissions amount to only 1.1 t. This is equivalent to a reduction of about 97 % from the determined level of 36.5 t/a (without adsorption) (Joas; et al. (2004): p. 34).

3.3.2.1.5.3 Uncertainties and time-series consistency in the category "Oil, distribution of oil products" (1.B.2.a.v)

The uncertainties in the category are quantified as follows: for the emission factors data, +/- 20% (95 % confidence interval, normal distribution); for the activity data, +/- 5% (Theloke et al., 2013).

3.3.2.1.5.4 Category-specific quality assurance / control and verification for the category "Oil, distribution of oil products" (1.B.2.a.v)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

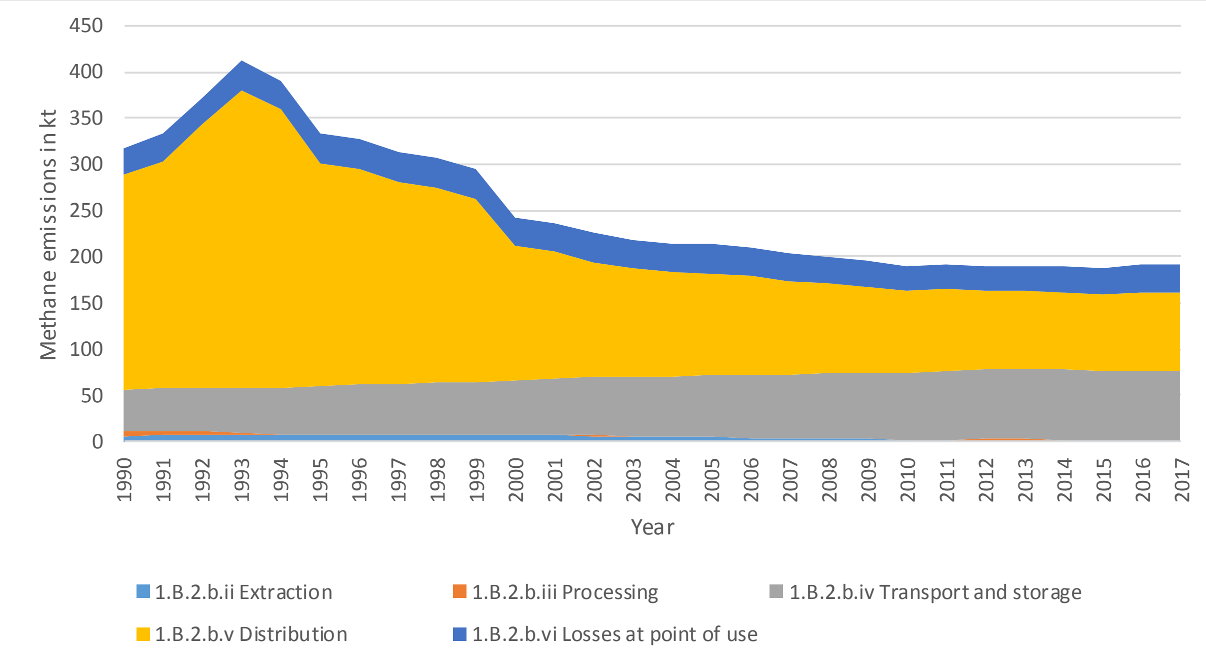
The data cannot be compared with those of other countries, since the CRF tables do not indicate what factors influenced the reported emissions. What is more, in the 2013 submission only Spain and Sweden reported NMVOC emissions in this category. With regard to methane emissions, IEF can be derived only for Iceland and Croatia. No cross-checking against the 2006 IPCC Guidelines is possible, since those Guidelines do not list any default factors.

3.3.2.2 Natural gas (1.B.2.b)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
L/T	**1.B.2.b Fugitive Emissions from Fuels: Natural gas**	**Gaseous fuels**	**CH_4**	**7,939.92**	**0.65%**	**4,790.60**	**0.54%**	**-39.7%**
-/-	1.B.2.b Fugitive Emissions from Fuels: Natural gas	Gaseous fuels	CO_2	1,407.72	0.12%	1,020.10	0.11%	-27.5%

The category 1.B.2.b "Natural gas" is a key category of CH_4 emissions in terms of emissions level and trend.

Figure 43: Development of methane emissions in category 1.B.2.b since 1990



3.3.2.2.1 "Natural gas, exploration" (1.B.2.b.i)

Gas	Method used	Source for the activity data	Emission factors used
CH_4	IE	IE	IE
NMVOC	IE	IE	IE

3.3.2.2.1.1 Category description, "Natural gas, exploration" (1.B.2.b.i)

Category 1.B.2.b.i is considered together with category 1.B.2.a.i (Oil, exploration). Consequently, the aggregated, non-subdivided data of 1.B.2.b.i are included in category 1.B.2.a.i.

3.3.2.2.1.2 Methodological aspects of the category "Natural gas, exploration" (1.B.2.b.i)

The possibility of breaking exploration down into oil exploration and natural gas exploration was reviewed (Herold et al., 2014), but then abandoned due to a lack of statistics and to the very small emissions quantities involved. The emissions are thus listed completely, for both oil exploration and gas exploration, under 1.B.2.a.i.

3.3.2.2.1.3 Uncertainties and time-series consistency of the category "Natural gas, exploration" (1.B.2.b.i)

See 1.B.2.a.i for explanations of uncertainties and time-series consistency.

3.3.2.2.1.4 Category-specific quality assurance / control and verification, category "Natural gas, exploration" (1.B.2.b.i)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity. See 1.B.2.a.i for an explanation of the verification procedure.

3.3.2.2.2 "Natural gas, production" (1.B.2.b.ii)

Gas	Method used	Source for the activity data	Emission factors used
CO_2, CH_4	Tier 2	AS	CS
NMVOC	Tier 2	AS	CS

3.3.2.2.2.1 Category description, "Natural gas, production" (1.B.2.b.ii)

The emissions of this category consist of emissions related to production.

Activity data

Table 152: Extracted quantity of natural gas, in billions of m³

1990	1995	2000	2005	2010	2015	2016	2017
15.3	19.1	20.1	18.8	12.7	8.6	7.9	7.3

(BVEG, 2018)

Emission factors

Table 153: Emission factors used for production

Gas	Emission factor	Method	source
CO_2	0.10 g/m³	Tier 2	Expert estimate
CH_4	0.08 g/m³	Tier 2	Expert estimate
NMVOC	0.02 g/m³	Tier 2	Expert estimate

Emissions and trend

Table 154: Emissions in category 1.B.2.b.ii

Gas	Total emissions			Trend		Remark
	1990	2016	2017	Since 1990	With respect to the previous year	
Methane	5,799 t	564 t	544 t	- 91 %	- 4 %	The emissions have decreased with respect to 1990, as a result of decreasing production and improved emissions-reduction technologies.
Carbon dioxide	1,450 t	694 t	711 t	- 51 %	2 %	
NMVOC	580 t	60 t	174 t	- 70 %	290 %	

3.3.2.2.2.2 Methodological aspects of the category "Natural gas, production" (1.B.2.b.ii)

Since 1998, the Federal association of the natural gas, oil and geothermal energy industries (BVEG) has determined the emissions from production and published the relevant data in its statistical report. For the period prior to 1998, the emissions have been determined with the help of default factors from the 2006 IPCC Guidelines. The emissions are calculated in keeping with the Tier 2 method.

3.3.2.2.2.3 Uncertainties and time-series consistency of the category "Natural gas, production" (1.B.2.b.ii)

In this category, the uncertainty for the activity data is given as 5 %. The figures are based on estimates of BVEG experts and national experts.

The uncertainties for the emission factors in the category amount to 25 %.

3.3.2.2.2.4 Category-specific quality assurance / control and verification, category "Natural gas, production" (1.B.2.b.ii)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The emission factors that have been used are of the same order of magnitude as those given in the 2006 IPCC Guidelines.

Table 155: Comparison of IEF with the relevant IPCC default values

Gas	CS emission factor used	IPCC GL 2006 (Table 4.2.5)	
	Units in [g/m³]	Units in [Gg/10⁶m³]	Units in [g/m³]
CO_2	0.10 g/m³	$1.4*10^{-05}$ to $1.8*10^{-04}$	0.014– 0.18
CH_4	0.08 g/m³	$3.8*10^{-04}$ to $2.4*10^{-02}$	0.380– 24.0
NMVOC	0.02 g/m³	$9.1*10^{-05}$ to $1.2*10^{-03}$	0.091– 1.20

3.3.2.2.3 Natural gas, processing (1.B.2.b.iii)

Gas	Method used	Source for the activity data	Emission factors used
CO_2, CH_4	Tier 2	AS	CS
CO	Tier 2	AS	CS
SO_2, NMVOC	Tier 2	AS	CS

3.3.2.2.3.1 Category description (1.B.2.b.iii)

The emissions of this category consist of emissions from the activities of pretreatment and processing.

After being brought up from underground reserves, natural gas is first treated in drying and processing plants. As a rule, such pretreatment of the natural gas takes place in facilities located directly at the pumping stations. Such processes separate out associated water from reserves, along with liquid hydrocarbons and various solids. Glycol is then used to remove the water vapour remaining in the gas (WEG (2008))[38]: p. 25). Natural gas dehydration systems are closed systems. For safety reasons, all of such a system's overpressure protection devices are integrated within a flare system. When such protection devices are triggered, the surplus gas is guided to a flarehead, where it can be safely burned. After drying, the natural gas is ready for sale and can be delivered to customers directly, via pipelines (EXXON, 2014). The relevant quantities of flared gas are reported under 1.B.2.c.

The natural gas drawn from Germany's Zechstein geological formation contains hydrogen sulphide. In this original state, the gas – known as "sour gas" – has to be subjected to special treatment. Such gas is transported via separate, specially protected pipelines (due to the hazardousness of hydrogen sulphide) to German processing plants that wash out its hydrogen sulphide via chemical and physical processes. About 40 % of the natural gas extracted in Germany is sour gas (WEG, 2008).

The natural gas that leaves processing plants is ready for use. The hydrogen sulphide is converted into elementary sulphur and is used primarily by the chemical industry, as a basic raw material.

Activity data

Table 156: Sulphur production from natural gas production in Germany, in kt

1990	1995	2000	2005	2010	2015	2016	2017
915	1,053	1,100	1,050	832	628	578	538

(BVEG, 2018)

Figures for natural gas production are presented in Chapter 3.3.2.2.2.1, in Table 152.

Emission factors

Table 157: Emission factors used for category 1.B.2.b.iii, "Processing"

Gas	Emission factor	Method	source
NMVOC	0.004 kg / 1,000 m³		
CH_4	0.04 kg / 1,000 m³	Tier 2	Association data
CO_2	351 kg / 1,000 m³		

[38] WEG 2008a: Erdgas-Erdöl, Entstehung-Suche-Förderung, Hannover, 34 p.

Emissions and trend

Table 158: Emissions in category 1.B.2.b.iii

Gas	Total emissions 1990	2016	2017	Trend Since 1990	With respect to the previous year	Remark
Methane	5,340 t	409 t	116 t	- 98 %	-71 %	The air-pollution emissions of the exploration and production industry are determined in keeping with a procedure accepted throughout the industry[39]. For this reason, the annual emissions figures vary somewhat from year to year and do not yield a straight line. The sharp increase in NMVOC emissions is due to a change of methods.
Carbon dioxide	1,404 kt	1,071 kt	1,018 kt	- 27 %	- 5 %	
NMVOC	12 t	31 t	12 t	0 %	-61 %	

3.3.2.2.3.2 Methodological issues (1.B.2.b.iii)

The emissions were calculated in keeping with the Tier 2 method.

For processing of sour gas, data of the BVEG (the former WEG) for the period since 2000 are used. Those data are the result of the members' own measurements and calculations. For the period prior to 2000, the average CO_2 emission factor reported by Austria, 0.23 t / 1,000 m^3, is used, since, according to the BVEG, the German desulphurisation plant is comparable to the Austrian plant.

For calculation of emissions from sour-gas processing, a split factor of 0.4 relative to the activity data is applied. That split factor is based on the WEG report on sour-gas processing (WEG, 2008).

3.3.2.2.3.3 Uncertainties and time-series consistency (1.B.2.b.iii)

For the emissions data, the category uncertainties are given as 10 to 30 %. Those figures are based on estimates of national experts, and they lie within the range listed for relevant default emission factors (IPCC (2003), Chapter 2.7.1.6.).

3.3.2.2.3.4 Category-specific quality assurance / control and verification (1.B.2.b.iii)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

Table 159: Comparison of IEF with the relevant IPCC default values

Source	CS emission factor used Units in [g/m³]	2006 IPCC GL (Table 4.2.4)[40] Units in [Gg/10⁶m³]	Units in [g/m³]
CO_2	351	$7.9*10^{-06}$+ $3.6*10^{-3}$+ $6.3*10^{-2}$	66.608
CH_4	0.04	$9.7*10^{-05}$ + $2.4*10^{-6}$	0.099
NMVOC	0.004	$6.8*10^{-05}$ + $1.9*10^{-6}$	0.068

A comparison with the IPCC default factors [Table 4.2.4 in the 2006 IPCC GL] shows that the national emission factors for methane lie within the range given for the default factors. The factor for carbon dioxide greatly exceeds the relevant default factor, however. Nonetheless, Germany's value in this category is of the same order of magnitude as Austria's (cf. the following table). The discrepancies with the IPCC default values result in that the German emission factors include the installations' energy inputs and sulphur production. Pursuant to the Federal association of the natural gas, oil and geothermal energy industry (BVEG), the factor cannot be split.

[39] WEG: "Leitfaden zu Erfassung der Umweltdaten der WEG Mitgliedsfirmen", published in-house, and last revised in Dec. 2016

[40] Addition of fugitive emissions, flare emissions and raw-CO_2 venting

No cross-checking against the corresponding figures of other countries could be carried out, since the CRF tables do not indicate what shares of processed natural gas must be assigned to the "sour gas" category.

Table 160: Comparison of emission factors for carbon dioxide

Source	CS emission factor used Units in [g/m³]
Austria	230
Germany	351

3.3.2.2.4 Gas, transmission (1.B.2.b.iv)

Gas	Method used	Source for the activity data	Emission factors used
CH_4 (transmission)	Tier 3	AS	CS
CH_4 (storage)	Tier 2	AS	CS

3.3.2.2.4.1 Category description (1.B.2.b.iv)

This source category's emissions consist of emissions from activities of gas producers and suppliers. In Germany, natural gas is transported from production and processing companies/plants to gas suppliers and other processors. In addition, natural gas is imported and transmitted via long-distance pipelines.

Almost all of the pipelines used to transmit natural gas are steel pipelines (Zöllner, 2014).

Activity data

Table 161: Length of long-distance high-pressure pipelines, in km

1990	1995	2000	2005	2010	2015	2016	2017
22,696	29,866	32,214	34,086	35,503	34,270	34,963	34,981

Kiesel (2016) and data from Grosse (2018)

Some of the natural gas is stored in underground reservoirs, to guard against the possibility of interruptions of pipeline transports (i.e. to assure the reliability of the gas supply).

Table 162: Underground gas-storage volume, in billions of m³

	1990	1995	2000	2005	2010	2015	2016	2017
Cavern reservoirs	2.8	4.8	6.1	6.8	9.2	14.3	14.8	15.0
Porous-rock reservoirs	5.2	8.5	12.5	12.4	12.1	9.8	9.4	9.5

(BVEG, 2018)

One important emissions pathway consists of the compressors that are used to maintain pressure in pipelines. They are spaced at intervals of about 100 km along lines (GASUNIE, 2014). At present, the compressors involved have a total power output of about 2,550 MW [data from "Netzentwickungsplan Gas 2012" ("2012 edition of the gas-network-development plan")]. The pipelines are also fitted with shut-off devices (sliding sleeves), which are safety mechanisms located at intervals of about 30 km along high-pressure pipelines, and with systems for regulating and measuring gas pressure.

Emission factors

Most of the gas extracted in Germany is moved via pipelines from gas fields and their pumping stations (either on land or off the coast). Imported gas is also transported mainly via pipelines.

Table 163: Emission factors used for methane emissions in category 1.B.2.a.iv, "Transmission"

System or mechanism	Value	Method	source
Long-distance high-pressure pipeline	159 kg/km	T3	Expert estimate
Compressor	30,229 m^3/MW	T2	Expert estimate
Sliding sleeve hub	46,845 m^3/No.	T2	Expert estimate
Systems for regulating and measuring gas pressure	764 m^3/No	T2	Expert estimate
Cavern reservoirs	0.05 kg / 1,000 m^3 (Vn)[41]	T2	Expert estimate
Porous-rock reservoirs	0.05 kg / 1,000 m^3 (Vn)[41]	T2	Expert estimate

Table 164: Emission factors used for carbon dioxide emissions in category 1.B.2.a.iv, "Transmission"

System or mechanism	Value	Method	source
Long-distance high-pressure pipeline	1.3 kg/km	T3	Expert estimate
Compressor	183 m^3/MW	T2	Expert estimate
Sliding sleeve hub	271 m^3/No.	T2	Expert estimate
Systems for regulating and measuring gas pressure	4.5 m^3/No	T2	Expert estimate
Cavern reservoirs	0.6 g / 1,000 m^3 (Vn) [41]	T2	Expert estimate
Porous-rock reservoirs	0.6 g / 1,000 m^3 (Vn) [41]	T2	Expert estimate

Emissions and trend

Table 165: Emissions in category 1.B.2.b.iv

Gas	Total emissions			Trend		Remark
	1990	2016	2017	Since 1990	With respect to the previous year	
Methane	44.4 kt	75.3 kt	75.4 kt	70 %	0 %	The emissions have been increasing as a result of addition of new long-distance high-pressure pipelines, including the attendant compressors and measuring and safety mechanisms.
NMVOC	487 t	921 t	922 t	89 %	0 %	
Carbon dioxide	210 t	312 t	312 t	49 %	0 %	

3.3.2.2.4.2 Methodological issues (1.B.2.b.iv)

The emissions from natural gas transmission were calculated in keeping with the Tier 3 method.

The emissions from natural gas storage, from compressor stations, from systems for regulating and measuring gas pressure and from sliding sleeve hubs were calculated in keeping with the Tier 2 method.

The emission factor for underground natural gas storage was derived via surveys of operators and analysis of statistics on accidents / incidents Langer (2012), and it is valid for pore-storage and cavern-storage facilities. It is seen as very conservative. The emission factor for the compressor systems and the sliding sleeve hubs has been obtained from the research project Zöllner (2014).

Results for above-ground gas storage facilities are reported in 1.B.2.b.v.

[41] Available volume of working gas, normed to 273 K and 1013 hPa.

3.3.2.2.4.3 Uncertainties and time-series consistency (1.B.2.b.iv)

For the emissions data, the category uncertainties are given as 10 to 30 %. Those figures are based on estimates of national experts, and they lie within the range listed for relevant default emission factors (IPCC (2003), Chapter 2.7.1.6.). For underground storage facilities, an uncertainty of -50% is assumed, since the factors used were obtained via a highly conservative approach.

3.3.2.2.4.4 Category-specific quality assurance / control and verification (1.B.2.b.iv)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity. In addition, quality checks of the data and texts were carried out by the firm of DBI Gas- und Umwelttechnik GmbH (Grosse, 2018).

A comparison of the category with the relevant IPCC default factors (Table 4.2.8) indicates that the emission factors for methane lie within the range given. For comparison values are available for carbon dioxide.

Table 166: Comparison of IEF with the relevant IPCC default values

System or mechanism	CS emission factor	2006 IPCC GL – Table 4.2.8
Compressor	30,229 m^3/MW	6,000 – 100,000 m^3/MW
Shut-off devices (sliding sleeve hubs) [42]	46,845 m^3/No.	1,000 – 50,000 m^3/No

The emission factors for the compressors and the shut-off devices lie within the range for the pertinent IPCC factors. The emission factor for compressors was verified by the projects Zöllner (2014) and Müller-Syring & Schütz (2014). The factor for sliding sleeve hubs has been obtained from a study carried out for the Russian transport network (Lechtenböhmer et al., 2005). It has been used due to a lack of national emission factors. This approach may be considered highly conservative.

3.3.2.2.5 Natural gas, distribution (1.B.2.b.v)

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier 3	AS	CS

3.3.2.2.5.1 Category description (1.B.2.b.v)

The emissions caused by gas distribution have decreased slightly, even though gas throughput has increased considerably and the distribution network has been enlarged considerably with respect to its size in 1990. One important reason for this improvement is that the gas-distribution network has been modernised, especially in eastern Germany. In particular, the share of grey cast iron lines in the low-pressure network has been reduced, with such lines being supplanted by low-emissions plastic pipelines. Another reason for the reduction is that fugitive losses in distribution have been reduced through a range of technical improvements (tightly sealing fittings such as flanges, valves, pumps, compressors) undertaken in keeping with emissions-control provisions in relevant regulations (TA Luft (1986) and TA Luft (2002)).

[42] The emission factor is calculated with regard to the components blow pump and valve (Zöllner, 2014); it is assumed that the listed IPCC default factor, due to its very high values, refers to sliding sleeves and not to measuring stations.

Activity data

Table 167: Gas distribution network; figures in km

Parameter	1990	1995	2000	2005	2010	2015	2016	2017
Total length of pipeline network[43]	282,612	366,987	362,388	402,391	471,886	476,561	481,327	486,140

(Kiesel, 2017), own survey

Table 168: Number of natural-gas-powered vehicles in Germany

	1990	1995	2000	2005	2010	2015	2017
Number	0	0	7,500	28,500	90,000	97,804	97,489

(Kraftfahrtbundesamt, 2017), own survey

Table 169: Emission factors used for methane emissions in category 1.B.2.b.v

System or mechanism	Value	Method	Source
Low-pressure pipeline made of steel and ductile cast iron	372 kg/km	Tier 3	Expert estimate
Low-pressure plastic pipeline	51 kg/km	Tier 3	Expert estimate
Low-pressure grey-cast-iron pipeline	445 kg/km	Tier 3	Expert estimate
Medium-pressure pipeline made of steel and ductile cast iron	207 kg/km	Tier 3	Expert estimate
Medium-pressure plastic pipeline	28 kg/km	Tier 3	Expert estimate
High-pressure pipeline made of steel and ductile cast iron	62 kg/km	Tier 3	Expert estimate
High-pressure plastic pipeline	0.3 kg/km	Tier 3	Expert estimate
Above-ground storage facilities	5 kg / 1,000 m^3 (Vn)[44]	Tier 2	Expert estimate
Gas-pressure-regulation (measuring) equipment	256 kg / No	Tier 2	Expert estimate
Natural-gas-powered vehicles	0.33 kg / vehicle	Tier 2	Expert estimate

Table 170: Carbon dioxide emission factors used for category 1.B.2.b.v

System or mechanism	Value	Method	Source
Low-pressure pipeline made of steel and ductile cast iron	3.1 kg/km	Tier 3	Expert estimate
Low-pressure plastic pipeline	0.4 kg/km	Tier 3	Expert estimate
Low-pressure grey-cast-iron pipeline	3.7 kg/km	Tier 3	Expert estimate
Medium-pressure pipeline made of steel and ductile cast iron	1.7 kg/km	Tier 3	Expert estimate
Medium-pressure plastic pipeline	0.2 kg/km	Tier 3	Expert estimate
High-pressure pipeline made of steel and ductile cast iron	0.5 kg/km	Tier 3	Expert estimate
High-pressure plastic pipeline	2.5 g/km	Tier 3	Expert estimate
Above-ground storage facilities	34 g / 1,000 m^3 (Vn)[44]	Tier 2	Expert estimate
Gas-pressure-regulation (measuring) equipment	1.7 kg / No	Tier 2	Expert estimate
Natural-gas-powered vehicles	2.3 g / vehicle	Tier 2	Expert estimate

43 The data given include building-connection lines

44 Available volume of working gas, normed to 273 K and 1013 hPa.

Table 171: Emissions and trend in category 1.B.2.b.v

Gas	Total emissions			Trend		Gas
	1990	2016	2017	Since 1990	With respect to the previous year	
Methane	232.9 kt	85.7 kt	85.1 kt	- 63 %	0 %	The emissions have been decreasing as a result of use of emissions-reducing materials in the pipeline network – and, especially, via replacement of grey cast iron pipes.
NMVOC	5.4 kt	1.8 kt	1.8 kt	- 63 %	0 %	
Carbon dioxide	1.8 kt	0.6 kt	0.6 kt	- 63 %	0 %	

3.3.2.2.5.2 Methodological issues (1.B.2.b.v)

Pipeline network

The calculation was carried out using the Tier 3 method, on the basis of the available network statistics of the German Association of Energy and Water Industries (BDEW) (136. Gasstatistik 2014 (2014 gas statistics) of the BDEW Kiesel (2016)) and of our own surveys. In the early 1990s, emissions from distribution of town gas were also taken into account in calculations. In 1990, the town-gas distribution network accounted for a total of 16 % of the entire gas network. Of that share, 15 % consisted of grey cast iron lines and 85 % consisted of steel and ductile cast iron lines.

The emission factors for the distribution network were verified in 2012 (Gottwald, 2012) and 2014 (Müller-Syring & Schütz, 2014).

The methane-emission factor used, 256 kg / station for the gas-pressure-regulation (-measuring) systems in the distribution network, was determined by Federal Environment Agency experts on the basis of data from the study Müller-Syring & Schütz (2014).

Storage reservoirs

Man-made above-ground storage facilities, for storage of medium-sized quantities of natural gas, help meet and balance rapid fluctuations in demand. In Germany, spherical and pipe storage tanks, and other types of low-pressure containers, are used for this purpose. Results from a relevant research project Langer (2012) have made it possible to derive new country-specific emission factors for this area. The emissions have been calculated in accordance with the Tier 2 method.

Natural-gas-powered vehicles, and CNG fueling stations

Use of vehicles running on natural gas continues to increase in Germany. Such vehicles are refueled at CNG fueling stations connected to the public gas network. In such refueling, compressors move gas from high-pressure on-site tanks. Some 900 CNG fuelling stations are now in operation nationwide (Langer, 2012). In keeping with the stringent safety standards applying to refuelling operations and to the tanks themselves, the pertinent emissions are very low – about 30 t per year. In the main, emissions result via tank pressure tests and emptying processes. The emissions have been calculated in accordance with the Tier 2 method.

Liquefied natural gas (LNG)

Natural gas can be liquefied, at a temperature of -161°C, for ease of transport. The liquefaction process is highly energy-intensive, however, and is normally used only in connection with long-distance transports. Germany has no LNG terminals at present (Langer, 2012). Gas imports arrive mostly in gaseous form, via long-distance pipelines, and they are included in 1.B.2.b.iv.

Germany now has one natural gas liquefaction facility and two satellite LNG storage facilities. Since the storage and transfer processes at those facilities are subject to the most stringent standards possible, emissions there can be ruled out. Gas can escape only in connection with maintenance work, and the gas quantities involved are extremely small. The quantities do not exceed more than a few hundred kilograms (Langer, 2012).

3.3.2.2.5.3 Uncertainties and time-series consistency (1.B.2.b)

For the emissions data, the category uncertainties are given as 20-30 %. Those figures are based on estimates of experts, and they lie within the range listed for relevant default emission factors (IPCC (2006), Table 4.2.4).

3.3.2.2.5.4 Category-specific quality assurance / control and verification (1.B.2.b.v)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity. In addition, quality checks of the data and texts were carried out by the firm of DBI Gas- und Umwelttechnik GmbH (Grosse, 2018).

It was not possible to compare the results for this category with the corresponding results of other countries, because the different sets of units involved cannot be converted for such comparison.

Table 172: Comparison of IEF with the relevant IPCC default values

Method	EF	AD	EM
CS (only the distribution network)	102 kg/km[45]	486,140 km	50 kt
IPCC 2006	1.1 * 10^{-3} Gg / millions of m^3	91 billion m^3[46]	100 kt

Both methods yield emissions on the same order of magnitude.

3.3.2.2.6 Natural gas, other leakage (1.B.2.b.vi)

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier 2	AS	CS

3.3.2.2.6.1 Category description (1.B.2.b.vi)

The category describes emissions from leakage in the industrial sector and in the residential and institutional/commercial sectors. The activity data are based on results of the German Association of Energy and Water Industries (BDEW) ("Gasstatistik" – gas statistics) and of our own surveys. The BDEW gas statistics appear with a time lag of up to three years. Data of the AGEB working group AGEB (2018) are used to bridge the resulting gap.

Activity data

Table 173: Activity data used for category 1.B.2.b.vi, "Fugitive emissions at sites of natural gas use"

	1990	1995	2000	2005	2010	2015	2016	2017
Number of gas meters in the residential and institutional/commercial sectors [millions]	10.3	12.7	12.8	13.3	12.9	13.0	13.0	13.0
Energy consumption of industry [TWh]	323	361	370	399	335	377	440	432

(Kiesel, 2016), (AGEB, 2018), (Grosse, 2017, 2018)

[45] Weighted EF

[46] The value is from (BVEG, 2018)

Emission factors

Table 174: Methane emission factors used for category 1.B.2.b.vi, "Fugitive emissions at sites of natural gas use"

Operational site	Gas	Value	Method	Source
Gas meters and fittings in the residential and institutional/commercial sectors	CH_4	2 m³/No[47]	Tier 2	Expert estimate
Fittings in industrial facilities	CH_4	0.4 m³ / 1,000 m³	Tier 2	Expert estimate

Emissions and trend

Table 175: Emissions in category 1.B.2.b.vi

Gas	Total emissions 1990	2016	2017	Trend Since 1990	With respect to the previous year	Remark
Methane	29.1 kt	30.1 kt	30.0 kt	3 %	0 %	The emissions development is influenced primarily by consumption increases in industry.
NMVOC	0.7 kt	0.7 kt	0.7 kt	3 %	0 %	
Carbon dioxide	0.2 kt	0.2 kt	0.2 kt	3 %	0 %	

3.3.2.2.6.2 Methodological issues (1.B.2.b.v)

The emission factors are country-specific, and they were determined via the research project "Methanemissionen durch den Einsatz von Gas in Deutschland von 1990 bis 1997 mit einem Ausblick auf 2010" ("Methane emissions via gas use in Germany from 1990 to 1997, with an outlook for 2010"); Frauenhofer ISI, 2000. Pursuant to Arbeitsblatt [Worksheet] G 600 (Technische Regel für Gasinstallationen [Technical rule for gas installations], DVGW (2018)) of the German Technical and Scientific Association for Gas and Water (DVGW), a leakage rate of 0-1 l/h has no affect on an installation's functionality. When a leak test shows that an installation is leaking a rate higher than that figure, the installation has to be repaired within the short term. National experts thus consider a value of 2 m^3/year to be suitable.

The emissions are calculated in keeping with the Tier 2 method.

3.3.2.2.6.3 Uncertainties and time-series consistency (1.B.2.b)

For the emissions data, the category uncertainties are given as 20 %. Those figures are based on estimates of experts, and they lie within the range listed for relevant default emission factors (Penman et al. (2000), Chapter 2.7.1.6.).

3.3.2.2.6.4 Category-specific quality assurance / control and verification (1.B.2.b.v)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity. In addition, quality checks of the data and texts were carried out by the firm of DBI Gas- und Umwelttechnik GmbH (Grosse, 2018).

Betzenbichler et al. (2016) compared the results for this category with other countries' corresponding results. This comparison yielded considerable differences between Germany's results and those of neighbouring countries. While a number of countries have emissions in this category, other countries' results are, on average, two orders of magnitude smaller than the

[47] Average factor with respect to natural gas loss per number of gas meters in residences

German results. While the 2006 IPCC Guidelines provide no method description for this category, their Table 4.2.8 presents a range for the expected emissions.

Table 176: Comparison of IEF with the relevant IPCC default values

System or mechanism	CS emission factor	2006 IPCC GL – Table 4.2.8
Losses at the point of use	2 m^3/No.[48]	2 to 20 m^3/No.

3.3.2.3 Venting and flaring (1.B.2.c)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
-/-	1.B.2.c Venting and Flaring		CO_2	543.52	0.04%	380.68	0.04%	-30.0%
-/-	1.B.2.c Venting and Flaring		CH_4	1.65	0.00%	2.74	0.00%	65.9%
-/-	1.B.2.c Venting and Flaring		N_2O	1.06	0.00%	0.13	0.00%	-87.5%

The categories in the overarching group of fugitive emissions from 1.B.2.c "Venting and flaring" cover greenhouse-gas and air-pollutant emissions either vented or flared directly into the atmosphere. The emissions from venting processes are included in the category 1.B.2.a.iv for oil, and in categories 1.B.2.b.iii and 1.B.2.b.iv for natural gas.

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 2	AS	CS
CH_4	Tier 2	AS	CS
N_2O	Tier 2	AS	CS
NMVOC	Tier 2	AS	CS

The category 1.B.2.c "Venting and flaring" is not a key category.

3.3.2.3.1.1 Category description, "Venting and flaring" (1.B.2.c)

Pursuant to general requirements of the Technical Instructions on Air Quality Control TA Luft (2002), gases, steam, hydrogen and hydrogen sulphide released from pressure valves and venting equipment must be collected in a gas-collection system. Wherever possible, gases so collected are burned in process combustion. Where such use is not possible, the gases are piped to a flare. Flares used for flaring of such gases must fulfill at least the requirements for flares for combustion of gases from operational disruptions and from safety valves. For refineries and other types of plants in categories 1.B.2, flares are indispensable safety components. In crude-oil refining, excessive pressures can build up in process systems, for various reasons. Such excessive pressures have to be reduced via safety valves, to prevent tanks and pipelines from bursting. Safety valves release relevant products into pipelines that lead to flares. Flares carry out controlled burning of gases released via excessive pressures. When in place, flare-gas recovery systems liquify the majority of such gases and return them to refining processes or to refinery combustion systems. In the process, more than 99 % of the hydrocarbons in the gases are converted to CO_2 and H_2O. When a plant has such systems are in operation, therefore, its flarehead will seldom show more than a small pilot flame.

Activity data

Table 177: Refined crude-oil quantity, in millions of t.

1990	1995	2000	2005	2010	2015	2016	2017
107	96	108	115	95	93	94	93

(MWV, 2018)

[48] It was not possible to include the emission factor for industry emissions within the comparison, since the relevant units cannot be converted.

Table 178: Flared natural gas, in millions of m³

1990	1995	2000	2005	2010	2015	2016	2017
36	33	36	19	12	10	9	11

(BVEG, 2018)

Emission factors

Flaring takes place at extraction and pumping systems and in refineries. In refineries, flaring operations are subdivided into regular operations and start-up / shut-down operations in connection with disruptions.

Table 179: Emission factors used for category 1.B.2.c, "Flaring emissions in natural gas extraction"

Gas	Value	Method	source
CO_2	1.777 kg/m³	Tier 2	Expert estimate
NO	$2*10^{-8}$ kg/m³	Tier 1	IPCC default value

Table 180: Emission factors used for category 1.B.2.c., "Flaring emissions at petroleum production facilities"

Gas	Value	Method	source
CO_2	9.1 kg/t	Tier 2	Expert estimate
N_2O	0.55 g/t	Tier 1	IPCC default value

Methane and NMVOC emissions are included under production. Pursuant to the Federal association of the natural gas, oil and geothermal energy industries (BVEG), the pertinent nitrous oxide emissions are extremely insignificant. In the interest of maintaining a conservative approach, the IPCC default value has been used in the relevant calculation.

Table 181: Emission factors used for category 1.B.2.c "Flaring emissions at refineries: normal flaring operations"

Gas	Value	Method	source
CH_4	0.29 g/t	Tier 2	Expert estimate
CO_2	2.86 kg/t	Tier 2	Expert estimate
N_2O	0.01 g/t	Tier 2	Expert estimate
CO	0.33 g/t	Tier 2	Expert estimate
NMVOC	2.80 g/t	Tier 2	Expert estimate
SO_2	8.43 g/t	Tier 2	Expert estimate
NO_x (as NO_2)	0.41 g/t	Tier 2	Expert estimate

Table 182: Emission factors used for category 1.B.2.c "Flaring emissions at refineries: disruptions of flaring operations"

Gas	Value	Method	source
CH_4	0.08 g/t	Tier 2	Expert estimate
CO_2	1.28 kg/t	Tier 2	Expert estimate
N_2O	0.3 mg/t	Tier 2	Expert estimate
CO	4.16 g/t	Tier 2	Expert estimate
NMVOC	2.27 g/t	Tier 2	Expert estimate
SO_2	15.23 g/t	Tier 2	Expert estimate
NO_x (as NO_2)	3.49 g/t	Tier 2	Expert estimate

The emission factors have been derived from the 2004 and 2008 emissions declarations (Theloke et al., 2013).

Emissions and trend

Table 183: Emissions in category 1.B.2.c "Venting and flaring"

Gas	Total emissions			Trend		Remark
	1990	2016	2017	Since 1990	With respect to the previous year	
Methane	66 t	112 t	109 t	65 %	- 3 %	Emissions from flaring systems have decreased continuously as a result of improvements in gas-recovery methods.
Carbon dioxide	544 kt	387 kt	381 kt	-30 %	- 2 %	
NMVOC	522 t	441 t	430 t	-18 %	- 2 %	
Nitrous oxide	3.6 t	0.5 t	0.4 t	- 89 %	- 7 %	

3.3.2.3.1.2 Methodological aspects of the category "Venting and flaring" (1.B.2.c)

Venting emissions are taken into account in category 1.B.2.b.iii. The SO_2 emissions are obtained from the activity data for the flared natural gas (Table 178) and an emission factor of 0.140 kg / 1,000 m^3, a factor which takes account of an average H_2S content of 5 % by volume.

The emission factors are determined on the basis of emissions reports, crude-oil-refining capacity and total capacity utilisation at German refineries. The guide for this work consists of the evaluation assessment of Theloke et al. (2013).

The emissions are calculated in keeping with the Tier 2 method.

3.3.2.3.1.3 Uncertainties and time-series consistency for the category "Venting and flaring" (1.B.2.c)

The quantitative uncertainties for the emission factors for flaring processes during normal operations are assumed to be +/-10 % (95 % confidence interval, normal distribution). The uncertainties for the activity data are assumed to be +/- 5 % (95 % confidence interval, normal distribution).

The uncertainties for the emission factors for disruption-related flaring processes (operations during disruptions; start-up / shut-down operations) are much larger, since the emissions quantities can vary widely from year to year. They are estimated to be -90 % / +300 % (95% confidence interval, log-normal distribution). The uncertainties for the activity data are assumed to be +/- 10 % (95 % confidence interval, normal distribution) (Theloke et. al. 2013).

3.3.2.3.1.4 Category-specific quality assurance / control and verification, category "Venting and flaring" (1.B.2.c)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

A comparison of the category with the IPCC Guidelines reveals considerable differences in individual factors. At the EU Workshop held in Dessau (cf. Harthan et al. (2017)), the participating experts agreed that the default values are considerably higher than the emission factors currently used in Europe.

Table 184: Comparison of IEF with the relevant IPCC default values

Gas and system	CS emission factor used[49]	IPCC GL 2006 (Table 4.2.4)	
	Units in [g/m³]	Units in [Gg/1000m³]	Units in [g/m³]
CO_2 in refinery flares	3,569	$3.4*10^{-02}$	34,000
CH_4 in refinery flares	0.32	$2.1*10^{-05}$	21
NMVOC in refinery flares	4.37	$1.7*10^{-05}$	17
CO_2 in oil production systems	7844	$4.1*10^{-02}$	41,000
CO_2 in natural gas production systems	1532	$1.2*10^{-03}$	1,200

3.3.2.4 Geothermal energy (1.B.2.d)

3.3.2.4.1 Category description (1.B.2.d)

The category 1.B.2.d "Geothermal energy" is not a key category.

Geothermal energy is a renewable form of energy. Geothermal energy systems that tap geothermal heat to a depth of 400 metres are classified as "near-surface" geothermal energy systems. Near-surface geothermal systems generate heating and cooling energy by means of heat pumps. They are also used for heating service water. Geothermal energy systems that tap geothermal heat at depths greater than 400 metres are classified as "deep" geothermal energy systems. Geothermal heating stations use the heat in their thermal-water flows directly, and provide heating and cooling to end consumers, via district / local heating and cooling networks. Geothermal power stations convert the heat in their thermal-water flows into electricity. In most cases, they produce heat as well, via processes for combined heat/power (CHP) production.

As of the end of 2017, a total of 36 deep geothermal power stations were in operation. In sum, they have an electrical output of 39 MW and a thermal output of 314 MW. Two stations are currently under construction.

Operation of geothermal power stations and heat stations in Germany produces no emissions of climate-relevant gases. The thermal-water circuits of such installations are closed and airtight, both above and below ground level. As a result, no emissions occur during their operation. What is more, releases of the gases dissolved in their heat-carrying fluids – primarily H_2, CH_4, CO_2 and H_2S – would not produce concentrations that would require reporting (cf. "Umwelteffekte einer geothermischen Stromerzeugung, Analyse und Bewertung der klein- und großräumigen Umwelteffekte einer geothermischen Stromerzeugung" ("Environmental effects of geothermal power generation; analysis and assessment of small-scale and large-scale environmental impacts of geothermal power generation")), FKZ 205 42 110, Chapter A.2.3.5). For this reason, the emissions are reported as "NO". In 2017, all geothermal energy systems met their own power requirements (primarily power for operating pumps) by drawing electricity from the grid. In the report, that use is included in the relevant categories.

3.3.2.4.2 Methodological issues (1.B.2.d)

The IPCC Reference Manual does not describe any methods for category 1.B.2.d "Other" (IPCC et al. (1997): Volume 3, p. 1.132f)

No emission factors for greenhouse gases and pollutants that could escape in connection with drilling for tapping of geothermal energy (both near-surface and deep energy) are known for Germany at present. As is known from oil and gas exploration, however, it is clear that virtually any drilling will lead to releases of gases bound in underground layers – and the gases involved can include H_2, CH_4, CO_2, H_2S and Rn (cf. "Environmental effects of geothermal electricity

[49] For refineries, determined as a mean value between normal operation and operation during disruptions

production; analysis and assessment of the small-scale and large-scale environmental effects of geothermal electricity production", FKZ 205 42 110, Chapter A.2.1.5). Drilling to tap near-surface geothermal energy can be expected to produce only very slight emissions. In all drilling to tap deep geothermal energy, blow-out preventers are used to prevent gas releases. In addition, drilling fluids are used to drive any gases released into boreholes back into the rock layers traversed in drilling. According to an estimate made in the framework of a study (Theloke et al., 2013), the fugitive emissions related to deep geothermal wells are on the order of kilograms. The emissions in this category are reported as NE, therefore, because their contribution to the total emissions is less than 0.05 % of the overall inventory or 500 kt CO_2 equivalents (pursuant to FCCC/SBSTA/2013/L.29/Add.1), and since it cannot be assured that annual inventories of such emissions (pursuant to FCCC/SBSTA/2013/L.29/Add.1, para 37) will be carried out. In Chapter 5, the pertinent emissions contribution to the overall inventory is presented (on a one-time basis). A compilation of all sources for which the entry "not estimated" is retained is presented in Annex 5 (Chapter 21).

3.3.2.4.3 Uncertainties and time-series consistency (1.B.2.d)

No explanations of uncertainties and time-series consistency are required.

3.3.2.4.4 Category-specific quality assurance / control and verification (1.B.2.d)

No explanations relative to source-specific quality assurance / control and verification are required.

3.3.2.5 Category-specific recalculations (1.B.2 all)

The figures for the past two years have been recalculated, because some of the statistics on which they had been based were provisional. This work led to the following inventory improvements, entailing recalculations:

Transport of natural gas

The lengths of transport network operators' pipelines, as of 2015, were revised in the framework of a project (Grosse, 2018).

Oil, distribution of petroleum products

The source for the data on quantities of the products diesel fuel, jet fuel, light heating oil and gasoline has changed. Formerly, it was the Association of the German Petroleum Industry (MWV; its Annual Report (Jahresbericht)); now it is the Federal Office of Economics and Export Control (BAFA). The activity data (quantities) were then adjusted, for the years 2010 through 2017, to the latest findings.

Table 185: Recalculations in category 1.B.2 – NMVOC emissions, in kt

	1990	1995	2000	2005	2010	2015	2016
2018 Submission	198.6	143.0	110.0	83.3	75.2	68.5	69.2
2019 Submission	198.6	143.0	110.0	83.3	75.0	68.8	69.1
Difference	0	0	0	0	-0.5	-0.3	0.1

Table 186: Recalculations in category 1.B.2 – methane emissions, in kt

	1990	1995	2000	2005	2010	2015	2016
2018 Submission	334	347	255	223	200	201	203
2019 Submission	334	347	255	223	200	198	200
Difference	0	0	0	0	0	3	2

Table 187: Recalculations in category 1.B.2 – carbon dioxide emissions, in kt

	1990	1995	2000	2005	2010	2015	2016
2018 Submission	2234	3479	2535	2487	2165	1849	1704
2019 Submission	2234	3479	2535	2487	2165	1849	1709
Difference	0	0	0	0	0	3	5

3.3.2.6 Planned improvements, category-specific (1.B.2 all)

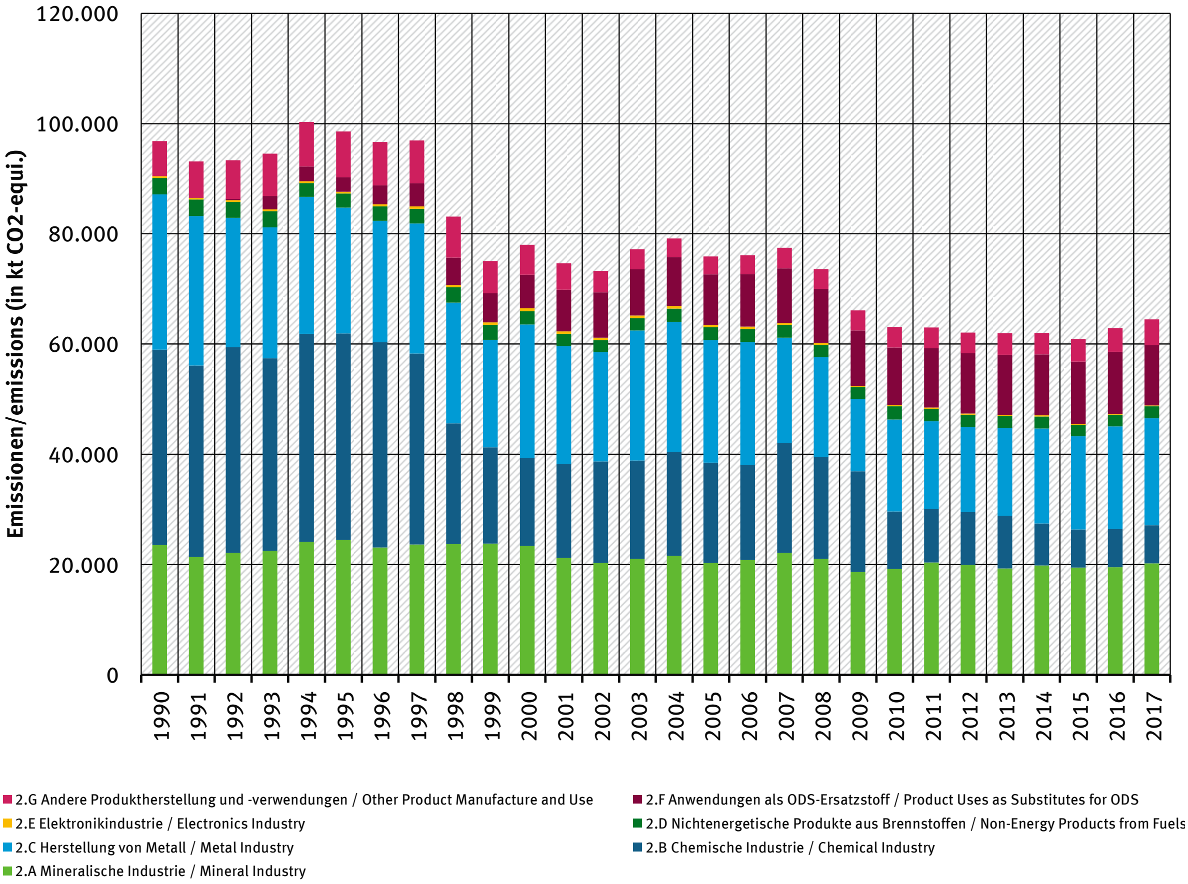
A research project is currently underway for analysis of the refineries' emissions declarations from the period 2004 through 2016. The resulting new emission factors will enter into future reporting.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4 Industrial processes (CRF Sector 2)

4.1 Overview (CRF Sector 2)

Figure 44: Overview of greenhouse-gas emissions in CRF Sector 2



4.2 Mineral industry (2.A)

The CRF category 2.A Mineral industry is divided into sub-categories 2.A.1 through 2.A.4. These fields include:

- cement clinker production (2.A.1),
- lime burning (2.A.2),
- glass production (2.A.3),
- ceramics production (2.A.4.a),
- other soda ash use (2.A.4.b),
- production of non-metallurgic magnesium products (2.A.4.c)
- other limestone and dolomite use (2.A.4.d).

4.2.1 Mineral industry: Cement production (2.A.1)

4.2.1.1 Category description (2.A.1)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
L/T	2.A.1 Mineral Products: Cement Production	Clinker Burning	CO_2	15,297.27	1.25%	13,408.15	1.50%	-12.3%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 2	AS	CS
NO_x, SO_2	Tier 1	AS	CS

The category *Cement production* is a key category for CO_2 emissions in terms of emissions level and trend. The remarks below refer only to production of cement clinkers, because clinker grinding is not relevant as a dust source in the present context. In Table 188, cement production is included solely for reference purposes, without emissions relevance in this context.

The clinker-burning process emits climate-relevant gases. CO_2 accounts for the great majority of these emissions. The CO_2 emissions from pertinent raw materials are tied directly to the quantities of cement clinkers that are produced. Pursuant to the German Emissions Trading Authority (DEHSt, 2018), clinker production in 2017 amounted to 24,802 kt·. Raw-material-related CO_2 emissions are calculated from plant-specific data, and taking account of discharged bypass dust, with a country-specific emission factor, as determined by the *German Cement Works Association (VDZ)*, of 0.53 t CO_2/t cement clinkers. On this basis, clinker production is seen to have produced raw-material-related CO_2 emissions of 13,408 kt CO_2 in 2017.

Table 188: Production and raw-material-related CO_2 emissions in the German cement industry

Year	Clinker production + discharged bypass dust[50] [kt/a]	Emission factor [t CO_2/t]	Raw-material-related CO_2 emissions [kt/a]	Cement production (kt/a)
1990	28,863	0.53	15,297	37,772
1991	25,927	0.53	13,741	34,341
1992	27,253	0.53	14,444	37,331
1993	27,417	0.53	14,531	36,649
1994	28,945	0.53	15,341	40,512
1995	29,363	0.53	15,562	35,862
1996	27,945	0.53	14,811	34,318
1997	28,821	0.53	15,275	34,148
1998	29,329	0.53	15545	35,601
1999	29,757	0.53	15,771	37,438
2000	28,779	0.53	15,253	35,414
2001	25,479	0.53	13,504	32,118
2002	24,194	0.53	12,823	31,009
2003	25,485	0.53	13,507	32,749
2004	26,544	0.53	14,068	31,854
2005	24,622	0.53	13,050	31,009
2006	25,170	0.53	13,340	33,630
2007	27,262	0.53	14,449	33,382
2008	25,620	0.53	13,579	33,581
2009	23,696	0.53	12,559	30,441

[50] The bypass-dust quantity is calculated via an expert assessment, oriented to actual clinker production, and applying the following assumptions: 1 % for the years 1990-2008; 2 % as of 2009.

Year	Clinker production + discharged bypass dust[50] [kt/a]	Emission factor [t CO_2/t]	Raw-material-related CO_2 emissions [kt/a]	Cement production (kt/a)
2010	23,456	0.53	12,431	29,915
2011	25,270	0.53	13,393	33,540
2012	25,073	0.53	13,289	32,432
2013	23,591	0.53	12,503	31,308
2014	24,348	0.53	12,905	32,099
2015	23,822	0.53	12,626	31,160
2016	23,892	0.53	12,663	32,674
2017	25,298	0.53	13,408	33,991

Source: Own calculations, derived from (BDZ, 2005) for the period through 1994; from (VDZ, 2016), for the period as of 1995; and from (DEHSt, 2016), (DEHSt, 2017), and (DEHSt, 2018), for the period as of 2015.

4.2.1.2 Methodological issues (2.A.1)

Activity data

Activity data are determined via summation of figures for individual plants (until 1994, activity data were determined on the basis of data of the BDZ German cement-industry association). As of 1995, following optimisation of data collection within the association, activity data were compiled by the VDZ, and by its cement-industry research institute (located in Düsseldorf), via surveys of German cement works and use of BDZ figures. In the main, the data consist of data published in the framework of CO_2 monitoring, supplemented with data for plants that are not BDZ members (in part, also VDZ estimates). This corresponds to the Tier 2 approach of the IPCC Guidelines ((IPCC, 2006): Volume 3, Chapter 2.2.1.1).

For internal reasons, the VDZ association was unable to provide the data for the years as of 2015. As a result, the cement-clinker figures are based on aggregated, plant-specific data of the DEHSt. A comparison covering the previous years 2005-2014 showed that the DEHSt's relevant emissions-trading figures and the VDZ's data on cement-clinker production differed by a constant percentage of about 1 %, meaning that a high degree of agreement between the two data sets may be assumed. In general, completeness is thus assured if one of the two data sets is used.

According to the VDZ, the applicable fraction of bypass dust, with respect to clinker production in the years 2009 through 2016, ranged between 1 and 2 %. In a conservative approach, this fraction is taken into account, as activity data, by assuming that it amounted to 2 % in the years since 2009. No detailed information on the applicable fraction of bypass dust is available for the years prior to 2009. In a conservative approach, it is assumed to have been a constant 1 % in the years 1990 through 2008.

Table 188 presents the activity data for cement clinkers, including the factors discharged bypass dust and cement.

Emission factors

The emission factor used for emissions calculation, 0.53 t CO_2 / t cement clinkers, is based on mass-weighted figures for individual plants, i.e. the VDZ determined the emission factor by aggregating plant-specific data relative to fractions of CaO and other metal oxides (MgO; in raw materials, and containing carbonate) in clinkers. The emission factor was determined in the framework of a research project, and it was confirmed by the VDZ in subsequent years. The procedure is in keeping with the Tier 2 method given in the IPCC Guidelines ((IPCC, 2006): Volume 3, Chapter 2.2.1.2).

In the German cement industry, dust separated from furnace exhaust gas is returned to the burning process. As a result, carbonate release from clinker raw materials can be determined directly from clinkers' metal-oxide content, without any need to take account of significant losses via the exhaust-gas pathway. In addition, the dust discharged via the bypass pathway is taken into account, for the entire time series, in determination of raw-material-related CO_2 emissions.

The emission factor of 0.53 t CO_2 / t cement clinkers was applied to the entire time series. Applying the conservative assumption that the bypass dust in question is completely deacidified, the same emission factor is used for this substance flow.

Raw-material-related CO_2 emissions in the cement industry are determined, in accordance with the *IPCC Guidelines* ((IPCC, 2006): Volume 3, Equation 2.2, in conjunction with Equation 2.5), via the following equation:

CO_2 emissions = emission factor ($EF_{clinkers}$) x clinker production + emission factor ($EF_{clinkers}$) x bypass dust (%) x clinker production

Table 188 shows the raw-material-related CO_2 emissions of the German cement industry, as determined with inclusion of bypass-dust discharge from clinker production, for the years covered by the report.

4.2.1.3 Uncertainties and time-series consistency (2.A.1)

For the activity data, time-series consistency is assured via the association's long history of data collection. For the years as of 2015, it is assured in that emissions-trading data has been proven, via excellent data agreement in previous years, to be a suitable alternative. For the emission factor, it is assured in that a consistent approach has been used for all years concerned.

The uncertainties given were determined via expert assessment.

Most companies are required to report clinker-production data within the framework of CO_2-emissions trading. The EU monitoring guidelines for emissions trading specify a maximum accuracy of 2.5 %. The uncertainties for the activity data used were thus estimated at -2.5 % and +2.5 %.

The uncertainty for the emission factor used was estimated at +/- 2 %. This was confirmed via surveys in the framework of a research project (Ruppert, 2009).

4.2.1.4 Source-specific quality assurance / control and verification (2.A.1)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

For purposes of quality assurance, all data used, including data from the BDZ, from the VDZ and from emissions trading, and comparative data from the literature, were checked for plausibility. During the inventory review (ICR 2016), materials of the VDZ were used to demonstrate that QSE-conformal procedures are being used. Those materials were accepted by the review team as proof. The emission factor determined for raw-material-related CO_2 emissions has been compared with the relevant figures of other countries. The small deviation (about 1 %) from the IPCC Tier 1 default factor, 0.52 t CO_2 / t clinkers ((IPCC, 2006): Volume 3, Equation 2.4), results from the higher lime content found in some German clinkers.

The emission factor used differs only slightly (1 %) from the average emission factors used in connection with the ETS in Germany, emission factors that are checked by authorities and reviewed in light of companies' obligations to provide records. To date, no calculations relative to the emission factor prior to the year 2000 are available. The same figure – the result of an expert assessment – has been used for all relevant years in that period.

4.2.1.5 Category-specific recalculations (2.A.1)

No recalculations are required.

4.2.1.6 Planned improvements, category-specific (2.A.1)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.2.2 Mineral industry: Lime production (2.A.2)

4.2.2.1 Category description (2.A.2)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
L/-	2.A.2 Mineral Products: Lime Production	Burning of limestone and dolomite	CO_2	5,986.62	0.49%	4,777.29	0.54%	-20.2%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 2	AS	D
NO_X, SO_2	Tier 1	AS	CS

The category *Lime production* is a key category for CO_2 emissions in terms of emissions level.

The statements made below regarding category 2.A.2 refer solely to the amounts of burnt lime and dolomite lime produced in German lime works. Additional relevant lime kilns, in addition to the lime-burning facilities covered by this chapter, have been identified in the iron and steel industry and sugar industry sectors. Those facilities are covered not in the present chapter, but in the sections for the relevant categories, 2.C.1 (Chapter 4.4.1) and 2.H.2 (Chapter 4.9.2). Information on other limestone-using sectors is provided in Chapter 4.2.4.4 (CRF 2.A.4d).

In 2017, production of burnt lime and dolomite lime was at about the same level seen in the previous year.

Table 189: Production and CO_2 emissions in the German lime industry

Year	Lime		Dolomite lime	
	Production [Millions of t]	CO_2 emissions [Millions of t]	Production [Millions of t]	CO_2 emissions [Millions of t]
1990	7.324	5.463	0.603	0.523
1991	6.475	4.830	0.605	0.525
1992	6.563	4.896	0.587	0.509
1993	6.853	5.112	0.527	0.457
1994	7.512	5.604	0.516	0.447
1995	7.611	5.678	0.556	0.482
1996	7.019	5.236	0.556	0.482
1997	7.115	5.308	0.542	0.470
1998	6.799	5.072	0.570	0.494
1999	6.815	5.084	0.491	0.425
2000	6.994	5.217	0.536	0.465
2001	6.665	4.972	0.523	0.453
2002	6.591	4.917	0.527	0.457
2003	6.732	5.022	0.446	0.386
2004	6.693	4.993	0.469	0.407

Year	Lime		Dolomite lime	
	Production [Millions of t]	CO_2 emissions [Millions of t]	Production [Millions of t]	CO_2 emissions [Millions of t]
2005	6.535	4.875	0.474	0.411
2006	6.646	4.958	0.472	0.409
2007	6.874	5.128	0.469	0.406
2008	6.868	5.124	0.464	0.402
2009	5.501	4.104	0.342	0.296
2010	6.124	4.569	0.342	0.296
2011	6.331	4.723	0.350	0.304
2012	6.036	4.503	0.242	0.210
2013	6.196	4.622	0.218	0.189
2014	6.401	4.775	0.228	0.197
2015	6.251	4.663	0.248	0.215
2016	6.216	4.636	0.232	0.201
2017	6.123	4.568	0.241	0.209

Source: Production: Basic data from (BV Kalk, 2018); supplemented by UBA

Because the applicable emission factor in this category is constant, CO_2 emissions and lime / dolomite-lime production depend linearly on each other; as a result, the above statements regarding activity data apply to CO_2 emissions mutatis mutandis.

4.2.2.2 Methodological issues (2.A.2)

In burning of limestone and dolomite, CO_2 is released, and it reaches the atmosphere via the exhaust gas of the process. The pertinent emissions level is obtained by multiplying the amount of product in question (lime or dolomite lime) by the relevant emission factor. Use of the emission factors explained below, together with country-specifically determined lime-production figures, is a Tier 2 method within the meaning of the *2006 IPCC Guidelines* ((IPCC, 2006): Volume 3, Chapter 2.3.1.1).

Emission factors

The pertinent CO_2 emissions are calculated with the following factors:

EF_{lime} 0.746 t CO_2/t lime (stoichiometric 0.785 * oxide fraction 0.95)
$EF_{dolomite\ lime}$ 0.867 t CO_2/t dolomite lime (stoichiometric 0.913 * oxide fraction 0.95)

The emission factors used are based on the stoichiometric factors, as well as on the assumption that 95 % of the burnt lime consists of CaO, that 95 % of the dolomite lime consists of CaO • MgO and thus that 5 % of the total mass consists of impurities that are not CO_2-relevant. This approach is in accordance with the *2006 IPCC Guidelines* ((IPCC, 2006): Volume 3, Chapter 2.3.1.2).

Activity data

The German Lime Association (BVK) collects the production data for the entire time series, on a plant-specific basis, and makes them available for reporting purposes. The quantities produced by plants that are not included in the German Lime Association's association statistics are estimated on the basis of existing information (such as operator figures, and data published in the framework of emissions trading) and then added to the German Lime Association's figures. This ensures that all of German lime production is taken into account. Ever since the relevant method was changed to conform with the 2006 IPCC Guidelines, it is also being assumed that, in all years of the reporting period as of 1990, 2 % of the burnt lime is being separated out as dust, via suitable waste-gas-scrubbing systems, and is not being returned to the burning process. This is taken into account via a fictive 2 % increase in the pertinent activity data. The 2 % increase has no longer been applied since 2015, however, because since that year the activity data provided by the BV Kalk German lime-industry association have included the quantities of dust that are filtered out.

The manner in which the activity data are determined conforms with the Tier 2 approach of the *2006 IPCC Guidelines* ((IPCC, 2006): Volume 3, Chapter 2.3.1.3).

4.2.2.3 Uncertainties and time-series consistency (2.A.2)

The EU monitoring guidelines for emissions trading call for activity data to have an accuracy of 2.5 %. Since a) the German Lime Association's (BV Kalk's) lime-production data are based on operators' figures as provided in the framework of CO_2-emissions trading, b) those data have been obtained via two separate, parallel channels and thus are quality-assured, and c) the plants not included in the association's statistics (and thus assessed after the fact) represent only a small share of the total number of plants concerned, the **uncertainties** for the **activity data** used are estimated to be 2.5 % and +2.5 %. These figures apply to both burnt lime and dolomite lime.

The uncertainties for the emission factors used for burnt lime were estimated to be -11 % and +5 %. The uncertainties for the emission factors used for dolomite lime were estimated to be -30 % and +2 %.

4.2.2.4 Category-specific quality assurance / control and verification (2.A.2)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The BV Kalk German lime-industry association determines the production quantities by carrying out two surveys within the association. These surveys, of which one has a technical focus and one has a commercial focus, query the individual plants within the association, and they are cross-checked against each other. Any plant-specific discrepancies between the two surveys are clarified before the activity data are forwarded to the Federal Environment Agency (UBA). The activity data provided to UBA thus undergo adequate quality assurance (Tier 2).

The comparison with the available information from the ETS yielded discrepancies that can be explained as the result of differences in methods: on the one hand, as differences between the specifications in the ETS and on the part of the IPCC, and, on the other, as the result of methodological changes made between ETS trading periods. During the inventory review (ICR 2016), graphic comparisons were successfully used to show that the discrepancies, which are of methodological origin, provide no grounds to doubt the quality of the inventories' data.

The IPCC default factors used are suitable for the country-specific method.

The comparison with the emissions-trading figures for process-related emissions showed good agreement.

4.2.2.5 Category-specific recalculations (2.A.2)

In contrast to what had previously been assumed in this regard, as of the year 2015 the activity data provided by the BV Kalk German lime-industry association included the quantities of dust that were filtered out. For this reason, as of the year 2015, the fictive 2 % increase in the activity data is no longer required. Therefore, recalculations for the years 2015 and 2016 were required. The 2 % increase had to be deducted from the raw-material-related CO_2 emissions for those two years.

4.2.2.6 Planned improvements, category-specific (2.A.2)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.2.3 Mineral industry: Glass production (2.A.3)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
-/-	2.A.3. Mineral Products: Glass Production	Production of various types of glass	CO_2	780.48	0.06%	926.84	0.10%	18.8%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 2	AS	CS
NO_X, NMVOC, SO_2	Tier 2	AS	CS

The category *Mineral products*: *Glass production* is not a key category.

4.2.3.1 Category description (2.A.3 Glass production)

Germany's glass industry produces a wide range of different glass types with different chemical compositions. Germany's glass sector comprises the following sub-sectors: container glass, flat glass, domestic glass, special glass and mineral fibres (glass and stone wool). The sub-sectors with the highest production shares are container glass (accounting for about half of total glass production) and flat glass (about one-fourth of total glass production) (BV Glas, 2017, 2018a). The inventory calculations do not include the category "water-glass production". All relevant soda-ash quantities for water-glass production are taken into account in 2.A.4.b (Chapter 4.3.7).

In production, homogeneous glass mixtures combining primary and secondary raw materials are melted down at temperatures between 1,450 °C and 1,650 °C. The process-related CO_2 emissions under consideration here are released from the raw-material carbonates during the melting process in the furnace. CO_2 emissions – in small amounts – also occur in neutralisation of HF, HCl and SO_2 in exhaust gases, with the help of limestone or other carbonates. Because the amounts involved are so small, these emissions are not considered here.

The following table shows the trends, since 1990, in activity data, process-related CO_2 emissions and the implied emission factors resulting for all glass types overall.

Table 190: Activity data and process-related CO_2 emissions since 1990, for IEF covering all glass types

Year	Activity data [t]	Process-related CO_2 emissions [t]	IEF for all glass types [t CO_2/ t Glas]
1990	6,561,849	780,480	0.119
1991	7,202,807	821,376	0.114
1992	7,228,752	810,610	0.112
1993	7,074,837	778,104	0.110
1994	7,760,000	747,225	0.096
1995	7,621,300	881,306	0.116
1996	7,519,600	853,395	0.113
1997	7,392,000	833,771	0.113
1998	7,314,000	803,411	0.110
1999	7,442,239	822,236	0.110
2000	7,505,000	846,300	0.113
2001	7,293,000	846,289	0.116
2002	7,084,000	800,501	0.113
2003	7,205,720	788,726	0.109
2004	7,088,900	791,150	0.112
2005	6,948,400	802,746	0.116
2006	7,285,600	842,228	0.116
2007	7,535,300	829,060	0.110
2008	7,513,900	824,868	0.110
2009	6,784,100	745,664	0.110

Year	Activity data [t]	Process-related CO_2 emissions [t]	IEF for all glass types [t CO_2/ t Glas]
2010	7,163,600	828,828	0.116
2011	7,341,600	835,138	0.114
2012	7,079,700	823,341	0.116
2013	7,255,900	860,111	0.119
2014	7,458,900	891,901	0.120
2015	7,397,900	916,423	0.124
2016	7,476,817	923,498	0.124
2017	7,552,202	926,840	0.123

It is clear that emissions tend to follow the trend in activity data. At the same time, the implied emission factors indicate that the correlation is not rigid; some discrepancies do occur. The discrepancies are due to annual fluctuations in production quantities of various individual glass types, and in cullet inputs. They are thus logical and calculatorily correct. The IEF has been increasing overall, for all types of glass. This is due to absolute and relative increases of products causing higher emissions – especially mineral fibres.

Emissions of "precursor substances," which also occur in connection with glass production, are not discussed in the present context. Due to limitations in the UNFCCC software, they cannot be reported in the present category, however; they are reported in Chapter 4.2.4.4.

4.2.3.2 Methodological issues (2.A.3 Glass production)

The CO_2 emissions (the main pollutant) are calculated via a Tier 2 method, because the detailed activity data are tied to specific emission factors (that are in keeping with the relevant carbonate concentrations). The following carbonates are taken into account as the main sources of CO_2 formation during the melting process: Calcium carbonate ($CaCO_3$), soda ash / sodium carbonate (Na_2CO_3), magnesium carbonate ($MgCO_3$) and barium carbonate ($BaCO_3$). In the present context, the CO_2 emissions from all carbonates are reported as a sum; inputs of raw-materials – soda ash – are considered under 2.A.4.b (cf. 4.2.4.2). Here, it should be noted that the calculated soda-ash-input quantities cannot be published, because data on soda ash production (cf. 4.2.4.2.2) are subject to statistical confidentiality and may not be derivable from balance sheets.

The production figures (**activity data**) are taken from the regularly appearing annual reports of the Federal Association of the German Glass Industry (Bundesverband Glasindustrie). "Production" refers to the amount of glass produced, which is considered to be equivalent to the amount of glass melted down. It must be remembered that a fraction of the molten glass, corresponding to the quantity of internal cullet, is not included in production statistics (see also the remarks below regarding cullet inputs). As a result, the figures given in the statistics correspond not to the actual quantities of molten glass involved, but to the molten-glass quantities consisting of primary raw materials and external cullet. Further processing and treatment of glass and glass objects are not considered.

The following activity data were determined for 2016:

Table 191: Glass: Activity data for the various industry sectors (types of glass)

Industry sector	Activity data, 2017 [t]
Container glass	4,011,120
Flat glass	2,115,694
Glass fibre and wool	378,034
Special glass	355,940
Stone wool	644,501
Domestic glass	46,914

Source: (BV Glas, 2018a)

The following sector-specific cullet percentages are assumed:

Table 192: Cullet percentages for the various types of glass

Industry sector	Cullet percentage [%] in the input raw material
Container glass	58 – 65 (annually varying)
Flat glass	10 (entire time series)
Domestic glass	5 (entire time series)
Special glass	5 (entire time series)
Glass fibre and wool	40 (entire time series)
Stone wool	40 (entire time series)

Source: (Gitzhofer et al., 2008), and surveys of BV Glas

The cullet percentage for container glass is known only for the western German Länder as of 1990. For Germany as a whole, it is known for the period since 1995. No data are available for the new German Länder for the period from 1990 to 1994. For that reason, an average cullet percentage input was estimated on the basis of the various glass sectors' average percentages of total glass production. In 2007, the firm of Gesellschaft für Glasrecycling und Abfallvermeidung mbH (GGA) was forced to cease operations, under cartel law. As a result, no reliable cullet-input data have been available from that source since 2007. Since 2012, the Federal Association of the German Glass Industry (BV Glas) has provided data, from association surveys, on cullet inputs in the container-glass industry for the period as of 2007(BV Glas, 2018b). The various sectors' cullet fractions contain only external cullet, since internal cullet is not included in production statistics, which are the basis for the relevant activity data. The total cullet fraction in vats can be considerably larger when internal cullet is involved.

Since the exhaust gases occurring during the melting process are drawn off together with combustion-related exhaust gases – i.e. as a collective exhaust-gas stream – measurements cannot be used to determine the CO_2 quantities produced by the German glass industry. For this reason, a calculation procedure is used that is based on the weight shares for the aforementioned carbonates and on cullet input in the container-glass and flat-glass industry. Figures on the chemical composition of the various types of glass produced in Germany have been taken from VDI-Richtlinie (guideline) 2578 (VDI, 1999) and from the ATV-DVWK Merkblatt (standards sheet of the German Association for Water, Wastewater and Waste) 374 (ATV, 2004).

The procedure used to determine **emission factors** for the various glass oxides involved and the pertinent emissions is described in detail in the NIR 2007 (Chapter 4.1.7.2, p. 251ff.).

The emission factors below were calculated for the various industry sectors. The factors vary annually in keeping with variations in cullet inputs (ranges are given for container glass).

Table 193: CO_2-emission factors for various glass types (calculated in comparison with figures from the 2006 IPCC Guidelines)

Glass type	Calculated emission factor [kg CO_2/ t $_{molten\ glass}$] – stoichiometric / incl. cullet input –	Default emission factors [kg CO_2/ t $_{molten\ glass}$] - pursuant to 2006 IPCC Guidelines ((IPCC, 2006): Vol. 3, Tab. 2.6)-
Container glass	193 / 49 – 86*	210
Flat glass	208 / 187	210
Domestic glass	120 / 114	100
Special glass	113 / 107	30 – 200
Glass fibre	198 / 119	190 – 250
Stone wool	299 / 179	-
Unspecified	174 / 139	-

* Most recently, 81 kg CO_2 per t of molten glass

The stoichiometrically calculated emission factors are very similar to the default factors. The emission factors, with inclusion of cullet inputs, are considerably lower than the default values, since cullet inputs tend to be very high in Germany. In the sole exception, this EF relationship does not apply to household and table glassware – possibly, as a result of the high quality requirements involved, which entail low cullet inputs.

4.2.3.3 Uncertainties and time-series consistency (2.A.3 Glass production)

The production data have been taken from the internal statistics of the Federal Association of the German Glass Industry (BV Glas). Since that association represents nearly all of Germany's container-glass and flat-glass manufacturers, the sectoral data it provides are highly accurate. An uncertainty of 5 % was thus assumed. The association's representation of all other glass sectors is incomplete, and thus the association cannot guarantee the completeness of the data for such other sectors. For this reason, an uncertainty of 10 % was assumed for those areas. Until about 2002, BV Glas also cross-checked the data against data of the *Federal Statistical Office*.

The uncertainty in the cullet figures for container glass lies within the customary range for statistical determinations. For the new German Länder, an uncertainty of 20 % has been assumed, because no statistical survey has been carried out; only an estimate is available. Use of data from the association's own internal surveys, relative to cullet use as of 2007, increases the uncertainties. For example, surveys take account only of production sites' internal cullet and external container-glass cullet, and do not cover any quantities of flat glass that may be used in container-glass production.

The figures on cullet use for all other glass types are considerably less precise, however, since only estimates are available for those areas. An uncertainty of 20 % was thus assumed.

For the CO_2 emission factors, an uncertainty of 14 % is used in the case of container glass, and a figure of 22 % is used for all other types of glass.

4.2.3.4 Category-specific quality assurance / control and verification (2.A.3 Glass production)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the Single National Entity.

The calculated emission factors were compared with several different sources, including the IPCC Guidelines ((IPCC, 2006)) and the "Baden-Württemberg 2004 emissions declaration" ("Emissionserklärung 2004 Baden-Württemberg"; (UMEG, 2004)), an emission-factor manual. According to that comparison, the calculated emission factors may be considered accurate. In addition, the IEF was compared with those of the following countries, which also report on soda ash use only as an integrated part of glass production, i.e. do not report on it separately: Austria (0.10), Italy (0.11) and the Netherlands (0.13). These values are comparable to the German IEF for the glass industry (which fluctuates around 0.1).

The calculated emissions were also cross-checked against the ETS data for Germany. This showed that the calculated emissions were about 1.3% higher than the emissions pursuant to ETS. This can be attributed to the incomplete sector coverage in the ETS.

The information provided regarding the chemical composition of the various glass types continues to be considered correct in the present context. The applicable rate of cullet input, for which the data still need to be improved (cf. Chapter 4.2.3.3), has considerable influence in this regard.

4.2.3.5 Category-specific recalculations (2.A.3 Glass production)

Minimal category-specific recalculations were carried out in the activity data for the year 2016, to take account of final production figures provided for that year by the Federal Association of the German Glass Industry (BV Glas).

4.2.3.6 Planned improvements, category-specific (2.A.3 Glass production)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.2.4 Mineral industry: Other process uses of carbonates (2.A.4)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
-/-	2.A.4. Mineral Products: Other process uses of carbonates	0	CO_2	1,457.67	0.12%	1,088.32	0.12%	-25.3%

The overarching category 2.A.4 – *Mineral products: Other process uses of carbonates* is not a key category. This category's characteristics are determined primarily by the ceramics industry, with regard to both emissions quantities and the relevant methods' level of detail.

4.2.4.1 Mineral industry: Ceramics (2.A.4.a)

4.2.4.1.1 Category description (2.A.4.a Ceramics)

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 2	NS	CS
NO_X, NMVOC, SO_2	Tier 1	NS	CS

Germany's ceramics industry, like its glass industry, is highly diverse. It produces many different products, with many different chemical compositions, for many different applications. Along with clay (the main raw material involved), sand and other natural raw-material mixtures, the industry also uses synthetically produced substances, such as aluminium oxide and silicon dioxide. The following application areas can be differentiated within Germany's ceramics sector: Structural ceramics (bricks, tiles, drain pipes), structural ceramics (toilet bowls, washbasins), ceramic tableware (dinnerware, household porcelain), technical ceramics (insulators, structural components), fireproof ceramics (furnace walls, refractory concrete), ceramic bonded abrasives and expanded clay (VDI Guideline 2585) (VDI, 2006). The largest production quantities, in terms of percentages, are achieved in the bricks sector (about 80 % of total ceramics production), followed by the fireproof products (about 10 %) and tiles (about 6 %) sectors.

In ceramics production, homogeneous mixtures consisting largely of primary raw materials – and only small quantities of secondary raw materials – are fired, primarily in tunnel kilns and hearth furnaces, at temperatures between 1,100 and 1,300 °C. The firing durations, which normally amount to several hours (BREF CER 2007)(European Commission, 2007a), can vary, depending on the products involved. Significantly higher firing temperatures are used in connection with refractory products and technical ceramics. The process-related CO_2 emissions under consideration here are released during firing processes in kilns. Emissions are produced from both carbonate and fossil components of raw materials. In some cases, process-related CO_2 emissions are also produced by pore-forming agents (such as sawdust, papermaking sludges and polystyrene), which are used especially in brick production (clay blocks). In determination of CO_2 emission factors, only non-biogenic fractions are taken into account.

The "ceramics products" time series (cf. Table 194) comprise the activity data and process-related CO_2 emissions of the entire ceramics industry in Germany, for the period since 1990[51]. The non-CO_2 emissions (NO_X, NMVOC, SO_2, etc.) for the entire ceramics industry are calculated via these activity data.

Table 194: Activity data and process-related CO_2 emissions in the ceramics industry (CRF 2.A.4.a), since 1990

	Activity data [kt]		Process-related CO_2 emissions [kt][52]
	Total ceramics production	CO_2-relevant ceramics production[52]	
1990	17,658	15,594	1,122
1991	18,366	16,380	1,188
1992	19,517	17,595	1,308
1993	21,697	19,795	1,495
1994	25,095	23,301	1,815
1995	25,237	23,402	1,745
1996	22,932	21,314	1,588
1997	23,207	21,561	1,615
1998	23,214	21,558	1,587
1999	22,720	21,174	1,558
2000	21,563	19,895	1,444
2001	18,357	16,716	1,201
2002	17,208	15,531	1,109
2003	17,182	15,483	1,115
2004	17,481	15,744	1,120
2005	15,248	13,596	935
2006	16,454	14,683	1,054
2007	16,623	14,728	1,061
2008	14,572	12,707	904
2009	12,080	10,764	763
2010	13,353	11,686	826
2011	14,512	12,748	908
2012	14,125	12,528	897
2013	13,886	12,334	896
2014	13,674	12,077	872

[51] Expanded clay is not included here, since no pertinent data (production quantities / activity data) are available

[52] Clay blocks, facing bricks, bricks for floor and road surfaces, roof tiles and accessories, tiles, stoneware, vitrified clay pipes and other structural formed products, household and sanitary ceramics: Porcelain, household and sanitary ceramics: Stoneware, earthenware

	Activity data [kt]		Process-related CO_2 emissions [kt][52]
	Total ceramics production	CO_2-relevant ceramics production[52]	
2015	13,419	11,858	848
2016	13,771	12,239	896
2017	14,082	12,464	904

Source: Own calculations (UBA) pursuant to (Gottwald et al., 2017)

4.2.4.1.2 Methodological issues (2.A.4.a Ceramics)

The 2006 IPCC Guidelines for National Greenhouse Gas Inventories 2006 contain information for calculation of process-related CO_2 emissions for the ceramics industry ((IPCC, 2006): Volume 3, Chapter 2.5.1 "Ceramics"). In general, the following product groups are normally allocated to this industrial production sector: roof tiles and masonry bricks, stoneware pipes, refractory products, expanded clay, wall and floor tiles, household ceramics, sanitary ceramics, technical ceramics, inorganic bonded abrasives. With regard to produced quantities, the product groups roof tiles and masonry bricks, refractory products and wall and floor tiles are especially relevant. In keeping with the available data, the emissions calculations take account of nearly all the products involved.

With regard to assessment of methods, the 2006 IPCC Guideline provide only sketchy information pertaining to carbonate inputs. Because the present method takes account of additional CO_2 sources, it is considered to be a country-specific Tier 2 method.

Activity data

In the area of production data (activity data), data of the Federal Statistical Office are used. In the interest of completing the database for all product categories of the ceramics industry – also with regard to determination of process-related CO_2 emissions – the annual production quantities were determined for each product category, in the framework of an expert opinion prepared in cooperation with the Federal Statistical Office (Gottwald et al., 2017). The period covered by the project was 1990 – 2015. The data provided by the Federal Statistical Office varied/vary with regard to the units used (tonnes, square meters, unit counts, value). To enable the data to be processed in a consistent manner, all units have been converted into tonnes [t]. Where produced quantities are not available in units of tonnes [t], conversion factors have to be applied. The conversion factors used are given in the project report.

Emission factors

The process-related CO_2 emissions originate in the raw materials used for the production of ceramic products. Normally, these consist of locally available loams and clays containing varying fractions of non-biogenic carbon (such as carbonates) and organic carbon. In addition, small quantities of process-related CO_2 emissions are produced by pore-forming agents, which are added to raw materials used for production of clay blocks. Most of the porosity agents used are renewable resources (such as sludges from the paper industry, including some with fossil components, and paper fibres). Small quantities of non-renewable substances (especially polystyrene) are also used, however. (Organic) binders, which are also used, in small quantities, in production of refractory and abrasive products, also contribute to process-related CO_2 emissions, but only in insignificant quantities.

The product-specific emission factors needed for inventory determination of process-related CO_2 emissions were thoroughly revised. This took place in two steps: In a first step carried out with regard to statistical data, the project established designations for CO_2-relevant product groups (Gottwald et al., 2017); cf. chapter 3.5 - Emissionsfaktoren und Einschätzung der Emissionsrelevanz. Then, the German Emissions Trading Authority (DEHSt) calculated specific emission factors (Rothe, 2017). In the process, verified installation data (emissions reports, product allocations, production quantities, ash contents of raw-material samples) available to the DEHSt for the years 2012 through 2015 were used[53]. Data on product groups considered of relevance with regard to CO_2 emissions, but for which the DEHSt was unable to determine emission factors directly, were supplemented (expert judgements) with the help of assumptions and of analogies to other product groups (raw-material composition)[54]. As a result of this step-by-step assessment process, refractory products, ornamental articles, technical ceramics and abrasives were excluded from the CO_2 calculations.

The following specific CO_2 emission factors have been determined for the pertinent product groups.

Table 195: CO_2 emission factors for various product groups

Product group	CO_2 emission factor [t_{CO2} / $t_{product}$]	Remarks
tiles, stoneware	0.018	DEHSt
clay blocks	0.1047	DEHSt
facing bricks	0.0189	DEHSt
bricks for floor and road surfaces	0.016	DEHSt / UBA*
roof tiles, accessories	0.0112	DEHSt
vitrified clay pipes and other structural formed products	0.0112	DEHSt / UBA*
household and sanitary ceramics: porcelain	0.009	DEHSt / UBA*
household and sanitary ceramics: stoneware, earthenware	0.018	DEHSt / UBA*

* Emission factors determined via expert assessment (see the above description)

Thanks to thorough revision of the product-specific emission factors, it is possible to determine a meaningful implied emission factor (IEF) for the German ceramics industry. It is obtained from the process-related CO_2 emissions and the activity data for CO_2-relevant ceramics production for the relevant year (cf. Table 194). With this approach, an IEF of 0.0725 $t_{CO2}/t_{product}$ has been calculated for 2017[55].

4.2.4.1.3 Uncertainties and time-series consistency (2.A.4.a Ceramics)

In keeping with the required conversions of unit counts, volume data and area data to produced masses (tonnes [t]), as well as with the uncertainties tied to determination of production statistics, the uncertainties for the activity data are estimated as + 6 % / - 7 %.

The uncertainties for the **CO_2 emission factors** used for the product groups listed in Table 195 vary – in part, considerably. For example, the uncertainties for the clay blocks product group are -18 % / +18 %, while those for tiles are -53 % / +53 %. Most of the determined uncertainties are tied to the empirical data of the DEHSt. For emission factors that were not determined directly (such as those for ceramic pipes, etc.), uncertainties shares for analogies used have been added (for household and sanitary ceramics, for example, the result is -57 % / +57 %).

[53] Installations (with relevant product allocations) that are included in emissions trading pursuant to the German Greenhouse Gas Emission Allowance Trading Act (TEHG) (installations with production outputs > 75 t/d). This includes the product groups bricks, tiles and refractory products. Products in the groups porcelain, sanitary, abrasives, and others, are not included.

[54] In Table 184, the pertinent emission factors have been marked with an "*". With regard to the raw materials concerned, such expert judgements considered the issue of whether the materials contain carbonates or organic material and are thus comparable.

[55] This value differs from the CO_2 IEF given in the CRF tables because that IEF (i.e. in the tables) includes the total activity data for all ceramic products. In so doing, it also subsumes products that, due to their raw-material composition and intended quality levels, include no carbonates or CO_2-relevant additives.

Time-series consistency, relative to activity data, is assured for the majority of the product groups listed in Table 195 and for the pertinent CO_2 emission factors. The time series for a few product groups have breaks (as a result of changes in the availability of statistical data, or of past changes in product grouping); such breaks have been noted and described in (Gottwald et al., 2017). With regard to the CO_2 emissions for this area, such time-series breaks are either irrelevant or negligible.

4.2.4.1.4 Category-specific quality assurance / control and verification (2.A.4.a Ceramics)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

It is not feasible to compare the emission factors with the IPCC default emission factors, because the Guidelines' emission factors are based solely on raw materials, while the country-specific emission factors are based on products.

With respect to the CO_2 IEF, Germany's ceramics industry, like the ceramics industries of most of the other countries, lies within the lower / medium part of the range. A listing of all the IEF values shows a major "break," however. The IEF values of some countries are higher by a factor of 5 – 10. One reason for this could be that those countries use a different method for determining CO_2 emissions and CO_2 emission factors; possibly, they compute those values via the raw-materials inputs.

As a result of the thoroughgoing revision of the inventory method, the calculated CO_2 emissions figures are meaningful and comparable. In each case, they are higher than the corresponding ETS emissions figure. This can be attributed to the ETS' partial sectoral coverage.

The German brick and tile industry association (Bundesverband der Ziegelindustrie) has provided information regarding an ongoing research project in which product quantities play an especially important role. In light of that information, the underlying raw densities for the facing bricks, clay blocks and roof tiles product groups will have to be reviewed, and possibly adjusted, in future submissions. Since the pertinent raw densities have to be applied in conversions from volume units / piece units to weight, within these product groups, it is likely that the total CO_2 emissions, and other emissions parameters, for this area will change as a result. This does not mean that all of the methods for the ceramics industry have to be reviewed, however.

4.2.4.1.5 Category-specific recalculations (2.A.4.a Ceramics)

No recalculations are required.

4.2.4.1.6 Planned improvements, category-specific (2.A.4.a Ceramics)

Currently, no improvements are planned, apart from the review referred to in Chapter 4.2.4.1.4.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.2.4.2 Non-metallic minerals industry: other soda ash use (2.A.4.b)

4.2.4.2.1 Category description (2.A.4.b)

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1	NS	D

The overarching category 2.A.4 – *Mineral products: Other process uses of carbonates* is not a key category.

Soda ash is used in a wide range of industrial applications. The most important areas of use include the glass industry, production of detergents and cleansers and the chemical industry. It is assumed that the carbon contained in soda ash is released sooner or later, regardless of the use involved, into the air as CO_2.

Emissions resulting solely from use of soda ash correlate in a fixed way to the pertinent calculated quantities used – in this context, outside of the glass industry (cf. the methodological issues in the following chapter):

Table 196: Activity data and use-related CO_2 emissions outside of the glass industry, since 1990

Year	Activity data [t]	CO_2 emissions [kt]
1990	809,885	336.1
1991	587,756	243.9
1992	402,053	166.9
1993	379,687	157.6
1994	429,884	178.4
1995	340,793	141.4
1996	336,440	139.6
1997	387,823	160.9
1998	452,848	187.9
1999	394,164	163.6
2000	411,281	170.7
2001	490,469	203.5
2002	437,769	181.7
2003	529,515	219.7
2004	500,956	207.9
2005	517,159	214.6
2006	484,871	201.2
2007	550,966	228.7
2008	538,477	223.5
2009	457,076	189.7
2010	528,885	219.5
2011	587,144	243.7
2012	516,444	214.3
2013	591,149	245.3
2014	516,915	214.5
2015	470,288	195.2
2016	495,780	205.7
2017	444,888	184.6

Source: Calculations of the Federal Environment Agency (UBA); for pertinent derivation, cf. the following chapter

4.2.4.2.2 Methodological issues (2.A.4.b)

Activity data

Since the 2010 inventory review, those soda ash inputs are determined that are not taken into account, for emissions calculations, in other categories. The relevant calculations are oriented to the greatest possible emissions from the applicable soda ash use. The total quantity of soda ash used in Germany is determined via balancing (quantity produced plus imports and less exports) (a). The relevant import and export quantities are taken from the foreign-trade statistics of the Federal Statistical Office (Statistisches Bundesamt, o.J.). Emissions from soda ash use in the glass industry are already taken into account, category-specifically, under category 2.A.3 (b). The soda ash quantities used in that category are deducted from the soda ash use of relevance in the present section. The activity data in the above table (c) have been obtained in accordance with the following formula:

c = a minus b

The value of 'a' for the year 2017 had to be determined by carrying the mean value of the previous five years forward, because the Federal Statistical Office provided export figures that were so high as to be implausible. At the time the inventory was being prepared, clarification of those figures was still underway.

Emission factor

Stoichiometrically, the emission factor for soda ash use is 415 kg CO_2 per tonne of soda ash, under the assumption that release is complete (a conservative approach).

4.2.4.2.3 Uncertainties and time-series consistency (2.A.4.b)

Activity data

The calculations of the relevant quantities of soda ash used exhibit large uncertainties (maximally, -18%/+18%), as a result of statistical fluctuations in soda-ash production, and in foreign trade in soda ash, and as a result of the calculatory assumptions on which the above derivation is based.

Emission factor

The emission factor for soda ash use is subject to small, explained uncertainties in the area of product purity and the completeness of the chemical transformations involved (-5%/+0%).

4.2.4.2.4 Category-specific quality assurance / control and verification (2.A.4.b)

General quality control and quality assurance, according to the QSE-Handbook, were carried out by the Single National Entity.

It is not possible at present to verify quantitatively the input quantities of soda ash that cannot be allocated to the glass industry. The pertinent estimates are conservative, however; they do not underestimate the quantities of relevance for the inventory. Qualitatively, the pertinent calculation results do not contradict the sales figures of soda-ash producers obtained on a sample basis.

The stoichiometric emission factor is in keeping with the default figures given in the IPCC Guidelines ((IPCC, 2006): Volume 3, Chapter 2, Table 2.1).

4.2.4.2.5 Category-specific recalculations (2.A.4.b)

Recalculations for 2015 and 2016 were required, to take account of updating of production figures in the glass industry and of a correction of a calculation for 2015.

4.2.4.2.6 Planned improvements, category-specific (2.A.4.b)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.2.4.3 Production of non-metallurgical magnesium products (2.A.4.c)

4.2.4.3.1 Category description (2.A.4.c)

The greenhouse-gas emissions from this category amount to less than 0.05 % of the total inventory (not including LULUCF), and they are less than 500 kt CO_2-equivalents. What is more, relevant annual surveys cannot be assured (UNFCCC, 2013a). For this reason, we are not reporting on this area. The present chapter thus presents a one-time quantitative estimation of the emissions that are not covered by the inventory as a result. In addition, a compilation of all sources listed as "not estimated" is presented in Annex 5 in Chapter 21 of the present report.

4.2.4.3.2 Methodological issues (2.A.4.c)

It was not possible to identify any suitable activity data for this category segment in the official statistics. Some product types, such as refractory bricks, are already included in the activity data for the ceramics industry (CRF 2.A.4.a, Chapter 4.2.4). The additionally identified category "production of other carbonates" is a collective in which magnesium carbonates are a non-quantifiable sub-quantity. The resulting time series shows only production quantities less than 300,000 t. The lowest threshold for inclusion would be about one million tonnes of a product with large fractions of CaO and MgO. That production threshold is not achieved with any relevant product type. This also applies to the product types already included in other categories.

Because the pertinent statistics contain collective categories, the potential CO_2 emissions cannot be precisely calculated. They are estimated to be considerably less than 100,000 t of carbon dioxide.

4.2.4.3.3 Uncertainties and time-series consistency (2.A.4.c)

No conclusions relative to uncertainties and time-series consistency can be drawn.

4.2.4.3.4 Category-specific quality assurance / control and verification (2.A.4.c)

Due to resources limitations, and to the area's minimal relevance, no QC/QA has been carried out for reporting in this area.

An initial relevant estimate was made in the framework of a research project. It was then reviewed by the specialised contact person within the Federal Environment Agency (UBA) and confirmed in the above-described manner.

4.2.4.3.5 Category-specific recalculations (2.A.4.c)

Recalculations are not considered here, due to the fact that the relevant emissions are not listed.

4.2.4.3.6 Planned improvements, category-specific (2.A.4.c)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.2.4.4 Non-metallic minerals industry: other limestone and dolomite use (2.A.4.d)

4.2.4.4.1 Category description (2.A.4.d)

This category's carbon-dioxide emissions are not reported separately; instead, they are reported in the sections for the categories that use limestone and dolomite (they are thus included elsewhere – IE). In the relevant categories, they are also taken into account in key-category analysis.

Emissions of the precursor substances SO_2, NO_X and NMVOC are reported in this category whenever the UNFCCC's 'CRF Reporter Inventory Software' does not permit them to be entered in sub-categories. Specifically, the pertinent emissions include the following:

- NO_X and NMVOC from 2.A.1, 2.A.2 and 2.A.3,
- SO_2 from 2.A.2 and 2.A.3, including a statistical figure for the territory of the "New German Länder" (states) in 1990.
- As a result of this allocation, no figures for pertinent activities can be given in the CRF tables.

All other precursor substances are reported in the categories to which the emissions are assigned (no restrictions in the CRF-Reporter software apply).

Until the 2014 Submission, and in supplementation to the requirements set forth in the 1996 IPCC Guidelines, in this category all production and use of limestone and dolomite were considered in balance form, and the results were compared with the inventory categories. This "limestone balance" (Röhling & Kludt, 2010) appeared most recently in the 2014 NIR.

No findings are available regarding use of limestone in emissions-relevant sectors other than the categories listed below.

4.2.4.4.2 Methodological issues (2.A.4.d)

The following section provides an overview of national limestone inputs. Emissions calculations are carried out for those categories in which CO_2 emissions are produced via limestone use:

- 1.A.1.a Flue-gas desulphurisation in power stations (limestone inputs)
- 2.A.1 Cement-clinker production (limestone fraction in the relevant raw materials)
- 2.A.2 Limestone production (limestone inputs)
- 2.A.3 Glass production (limestone fraction in the relevant raw materials)
- 2.A.4.a Ceramics production (carbonate fraction in the raw materials)
- 2.B.7 Soda ash production (limestone inputs)
- 2.C.1 Iron and steel production (limestone inputs and lime kilns)
- 2.H.2 Sugar production (lime furnaces)
- 3.G Soil liming in agriculture and forestry (limestone and dolomite)

The pertinent data are updated in the relevant categories (cf. the above list). In addition, pertinent methodological aspects are explained in the relevant category chapters.

4.2.4.4.3 Uncertainties and time-series consistency (2.A.4.d)

Information regarding uncertainties for activity data and emission factors for the relevant limestone uses is provided in the relevant category chapters.

4.2.4.4.4 Category-specific quality assurance / control and verification (2.A.4.d)

General quality control and quality assurance, in keeping with the requirements of the QSE manual and its associated documents, have been carried out in those categories into which category 2.A.4.d leads.

The activity data and the emission factors for the relevant limestone uses are verified and updated in the relevant categories.

4.2.4.4.5 Category-specific recalculations (2.A.4.d)

Recalculations have been carried out in the relevant categories.

4.2.4.4.6 Planned improvements, category-specific (2.A.4.d)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.3 Chemical industry (2.B)

Category 2.B is divided into the sub-categories 2.B.1 through 2.B.10. These include ammonia production (2.B.1), nitric acid production (2.B.2), adipic acid production (2.B.3), caprolactam, glyoxal and glyoxylic acid production, (2.B.4), carbide production (2.B.5), titanium dioxide production (2.B.6), soda ash production (2.B.7), petrochemical and carbon black production (2.B.8) and production of fluorinated chemicals (2.B.9).

In the category *Other* (2.B.10), only precursor substances from production of fertilisers and sulphuric acid are reported. Production of dodecanedioic acid is described in 2.B.10, while process-related N_2O emissions are reported under 2.G.3, for reasons of confidentiality.

4.3.1 Chemical industry: Ammonia production (2.B.1)

4.3.1.1 Category description (2.B.1)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
L/-	2.B.1 Chemical Industry	Ammonia production	CO_2	6,025.00	0.49%	4,228.00	0.47%	-29.8%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 3	PS	PS
NO_X			D

The category *Chemical industry*: *ammonia production* is a key category for CO_2 emissions in terms of emissions level.

Ammonia is produced on the basis of hydrogen and nitrogen, using the Haber-Bosch process, which also forms CO_2. Hydrogen is produced from synthetic gas (usually) based on natural gas, via a highly integrated process, *steam reforming*, while nitrogen is produced via air dissociation.

The various plant types for the production of ammonia cannot be divided into individual units and be compared as independent process parts, due to the highly integrated character of the procedure. In *steam reforming*, the following processes are distinguished:

- ACP – *advanced conventional process* with a fired primary reformer and secondary reforming with excess air (stoichiometric H/N ratio)
- RPR – *reduced primary reformer process*, carried out under mild conditions in a fired primary reformer, and with secondary splitting with excess air (sub-stoichiometric H/N ratio)
- HPR – *heat exchange primary reformer process* – autothermic splitting with heat exchange using a steam reformer heated with process gas (heat exchange reformer) and a separate secondary reformer or a combined autothermic reformer using excess air or enriched air (sub-stoichiometric or stoichiometric H/N ratio).

The following procedure is also used:

- Partial oxidation – gasification of natural gas, fractions of heavy mineral oil or vacuum residues in production of synthetic gas.

As of mid-2014, ammonia is being produced in Germany at only four locations. The production operations use both the steam-reforming and partial-oxidation processes.

The production decrease of more than 15 % (corresponding to an amount of nearly 300 kt) in the first year after German reunification was the result of a market shake-up, over 2/3 of which was borne by the new German Länder. The production level then remained nearly constant in the succeeding years until 1994. It has not been possible to determine the reason for the renewed growth as of 1995, which returned production to the level seen in 1990. However, the growth could be due to resumption of production processes in the new German Länder, following extensive modernisations. Since 1995, production levels have fluctuated only slightly. The nearly 8% production decrease that occurred in 2009 was due to the global economic crisis. Until 2013, the IEF was higher than that of other countries, since in Germany heavy fuel oil is used for partial oxidation, in addition to natural gas. Heavy fuel oil produces significantly higher CO_2 emissions than natural gas does. Since mid-2013, partial oxidation has been carried out primarily with natural gas. In addition, sizable quantities of CO_2 are being captured and processed into urea for use in AdBlue, as well as for use as fertilizer. As a result, the IEF no longer differs significantly from those of other countries.

4.3.1.2 Methodological issues (2.B.1)

In keeping with this category's classification as a key category for CO_2 emissions, since the 2010 report the emissions data for this category have been collected and reported pursuant to Tier 3, apart from the data for one plant. Until 2012, those data were obtained pursuant to the Tier 2 method; a default figure for carbon content was used. As of 2013, all plant data have been obtained pursuant to the Tier 3 method. This is being carried out on the basis of a co-operation agreement with the relevant plant operators for delivery of plant-specific data.

The operators transmit their plant-specific data to the Industrieverband Agrar (IVA) agrochemical industry association. That association anomymises the data, for reasons of confidentiality, and then transmits it, in plant-specific form, to the Federal Environment Agency (UBA). The Federal Environment Agency carries out quality assurance and then aggregates the data.

The plant operators report:

- the ammonia quantities produced (**activity data**),
- the quantities of raw materials used in the process (natural gas, heavy mineral oil), less the pertinent fuel quantities used for energy purposes and so reported in the Energy Balance (TFR_i),
- the raw materials' carbon content factor (CCF_i) and carbon oxidization factor (COF_i),
- the quantity of CO_2 that undergoes further processing (R_{CO2}), and the purpose for which it is used.

CO_2 emissions:

The CO_2 emissions are calculated in keeping with Equation 3.3 in the 2006 IPCC Guidelines (IPCC, 2006):

$$E_{CO2} = \sum (TFR_i * CCF_i * COF_i * 44/12 - R_{CO2})$$

The recovered quantity of CO_2 that is used in other production processes – such as urea production – (and is reported in connection with those other processes) is not included in the non-reported emissions.

As of 2013, all ammonia plants are subject to emissions trading requirements. As a result, all plants meet emission-trading requirements pertaining to determination of carbon content.

One producer uses a standard factor that has been obtained via ongoing operational analysis (C content = 86.1 % by weight). Until 2013, a second producer used the IPCC default value for natural gas. For the other gases – the gas mixtures used – that producer determined the applicable C content levels analytically, on the basis of the C content levels of the individual gases contained and their quantity shares of the mixtures. In two cases, producers use the data provided by the relevant natural gas suppliers.

Emission factor for NO_x:

The emission factor that has been used for NO_X is the default emission factor given by the *CORINAIR Guidebook*, 1 kg/t HNO_3 ((EMEP, 2009): EMEP EEA Emission Inventory Guidebook, TFEIP-endorsed draft, May 2009).

4.3.1.3 Uncertainties and time-series consistency (2.B.1)

The uncertainties reported by the operators are aggregated by UBA, in keeping with Equation 3.2 ((IPCC, 2006): Vol. 1, Ch. 3), and entered into the tables.

The uncertainty for the activity data is ± 0.6 %. The uncertainty for the emissions is ± 1 %.

4.3.1.4 Category-specific quality assurance / control and verification (2.B.1)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

4.3.1.5 Category-specific recalculations (2.B.1)

No recalculations have been carried out.

4.3.1.6 Planned improvements, category-specific (2.B.1)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.3.2 Chemical industry: Nitric acid production (2.B.2)

4.3.2.1 Category description (2.B.2)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
L/T	2.B.2 Chemical Industry	Nitric acid production	N_2O	3,258.45	0.27%	492.82	0.06%	-84.9%

Gas	Method used	Source for the activity data	Emission factors used
N_2O	Tier 3	PS	PS

The category *Chemical industry*: *Nitric acid production* is a key category for N_2O emissions in terms of emissions level and trend.

In production of nitric acid, nitrous oxide occurs in a secondary reaction. In Germany, there are currently nine nitric acid production plants.

HNO_3 production occurs in two process stages:

- **Oxidation** of NH_3 to NO and
- **Conversion of** NO to NO_2 and **absorption** in H_2O.

Details of the process are outlined below:

Catalytic oxidation of ammonia

A mixture of ammonia and air at a ratio of 1:9 is oxidised, in the presence of a platinum catalyst alloyed with rhodium and/or palladium, at a temperature of between 800 and 950 °C. The relevant reaction, according to the Ostwald process, is as follows:

$$4\ NH_3 + 5\ O_2 \rightarrow 4\ NO + 6\ H_2O$$

Simultaneously, nitrogen, nitrous oxide and water are formed by the following undesired secondary reactions:

$$4\ NH_3 + 3\ O_2 \rightarrow 2\ N_2 + 6\ H_2O$$

$$\mathbf{4\ NH_3 + 4\ O_2 \rightarrow 2\ N_2O + 6\ H_2O}$$

All three oxidation reactions are exothermic. Heat may be recovered to produce steam for the process and for export to other plants and/or to preheat the residual gas. The reaction water is condensed in a cooling condenser, during the cooling of the reaction gases, and is then conveyed into the absorption column.

4.3.2.2 Methodological issues (2.B 2)

In keeping with the 2006 IPCC Guidelines (IPCC, 2006), nitric-acid production is now reported plant-specifically, in accordance with the Tier 3 standard. This is being carried out on the basis of a co-operation agreement with the relevant plant operators for delivery of plant-specific data. Through the 2014 reporting round, six operators sent data to the Industrieverband Agrar (IVA) industrial association. After carrying out quality assurance, the IVA aggregated the data, to protect confidentiality, and then transmitted the so-aggregated data to the Federal Environment Agency (AD and EF). Two companies sent their data (AD, EF and N_2O emissions, and information about any reduction equipment used) directly to the Federal Environment Agency. After carrying out quality assurance, the Federal Environment Agency then aggregated those companies' data with the data provided by the IVA and entered the so-aggregated data into the CSE emissions database.

The relevant cooperation agreement was adapted for the new commitment period and in keeping with the new 2006 IPCC Guidelines. The Federal Environment Agency now receives the plant-specific data for six operators, for a total of seven plants, in anonymised form, via the IVA. Two other operators send their data directly to the Federal Environment Agency.

The plant operators report:

- the quantities of nitric acid produced (**activity data**);
- the EF;
- the N_2O emissions measured in the raw gas;
- where emissions-reduction equipment is used, the N_2O emissions measured in the emissions-reduced exhaust gas;
- the uncertainties for the activity data, the emission factor and emissions reductions.

The emissions-control technologies used include, in some cases, catalytic decomposition directly following ammonia combustion.

Until 2006, production quantities correlated with the N_2O emissions. Subsequently, a considerable decoupling of production quantities and N_2O emissions has become apparent that is due to use of emissions-reduction equipment.

NO_X **emission factor:**

The emission factor that has been used for NO_X is the default emission factor given by the *CORINAIR Guidebook*, 10 kg/t NH_3 ((EMEP, 2009): EMEP EEA Emission Inventory Guidebook, TFEIP-endorsed draft, May 2009).

4.3.2.3 Uncertainties and time-series consistency (2.B.2)

Activity data:

The activity-rate uncertainty has been determined by the Federal Environment Agency in keeping with Equation 3.2 ((IPCC, 2006), Vol. 1, Ch. 3), on the basis of figures provided by the operators. The pertinent uncertainty is ± 1 %.

Emission factor:

For the N_2O emission factor, the operators give an uncertainty of ± 5 %.

4.3.2.4 Source-specific quality assurance / control and verification (2.B.2)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

4.3.2.5 Category-specific recalculations (2.B.2)

No recalculations have been carried out.

4.3.2.6 Planned improvements, category-specific (2.B.2)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.3.3 Chemical industry: Adipic acid production (2.B.3)

4.3.3.1 Category description (2.B.3)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
L/T	2.B.3 Chemical Industry	Adipic acid production	N_2O	18,076.68	1.48%	200.86	0.02%	-98.9%

Gas	Method used	Source for the activity data	Emission factors used
N_2O	Tier 3	PS	PS
NO_X, CO	NE	NE	NE

The category *Chemical industry*: *adipic acid production* is a key category for N_2O emissions in terms of emissions level and trend.

On an industrial scale, adipic acid is produced via oxidation of a mixture of cyclohexanol and cyclohexanone with nitric acid. In that reaction, considerable amounts of nitrous oxide (N_2O) are formed.

Until the end of 1993, the two sole German producers emitted all of their nitrous oxide directly into the atmosphere. One producer has since put into operation a system for thermal decomposition of nitrous oxide into nitrogen and oxygen. Decomposition takes place nearly completely. In 2009, a second, additional (i.e. redundant) thermal N_2O-decomposition facility was added. N_2O-decomposition rates of over 99% are now being achieved.

At the end of 1997, the other producer put a catalytic N_2O-decomposition system into operation that, in constant operation, achieves an N_2O-decomposition rate of 97-98 %. At the end of 2009, a second, redundant decomposition reactor was added.

Since 2010, N_2O emissions have decreased further, significantly, since the two producers have each installed a redundant waste-gas-treatment facility.

In March 2002, a third producer, with one plant, began production. That plant also uses the thermal N_2O-decomposition process. N_2O-decomposition rates of over 99% can now be achieved. Since 2013, that producer also has had the option of using a redundant emissions-reduction system if his primary system should fail.

The overall fluctuations in the decomposition rates – and, thus, in the residual emissions – are the result of functional impairments in the emissions-control equipment, of planned interruptions in their operation and of variances in production volumes.

From 1990 to the present, production has nearly doubled, as a result of growth in demand.

4.3.3.2 Methodological issues (2.B.3)

Since 1990, N_2O emissions from adipic acid production have been calculated on the basis of plant-specific data.

In those years in which no systems for reducing nitrous oxide emissions were in operation, the two producers only provided production-quantity data. The nitrous oxide emissions for that period – until 1994, for one facility, and until 1997, for the other – were calculated with the IPCC default emission factor. The calculation of N_2O emissions for those years is in keeping with a Tier 2 approach. For the subsequent period, the two producers continuously measured their nitrous oxide emissions and, in addition to providing data on production and on N_2O emissions, also provided the background information, on a confidential basis, that is needed to assess the precision of the reported data. The third producer has been measuring emissions continuously since 2013. In the period prior to that year, that producer had calculated, on the basis of the quantities of produced adipic acid and a suitable emission factor, the quantities of nitrous oxide that were emitted in two possible plant states (unreduced and reduced operation). Those calculations also took into account a) the periods of time for which each plant state was maintained, and b) the plant load levels. An emission factor, taking account of the quantities of adipic acid produced and the results of nitrous-oxide-concentration measurements, was determined for each of the two operational states. The emissions have not been recalculated, retroactively to the year 1990, following the change of the survey method in this area.

Determination of N_2O emissions on the basis of continuous nitrous oxide measurement is in keeping with the Tier 3 method set forth in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories ((IPCC, 2006): Vol. 3, Ch. 3.4.2.1).

4.3.3.3 Uncertainties and time-series consistency (2.B.3)

For installations with thermal decomposition, the 2006 IPCC GL ((IPCC, 2006): Vol. 3, Tab. 3.4) give uncertainties for the N_2O-decomposition rate of +/- 0.5%; for installations with catalytic decomposition, they give uncertainties of +/- 2.5%.

According to producers' information, the uncertainties for the emissions, regardless of what reduction process is used, lie within a range of about +/-1 to 6%. The range for the uncertainties relative to production quantities is given as <0.1% to about 1%. The uncertainty for the EF is thus set at 6 %, while that for the production quantities is set at 2%.

4.3.3.4 Source-specific quality assurance / control and verification (2.B.3)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the the Single National Entity.

Information provided by producers enjoys a high degree of confidentiality protection. For this reason, only emissions figures can be listed in the CRF tables. The reported emissions and activity data have been reviewed by a Federal Environment Agency expert and cross-checked against other data sources. .

Comparisons of the IEF with the IEFs of other countries are possible only to a limited degree; only Italy and the U.S. consistently report an emission factor for N_2O. The lower of those two IEFs is comparable to the German national emission factor. For this category, comparisons with PRTR data are not feasible.

Two of the three producers have each carried out a JI project. The results of those projects can be downloaded from the JI and CDM project database[56] of the German Emissions Trading Authority (DEHSt) (the relevant project IDs are DE-1000017 and DE-1000018). The inventory data have been compared with the projects' corresponding figures for the period 2008 through 2012 – and confirmed by that comparison.

4.3.3.5 Category-specific recalculations (2.B.3)

The N_2O emissions had to be changed for 2016, because one producer corrected his reported nitrous oxide emissions data for that year. The emissions in this category increased by 1% as a result.

4.3.3.6 Planned improvements, category-specific (2.B.3)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.3.4 Chemical industry: Caprolactam, glyoxal and glyoxylic acid (2.B.4)

4.3.4.1 Category description (2.B.4)

The category *Chemical industry*: *Caprolactam, glyoxal and glyoxylic acid* is not a key category.

Industrially, ε-caprolactam is the most important lactam. It is used primarily for production of PA 6. There are two producers in Germany.

Glyoxal is used in the production of a wide range of products. It serves to improve product properties. There is one producer. The process used by that producer for glyoxal production (oxidation of ethylene glycol during the gas phase) is not a source of process-related nitrous oxide emissions.

The producer reports that no glyoxal delivered to customers in Germany is processed into glyoxylic acid. We are not aware of any glyoxylic acid production in Germany from other raw materials.

4.3.4.2 Methodological issues (2.B.4)

Caprolactam

Both producers use a synthesis pathway via hydroxylammonium sulfate (HAS), in the production of which ammonia is oxidised. Ammonia oxidation is the factor primarily responsible for the N_2O emissions in the production process.

Both producers also employ a thermal waste-gas treatment system to destroy nitrous oxide. Both producers' systems have a redundant design. The temperatures involved are much higher than the decomposition temperature of nitrous oxide. As a result, only very small quantities of emissions occur.

For one of the two producers, the pertinent N_2O emissions are assigned to nitric acid production (2.B.2), in the interest of consistency with emissions trading data. A Tier 3 reporting method is used. For that system, therefore, "IE" is entered under 2.B.4a in the CRF Table.

With regard to the other producer's installation, the Single National Entity has access to detailed information that indicates that the pertinent post-combustion system can be assumed to

[56] cf.: https://www.jicdm.dehst.de/promechg/pages/project1.aspx

completely eliminate the nitrous oxide quantities involved. But since the operator of that system is not subject to measurement obligations, and in order to prevent any underestimation of nitrous oxide emissions from other emission sources, the N_2O emissions have been quantitatively estimated, on a one-time basis, using a Tier 2 method. For the estimate, a production capacity is derived from press reports[57], and from the 2006 IPCC-RL the N_2O standard emission factor for the production of caprolactam (9 kg N_2O/t caprolactam, pursuant to (IPCC, 2006): Vol. 3, Chapter 3.5, Table 3.5) is used. In addition, standard factors for thermal waste-gas treatment in adipic acid production (98.5 % reduction rate, and 99.91 % capacity utilisation, pursuant to (IPCC, 2006): Vol. 3, Chapter 3.4, Table 3.4), are used. The capacity utilisation factor for the redundantly designed waste-gas-treatment system is obtained from the 97% capacity utilisation factor for the main installation, and the 97% factor for the second installation that is used for the 3% during which the main system cannot be used. In using standard factors given by the IPCC-RL, Germany is following recommendations provided by the Expert Review Team for the 2016 In Country Review. For the year 2015, the estimate is 10.7 kt CO_2-eq. for this installation. On the basis of the installation's emissions level, the permissibility of reduced emissions reporting pursuant to FCCC/SBSTA/2013/L.29/Add.1, para 37(b) has been reviewed. To that end, the other installation's N_2O emissions were calculated on the basis of standard emission factors and the applicable production capacity. A total of 17.9 kt CO_2-eq. resulted for both installations taken together. Since the calculated N_2O emissions from the category account for less than 0.05 % of the total inventory (not including LULUCF), since they do not exceed 500 kt CO_2 equivalents, and since annual recording cannot be carried out (in keeping with FCCC/SBSTA/2013/L.29/Add.1, para 37), we opt not to report on this area ((IPCC, 2006): Vol. 3, Ch. 3.5). . In addition, a compilation of all sources listed as "not estimated" is presented in Annex 5 in Chapter 21 of the present report. In the CRF Table, the two installations are listed under 2.B.4.a, and marked as "IE" and "NE," respectively. That notation is in keeping with the information and recommendations provided in the In Country Review.

4.3.4.3 Uncertainties and time-series consistency (2.B.4)

For the activity data, an uncertainty of ± 30% is assumed. For the standard factors, the pertinent uncertainties given in the 2006 IPCC-GL (IPCC, 2006) apply.

4.3.4.4 Source-specific quality assurance / control and verification (2.B.4)

Due to limited resources and minimal relevance QA/QC has not been conducted for this years reporting in this category.

Only a few sources are available that can serve as a basis for verification of the producer information given in press reports. For the years 1995 through 2008, quantity data for ε-caprolactam production are available ((Statistisches Bundesamt, FS 4, R 3.1), Produzierendes Gewerbe, Produktion im Produzierenden Gewerbe ("manufacturing industry, production in the manufacturing industry"). Since 2009, produced quantities of ε-caprolactam have no longer been listed separately, as a result of adaptations to international classifications. As a result, statistical surveys of produced quantities of ε-caprolactam have not been possible since then. ε-caprolactam does continue to be listed separately in foreign-trade statistics. Data on import quantites since 1996, and on export quantities since 2009, are available in such statistics. The import and export quantities have remained relatively stable.

[57] Inter alia BASF Press information P293/16 – "BASF richtet Caprolactam-Produktion in Europa" ("BASF sets up caprolactam production in Europe")
New in https://www.basf.com/documents/corp/de/news-and-media/news-releases/2016/09/P293_Neuausrichtung_Caprolactam_Produktion_Europa.pdf (Aufruf 25.10.2017)

4.3.4.5 Category-specific recalculations (2.B.4)

No recalculations are required.

4.3.4.6 Planned improvements, category-specific (2.B.4)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.3.5 Chemical industry: Carbide production (2.B.5)

4.3.5.1 Category description (2.B.5)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
-/-	2.B.5. Chemical Industry	Carbide production	CO_2	443.16	0.04%	4.31	0.00%	-99.0%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 3	PS	PS (CaC2) NO (SiC)

The category *Chemical industry*: *Carbide production* is not a key category.

During the reunification period, calcium carbide production took place primarily in the new German Länder. A short time later, production there was discontinued, while only one producer remained in the old German Länder. According to the responsible specialised association within the VCI, no silicon carbide has been produced in Germany since 1993. Emissions from this sector thus no longer occur.

4.3.5.2 Methodological issues (2.B.5)

Activity data:

Since Germany has only one producer, the relevant data must be kept confidential. The producer communicates the data directly to the Federal Environment Agency on an annual basis. The data, as of the data for 1997, were obtained from the operator's life cycle assessment and from his annual environmental declarations pursuant to the EMAS (the facility has been certified since 1997). The only published data consists of those for amounts produced in the former GDR. Those data were published, until 1989, by that country's central statistical authority. Those figures were used, in combination with existing estimates for 1991 and 1992, to interpolate production in the new German Länder in 1990.

Emission factor:

The stoichiometric emission factor for CO_2 is 688 kg per tonne of calcium carbide (44 g mol^{-1} / 64 g mol^{-1}). Until 1992, this emission factor was used for production in the new German Länder.

Using covered furnaces, producers collect all of the carbon monoxide produced in the process and use it for energy generation. The resulting carbon dioxide serves as auxiliary material in production of calcium cyanamide and derived products. Reactions in these processes yield carbon dioxide in mineral form, as black chalk. In this form, it is used in agriculture. In 2012, carbide-furnace operations were smoothed out in a way that considerably reduced the amount of surplus furnace gas that had to be flared off. The new operational mode has also enabled the furnaces to run more "calmly", meaning that they produce fewer pressure surges that have to be buffered via raw-gas flares. The emission factor also includes the CO_2 emissions from flare use.

As a result, the emission factor for carbon dioxide from calcium carbide production is now substantially lower than it has been in previous years.

Upon request, the relevant producer provides the Federal Environment Agency with data on total emissions and on quantities produced. The emission factor is obtained by dividing the emissions quantity by the activity data.

4.3.5.3 Uncertainties and time-series consistency (2.B.5)

The uncertainties relative to the data provided by the producer are considered slight overall.

4.3.5.4 Category-specific quality assurance / control and verification (2.B.5)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

Producers' relevant figures enjoy a high degree of confidentiality protection. For this reason, only emissions figures can be listed in the CRF tables. No calculations for verification could be carried out. It may be noted, however, that some of the figures have also been provided to licensing authorities and thus are considered trustworthy.

4.3.5.5 Category-specific recalculations (2.B.5)

No recalculations have been carried out.

4.3.5.6 Planned improvements, category-specific (2.B.5)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.3.6 Chemical industry: Titanium dioxide production (2.B.6)

There are several producers of titanium dioxide in Germany. One of the plants involved produces titanium dioxide via the chloride process. The others produce using the sulfate process, and emit no process-related CO_2. The estimate of the pertinent CO_2 emissions is an expert estimate. It has been made on the basis of the production capacity and of an emission factor that itself is based on an expert estimate. This estimate was made with confidential data that, by virtue of their confidentiality, cannot be presented here.

Since the greenhouse-gas emissions from the category titanium dioxide production account for less than 0.05 % of the total inventory (not including LULUCF), *and* since they would not exceed 500 kt CO_2 equivalents (significance thresholds pursuant to FCCC/SBSTA/2013/L.29/Add.1), and since annual recording cannot be assured (in keeping with FCCC/SBSTA/2013/L.29/Add.1, para 37), we opt not to report on this area ((IPCC, 2006): Vol. 3, Ch. 3.7). In addition, a compilation of all sources listed as "not estimated" is presented in Annex 5 in Chapter 21 of the present report.

4.3.7 Chemical industry: Soda-ash production (2.B.7)

4.3.7.1 Category description (2.B.7)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
-/-	2.B.7. Chemical Industry: soda ash	production of soda ash	CO_2	667.25	0.05%	460.12	0.05%	-31.0%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1	NS	CS

The category *Soda ash production* is not a key category.

In Germany, soda ash is produced only chemically. The country has 3 production facilities that use[58] the Solvay process[59]. In principle, the CO_2 contained within the calcium carbonate used in the process is bound within the product, soda ash (Na_2CO_3), and is released – if at all – only when that product is used. But since production via the Solvay process yields a CO_2 surplus, process-related CO_2 emissions result.

In the calcination part of the process, coke / anthracite is also used, and this produces additional (energy-related) carbon-dioxide emissions.

4.3.7.2 Methodological issues (2.B.7)

Activity data

The *Federal Statistical Office* determines the total amounts of soda ash produced in Germany. From 1995 to 2008, the sum total has comprised the categories of *light soda* (production number 2413 33 103, disodium carbonate in powder form, with a fill density of less than 700 g/l) and *heavy soda* (production number 2413 33 109, other disodium carbonate). Since 2009, light and heavy soda have been reported in combination, in one position (notification number 2013 43 100). Of that quantity, only the portion "intended for sale" ("zum Absatz bestimmt") is taken into account. This prevents double-counting, since heavy soda is produced from light soda. Since Germany has only two producers, the production-quantity data, which are taken from official statistics, must be kept confidential.

Emission factor

The emission factor is calculated from the carbon dioxide emissions, as determined in keeping with the pertinent ETS-CO_2 balance, and from the production quantities involved. Since the production-quantity data, as taken from official statistics, has to be kept confidential, the relevant EF cannot be given here.

The coke quantity used in burning the relevant lime has already been included in the Energy Balance as a non-energy-related use (i.e. without inclusion of CO_2 emissions).

4.3.7.3 Uncertainties and time-series consistency (2.B.7)

Activity data

There are uncertainties regarding the production statistics given by the Federal Statistical Office, since – for example – the relation between light and heavy soda ash fluctuates widely, especially in the first years for which separate statistics are provided.

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[58] Other processes that are less important in terms of the production quantities involved are not considered here, because they use carbon dioxide from sources other than limestone.

[59] Ammonia-soda process pursuant to Ernst Solvay

Emission factor

The uncertainty of the emission factor, with regard to production of soda ash, is calculated from the uncertainties for the ETS emission balance and the uncertainties for the pertinent production data.

4.3.7.4 Source-specific quality assurance / control and verification (2.B.7)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The CO_2 balance for determination of the relevant emissions is produced with the help of data from emissions trading. Those data have been fully checked and verified in the framework of the EU Emissions Trading System (ETS).

4.3.7.5 Category-specific recalculations (2.B.7)

Recalculations were needed only to take account of an updated – and only slightly adjusted – figure for the year 2016.

4.3.7.6 Planned improvements, category-specific (2.B.7)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.3.8 Chemical industry: Petrochemical and carbon black production (2.B.8)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
-/-	2.B.8. Petrochemical and carbon black production		CO_2	973.97	0.08%	885.47	0.10%	-9.1%
-/-	2.B.8. Petrochemical and carbon black production		CH_4	333.69	0.03%	501.68	0.06%	50.3%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 2 (carbon black) CS (petrochemical industry)	NS	D (carbon black) CS (petrochemical industry)
CH_4	Tier 1	NS	D
CO, SO_2	Tier 1 (carbon black)	NS	D (carbon black)
NMVOC	Tier 1 (petrochemical industry)	NS	C & CS (petrochemical industry)

The category *Chemical industry*: *Petrochemical and carbon black production* is not a key category. Carbon-black production predominates in this category, accounting for about 75 % of its emissions.

4.3.8.1 Chemical industry: Petrochemicals (2.B.8 Petrochemicals)

4.3.8.1.1 Category description (2.B.8 Petrochemicals)

The petrochemicals sector produces basic organic chemicals, from natural gas and from petroleum fractions, that are processed into a great many different intermediate and end products (primarily polymers). Under 2.B.8, the 2006 IPCC Guidelines (IPCC, 2006) list production of the basic chemicals (a) methanol, (b) ethylene, (c) ethylene chloride and vinyl chloride, (d) ethylene oxide and (e) acrylonitrile on account of the carbon dioxide and methane emissions such production can entail.

Production of petrochemicals and derivatives, along with production of pharmaceuticals, production of fine and specialty chemicals and production of polymers, is one of the most important sectors of the chemical-pharmaceutical industry in terms of production value[60].

4.3.8.1.2 Methodological issues (2.B.8 Petrochemicals)

Activity data

No installation-related data are available with regard to production of the above products; only nationally aggregated production quantities are available. The data, for the period as of 1990, are provided to the Federal Environment Agency by the Federal Statistical Office on the basis of its Fachserie 4, Reihe 3.1, "Produzierendes Gewerbe, Produktion im Produzierenden Gewerbe" (Statistisches Bundesamt, FS 4, R 3.1). They include confidential data.

In official production statistics, petrochemicals and derivatives are listed as "other basic organic substances and chemicals" ("sonstige organische Grundstoffe und Chemikalien") under WZ-Nummer (number within the German Classification of Economic Activities) 20.14.

The data on acrylonitrile-production quantities are subject to confidentiality requirements. The production-quantity data for methanol and ethylene dichloride are subject to confidentiality requirements in certain years. For these reasons, all production quantities for the products in groups a) through e) are aggregated and then reported, together with the pertinent CO_2 and CH_4 emissions, under 2.B.8.g.

For determination of NMVOC emissions, production of products that have to be reported under the CLRTAP is also taken into account, in addition to production of the products in groups a) through e). Detailed reporting on products that have to be reported under the CLRTAP is provided in the Informative Inventory Reports (IIR) pursuant to the CLRTAP.

CO_2 emission factors

Since 2013, pursuant to Annex 1 Part 2 Activity No. 27 German Greenhouse Gas Emission Allowance Trading Act (TEHG), all of the installations located in Germany for production of the aforementioned organic basic chemicals have been subject to the EU Emissions Trading System (ETS), because their production outputs are greater than 100 t/d (36,500 t/a).

A comparison of a) the total CO_2 emissions of the ETS installations pursuant to a) through e) that have been reported for purposes of the greenhouse-gas-emissions-trading system with b) the CO_2 emissions for the year 2013 as calculated with the new IPCC standard emission factors shows that the standard emission factors lead to higher emissions. And this proves to be the case even though the total installation-related emissions from emissions trading include both emissions from combustion processes and other process-related emissions. In the German greenhouse-gas inventory, most combustion-related emissions are already taken into account via the energy statistics for the energy sector. The standard emission factors thus cannot be used – their use would result in double-counting.

Along with combustion processes in boilers and cracking furnaces, the CO_2 emission sources to be considered include combustion processes in flares, decoking processes and other process-related emissions.

It would not be justified to quantify the other process-related emissions, since the installation-related CO_2 emissions of steam cracker units, which are far and away the largest group of emitters considered in this context, occur almost exclusively via combustion in cracking furnaces, auxiliary

[60] Chemiewirtschaft in Zahlen 2016, Verband der Chemischen Industrie e.V. (2017) https://www.vci.de/services/publikationen/broschueren-faltblaetter/chemiewirtschaft-in-zahlen.jsp

boilers or flares. With the exception of flares in the petrochemical industry, such combustion-related emissions are included in the energy-sector section in 1.A.2.c.

The CO_2 emissions from flaring losses are quantified, however, in order to fulfill the inventory aim of recording emissions as completely as possible. In future, decoking processes will also be included. Only that fraction of flare gases is considered that can be allocated to the aforementioned products in groups a) through e).

Since pre-2013 ETS data are not available for all of the aforementioned products, the CO_2 emissions are calculated on the basis of a CO_2 emission factor derived for 2013 and of the annually produced quantities of the relevant products.

Because residual gases and flare gases are often transported between installations (with different installations producing different products), it seems useful to use an emission factor that is aggregated over all of the products considered in this category. As a result of this aggregation, uncertainties in allocation of emissions of the aforementioned production processes to the products listed under a) through e) are taken into account, especially because CO_2 emissions from flares of the aforementioned installations are not necessarily tied to just one of the products in categories a) through e). At chemical industry sites, gases from various different production processes that need to be flared are often flared in a central flare that, in terms of its licensing, is allocated only to one production installation. As a result, in such cases, the emissions quantity allocated to a given product can be greater than the emissions quantity actually caused by the relevant production process. On the other hand, gases from processes a) through e) that need to be flared may be transported to a flare in an installation that is not considered in the present context, with the result that the emissions quantity considered is lower than the actual product-related emission quantity involved.

The flare emissions (ETS data) allocated to the various relevant chemical-industry installations for the year 2013 have been summed and then divided by the total production quantity for all products in a) through e) that were produced in 2013; this yields the emission factor for flaring losses (EFflaring). The flare emissions of the steam cracker units are refinery sites have been determined via the units' known capacities. The resulting EFflaring for the aforementioned petrochemicals is 28 kg/t product. That emission factor has been used to retroactively calculate annual emissions, using a Tier 1 method, back to 1990.

CH_4 emission factors

The IPCC Guidelines list all of the aforementioned installations as potential emission sources.

Pursuant to Point 5.2.5 of the TA Luft (Technical Instructions on Air Quality Control), German plants subject to the TA Luft must meet a standard of 50 mg/m^3 (total carbon) for total mass concentration of organic substances (NMVOC and CH_4, but not including organic substances in dust form). The current state of the art provides for thermal post-combustion of volatile organic substances from plants for production of primary organic chemicals.

A major German producer has reported that the methane emissions occurring in areas involving ethylene, methanol, ethylene dichloride and styrene are negligible, thanks to the thermal post-combustion processes employed since the 1980s.

No data from emissions trading can be used for reporting on methane emissions from chemical industry installations, since the currently valid German Greenhouse Gas Emission Allowance Trading Act (TEHG) of July 2011 does not mandate reporting on CH_4. Furthermore, since no information from other installation operators is available that could be used for quantification of CH_4 emissions, the methane emissions for all petrochemical industry installations as a whole are calculated via a Tier 1 method, with the IPCC 2006 standard emission factors ((IPCC, 2006): Vol. 3, Ch. 3.9.2.2).

NMVOC emission factors

The NMVOC EF have been obtained from the relevant BREF (Best Available Techniques Reference Document) and from confidential figures provided by German producers. Until 1994, the default factors in EMEP/CORINAIR Emission Inventory Guidebook were used. Relevant detailed reporting is provided in the Informative Inventory Report pursuant to the CLRTAP.

4.3.8.1.3 Uncertainties and time-series consistency (2.B.8 Petrochemical industry)

CO_2

The "backward projection" of the aforementioned production-related emission factor for flaring losses, from the 2013 emissions reports to earlier years (back through 1990) is subject to large uncertainties. On the one hand, in many cases the flare emissions reported in the ETS for report year 2013 were determined and reported on the basis of estimates. On the other, it must be assumed that CO_2 emissions from the flares allocated to the relevant installations, under licensing law, cannot be completely assigned to production of the products in groups a) through e). For example, gases (including waste gases) from other production processes are burned in the flares under consideration here. What is more, over time, installations can make local internal changes in routing of waste gases from various processes. Such changes further increase the uncertainty of "back-calculated" product-specific emissions. In addition, the ratios of production quantities to flare gases, for the installations considered, can differ considerably in various years from the corresponding ratios in 2013.

Due to limited data availability, the possibility that some energy-sector items are being double-counted cannot be completely ruled out. Extrapolation of flare emissions of steam cracker units also contributes to the uncertainty of the emission factor. An uncertainty of ± 50 % is thus being assumed.

Consistency of the time series is assured, because a consistent method was used to calculate the emissions back through 1990, and because there are no gaps in the activity data and no jumps (discontinuities) in the emission factor.

CH_4

In the 1980s, thermal post-combustion was introduced on a large scale. As a result, point-source emissions of organic substances from German plants are likely to be low. Use of standard emission factors is probably leading to overestimation of the emissions. Since the resulting uncertainties cannot be estimated, the Tier-1-method uncertainties given in Table 3.27 of the 2006 IPCC Guidelines ((IPCC, 2006): Vol. 3) have been used.

Consistency of the time series is assured, because a consistent method was used to calculate the emissions back through 1990, and because there are no gaps in the activity data and no jumps (discontinuities) in the emission factors.

Activity data

The activity data have been taken from official statistics for which inaccuracies of ±20 in statistical data collection are assumed.

4.3.8.1.4 Category-specific quality assurance / control and verification (2.B.8 Petrochemical industry)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the Single National Entity.

The quantity of ethylene produced in 2013, as reported by the Federal Statistical Office, was compared with capacity data provided by the Association of Petrochemical Producers in Europe (APPE; Petrochemicals Europe[61]). The resulting national standard capacity-utilisation factor of 0.858 is comparable to the standard capacity-utilisation factor pursuant to Article 18 (2) of Commission Decision 2011/278/EU (European Commission, 2011).

It is not possible to compare the national emission factor for CO_2 with the standard CO_2 emission factors given in the 2006 IPCC Guidelines, and with the emission factors of the other countries, because those emission factors do not include any CO_2 emissions from flares.

No further sources are available for data verification.

4.3.8.1.5 Category-specific recalculations (2.B.8 Petrochemical industry)

No recalculations are required.

4.3.8.1.6 Planned improvements, category-specific (2.B.8 Petrochemical industry)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.3.8.2 Chemical industry: Carbon black production (2.B.8 Carbon black)

4.3.8.2.1 Category description (2.B.8 Carbon black)

Carbon black is produced via incomplete combustion of gaseous or liquid hydrocarbons. Defined specifications for carbon black are achieved by carefully controlling and monitoring production processes. In Germany, carbon black is produced from hard-coal-tar oils (anthracene oils) and from oils produced by petroleum refineries (pyrolysis / cracking oils).

A total of 90 % of the carbon black produced in Germany is produced via the furnace black process. The remaining 10 % is produced via the flame-pressure and gas black processes.

4.3.8.2.2 Methodological issues (2.B.8 Carbon black)

CO_2 emissions

A comparison of the CO_2-emissions figures reported to date with the figures reported to the German Emissions Trading Authority (DEHSt) showed that the latter figures (the CO_2 emissions reported to the DEHSt) are considerably lower. An additional installation, which is not subject to emissions-trading requirements, has been considered in this regard, but its CO_2 emissions do not suffice to explain this difference. Consultations with the existing data supplier have suggested that sales figures – instead of production figures – are being reported in some cases for the production statistics being used. The activity data used to date was thus too high, to a considerable degree. As of 2005, therefore, the DEHSt emissions figures are used and, with the default emission factor from the 2006 IPCC Guidelines ((IPCC, 2006): Vol. 3, Table 3.23, Furnace Black Process (default process), primary feedstock), the activity data are back-calculated. The unknown emissions of an

[61] Website: http://www.petrochemistry.eu

additional installation not subject to emissions-trading requirements have been estimated. That installation was decommissioned in 2016, along with another installation that was subject to emissions-trading requirements. Five installations, operated by a total of two operators, are still in operation in Germany.

CH_4 emission factors

The international guidelines give very little attention to this source category. The IPCC Guidelines list carbon black production as a potential emission source.

Pursuant to Point 5.2.5 of the TA Luft (Technical Instructions on Air Quality Control), German plants subject to the TA Luft must meet a standard of 50 mg/m^3 (total carbon) for total mass concentration of organic substances (NMVOC and CH_4, but not including organic substances in dust form). In keeping with these technical standards, the three German producers of carbon black report an emission factor of 0.027 kg methane per tonne of carbon black. Since the relevant technology has been in service since the 1970s, this EF is rounded off to 0.03 kg/t and applied to the entire time series.

Emission factors for NMVOC, CO and SO_2

For pollutants other than the methane considered above, the emission factors listed in the following table were used for Germany.

Table 197: Emission factors used in Germany for other pollutants

	Carbon black [kg CO / t]	Carbon black [kg SO_2/t][62]
1990	4.8 / 5	19.5 / ([63])
1991	4.6 / 5	19 / 20
1992	4.4 / 5	18.5 / 20
1993	4.2	18
1994	4	17.5
1995	3.75	17
1996	3.5	16
1997	3.25	15
1998	3	14
1999	2.9	13.4
2000	2.8	12.8
2001	2.7	12.54
2002	2.65	12.28
2003	2.6	12.0
2004	2.55	11.7
2005	2.5	11.5
2006	2.5	11.2
2007	2.5	10.9
2008	2.5	10.6
2009	2.5	10.3
since 2010	2.5	10.0

The EF figures for CO and SO_2, for production of carbon black, are based on the BREF Large Volume Inorganic Chemicals - LVIC – S (European Commission, 2007b) and are identical with the default values presented in the 2008 CORINAIR manual (first order draft).

[62] Where two EF are listed, the second figure refers to the new German Länder.

[63] No EF is listed for the new German Länder, since these SO_2 emissions can be taken account of only as a lump sum.

Activity data

The production statistics of the Federal Statistical Office include the following products (cf. the following table).

Table 198: Reporting numbers (Meldenummern) from production statistics

Line	Carbon black
through 1994	4113 70
from 1995 through 2005	2413 11 300

The figure for carbon-black production in the new German Länder in 1990 was taken from the Statistical Yearbook (Statistisches Jahrbuch) for the Federal Republic of Germany ((Statistisches Bundesamt, 1992): p. 234); the figures for 1991 and 1992 were estimated, due to confidentiality requirements. The other data for carbon black production as of 1990 have been taken from the Federal Statistical Office ((Statistisches Bundesamt, FS 4, R 3.1): Produzierendes Gewerbe, Produktion im Produzierenden Gewerbe ("Manufacturing industries, production in manufacturing industries")). For the period as of 2005, the activity data are back-calculated from the CO_2 emissions, using the default CO_2 emission factor.

4.3.8.2.3 Uncertainties and time-series consistency (2.B.8 Carbon black)

While the activity data are seen to fluctuate somewhat over time, their fluctuations are largely in keeping with global economic fluctuations.

4.3.8.2.4 Category-specific quality assurance / control and verification (2.B.8 Carbon black)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

4.3.8.2.5 Category-specific recalculations (2.B.8 Carbon black)

The emissions have been downwardly corrected corrected for the period 2005 through 2015. This change has been carried out in order to take account of a correction of the emission calculation.

Carbon black	EM new	EM old	Difference, EM CO_2	EM new	EM old	Difference, EM CH_4	AR new	AR old	Difference, AR
	t CO_2	t CO_2	t CO_2	t CH	t CH	t CH	t	t	t
2005	706,102	741,407.10	-35,305.10	10.81	11.35	-0.54	360,256.12	378,268.93	-18,012.81
2006	735,610	772,390.50	-36,780.50	11.26	11.82	-0.56	375,311.22	394,076.79	-18,765.56
2007	749,876	787,369.80	-37,493.80	11.48	12.05	-0.57	382,589.80	401,719.29	-19,129.49
2008	683,391	717,560.55	-34,169.55	10.46	10.98	-0.52	348,668.88	366,102.32	-17,433.44
2009	605,210	635,470.50	-30,260.50	9.26	9.73	-0.46	308,780.61	324,219.64	-15,439.03
2010	746,556	783,883.80	-37,327.80	11.43	12.00	-0.57	380,895.92	399,940.71	-19,044.80
2011	675,887	709,681.35	-33,794.35	10.35	10.86	-0.52	344,840.31	362,082.32	-17,242.02
2012	631,059	662,611.95	-31,552.95	9.66	10.14	-0.48	321,968.88	338,067.32	-16,098.44
2013	647,815	680,205.75	-32,390.75	9.92	10.41	-0.50	330,517.86	347,043.75	-16,525.89
2014	695,180	729,939.00	-34,759.00	10.64	11.17	-0.53	354,683.67	372,417.86	-17,734.18
2015	697,469	732,342.45	-34,873.45	10.68	11.21	-0.53	355,851.53	373,644.11	-17,792.58
2016	722,624	722,624	0.00	11.06	11.06	0.00	368,685.71	368,685.71	0.00
2017	630,489			9.65			321,678.06		

4.3.8.2.6 Planned improvements, category-specific (2.B.8 Carbon black)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.3.9 Chemical industry: Fluorochemical production (2.B.9)

KC	Category	Activity	EM of	1995 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1995-2017
L/T	**2.B.9 Fluorochemical production**		**HFC**	**5,335.15**	**0.44%**	**65.24**	**0.01%**	**-98.8%**
-/-	2.B.9. Fluorochemical production		SF_6	159.60	0.01%	78.75	0.01%	-50.7%
-/-	2.B.9. Fluorochemical production		PFC	C	C	C	C	C

Gas	Method used	Source for the activity data	Emission factors used
HFC	Tier 3	PS	PS
SF_6	Tier 3	PS	PS

The category *Fluorochemical production* is a key category for HFC emissions in terms of emissions level and trend. It is subdivided into 2.B.9.a By-product emissions and 2.B.9.b Fugitive emissions.

4.3.9.1 By-product emissions (2.B.9.a)

4.3.9.1.1 Category description (2.B.9.a)

For process-related reasons, production of HCFC-22 produces up to 3 % HFC-23 as a by-product. For technical reasons, even when the HFC-23 is subjected to further processing (for example, to produce refrigerants) or is collected and then broken down into other substances, some HFC-23 is always released into the atmosphere.

Germany formerly had two production plants for HCFC-22. Those two plants, which were operated by a single company, were located in Frankfurt and Bad Wimpfen. In 1995, a CFC-cracking plant went into operation in Frankfurt that cracked, at high temperature, excess HFC-23 produced during production of HCFC-22 and that recovered hydrofluoric acid; i.e. no significant emissions were produced. HFC-23 produced at the second German production facility was captured in large amounts at the production system itself; the substance was then sold as a refrigerant or – following further distillative purification – as an etching gas for the semiconductor industry. Beginning in 1999, the excess amount that could not be sold was delivered to the cracking facility in Frankfurt. That measure substantially reduced emissions. In mid-2010, HCFC-22 production was terminated at one site. At the other site, it was significantly reduced, and all remaining production serves teflon production. The production quantities have remained at a constant low level since then. Since the installation is directly connected to a CFC-cracking plant, only very slight emissions occur.

4.3.9.1.2 Methodological issues (2.B.9.a)

In keeping with manufacturer information from 1996, HFC-23 emissions are assumed to have remained constant in the years 1990 to 1994.

Beginning in 1995, the producer calculated emissions, via a mass-balance procedure, on the basis of HCFC-22 production, HFC-23 concentrations in exhaust gas (as measured annually), sales of HFC-23 and quantities of HFC-23 delivered to the cracking plant. For reporting year 1995, emissions-reduction measures (the cracking plant) for the first production plant were assumed to have been in place since mid-year. Since report year 2011, the relevant production quantities have been estimated by experts, and the resulting estimates have been used to determine the emissions. The estimates are made in light of comparable production facilities in other European countries.

Activity data

There is only one HCFC producer in Germany. That company's data, therefore, are subject to confidentiality. Until 2010, the emissions and production quantities were reported to the Federal Environment Agency, but only in aggregated form. Since 2011, data of the Federal Statistical Office have been used. The activity data for HFC-23 are reported together with those for HFCs, PFCs and SF_6, as an "unspecified mix," in 2.B.9.

Emission factors

An emission factor of 0.15 kg HFC-23 / kg HCFC-22 is used for the period as of 2011.

Emissions

Until 2010, the relevant HFC-23 emissions were reported by the producer. Since 2011, experts' assessments have been relied on as well.

Since there are fewer than three producers in Germany, the emissions data are confidential. The HFC-23 emissions are reported as an "unspecified mix" in 2.B.9, as an aggregate of 2.B.9a and 2.B.9b.

4.3.9.1.3 Uncertainties and time-series consistency (2.B.9.a)

The production data on which the emissions calculation is based have been obtained from the Federal Statistical Office, and may be assumed to be very precise.

4.3.9.1.4 Source-specific quality assurance / control and verification (2.B.9.a)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

No other data sources, apart from the data provided by the Federal Statistical Office and the producer, are available for review of the F-gas quantities determined for emissions reporting purposes, i.e. for review that would serve as a basis for verification. Comparisons with other countries have revealed no requirements for improvements. The emission factors are of the same order of magnitude as those of other European countries.

4.3.9.1.5 Category-specific recalculations (2.B.9.a)

No recalculations are required.

4.3.9.1.6 Planned improvements, category-specific (2.B.9.a)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.3.9.2 Production-related emissions (2.B.9.b)

4.3.9.2.1 Category description (2.B.9.b)

In Germany, one company produces these gases; its HFC und SF_6 production takes place at two locations. Emissions trends are tied to trends in amounts produced. While SF_6 and HFC-134a are produced in Germany, until 2008 no complete synthesis of HFC-227ea was carried out in Germany. Part of the HFC-227ea produced in Tarragona, Spain, undergoes subsequent distillation, in Germany, to pharmaceutical purity (use in dosing aerosols). That process produces emissions as a result of minor gas losses.

HFC-134a has been produced since 1994, while HFC-227ea has been produced since 1996.

Emissions of HFC-134a have remained relatively constant since 2011. The fluctuations seen result from slight differences in annual production quantities.

Emissions of HFC-227ea have been increasing since 2009, in parallel with increases in production quantities. An exception is seen in 2012, in which less HFC-227ea was sold, and thus the emissions level was lower.

Between 1990 and 1994, CF_4 (PFC-14) was also produced in Germany.

4.3.9.2.2 Methodological issues (2.B.9.b)

Emission factors

It is possible to calculate an emission factor from the emissions and production quantities reported by the producer until 2010. That emission factor is assumed to remain applicable – i.e. the emission factor is assumed to remain constant – in subsequent years. The emission factor is not published, however, because the underlying data are confidential.

Activity data

Because the HFC producer in Germany is the country's sole producer, that company's data are confidential. Until 2010, the emissions and production quantities were reported to the Federal Environment Agency, but only in aggregated form. Since 2011, data of the Federal Statistical Office have been used.

4.3.9.2.3 Uncertainties and time-series consistency (2.B.9.b)

The production figures used as a basis for emissions calculation may be considered highly accurate, since they come directly from the producer's internal records or from official statistical surveys.

4.3.9.2.4 Category-specific quality assurance / control and verification (2.B.9.b)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

No other data sources, apart from the data provided by the Federal Statistical Office, are available for review of the F-gas quantities determined for emissions reporting purposes, i.e. for review that would serve as a basis for verification. Comparisons with other countries have revealed no requirements for improvements. The emission factors are of the same order of magnitude as those of other European countries.

4.3.9.2.5 Category-specific recalculations (2.B.9.b)

No recalculations are required.

4.3.9.2.6 Planned improvements, category-specific (2.B.9.b)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.3.10 Chemical industry – other: Emissions from other production processes (2.B.10)

4.3.10.1 Category description (2.B.10)

The GHG precursor substances from production of fertilisers and sulphuric acid are reported in this category. While N_2O emissions from production of dodecanedioic acid are described here, they are included in 2.G.3, for reasons of confidentiality. Among dicarboxylic acids, dodecanedioic acid ranks second, in terms in terms of the quantities involved. It is surpassed only by adipic acid in this regard. There is one producer in Germany.

4.3.10.2 Methodological issues (2.B.10)

N_2O emissions

The N_2O emissions are calculated via a Tier 2 method. The relevant production-quantity data were taken from a one-time query of the producer. The data are carried forward. The N_2O emissions have been greatly reduced, via waste-gas treatment in a treatment facility.

4.3.10.3 Uncertainties and time-series consistency (2.B.10)

Time-series consistency is assured, because the data set resulting from one-time data collection has also been applied to the other years involved. Since the figures are based on qualitative information provided by the manufacturer, and refer only to one year, large uncertainties, of + 300 % / - 20 %, have to be assumed.

4.3.10.4 Source-specific quality assurance / control and verification (2.B.10)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

4.3.10.5 Category-specific recalculations (2.B.10)

No recalculations are required.

4.3.10.6 Planned improvements, category-specific (2.B.10)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.4 Metal production (2.C)

Category 2.C is divided into the sub-categories 2.C.1 through 2.C.7. In the CSE emissions database, the sub-category Iron and steel production (2.C.1) includes sinter production, pig-iron production, production of direct-reduced iron (DRI), iron and steel production and production of tempered castings. Production of ferroalloys (2.C.2) has only minor importance in Germany. For this reason, it is not further subdivided in the present report. Aluminium production (2.C.3) is sub-divided into primary aluminium and resmelted aluminium. Use of SF_6 in aluminium and magnesium production (2.C.4) is not further sub-divided. In the Central System of Emissions (CSE), sub-point (2.C.5) comprises lead production. (2.C.6) comprises zinc production. (2.C.7) includes copper production (2.C.7a), nickel production (2.C.7b) and other production (2.C.7c). No greenhouse-gas emissions result in Germany from these categories.

4.4.1 Metal production: Iron and steel production (2.C.1)

4.4.1.1 Category description (2.C.1)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
L/T	2.C.1 Metal Production: Iron and steel production	Steel (integrated production)	CO_2	22,810.29	1.86%	18,060.12	2.03%	-20.8%
-/-	2.C.1. Metal Production: Iron and steel production	Steel (integrated production)	N_2O	26.54	0.00%	15.55	0.00%	-41.4%
-/-	2.C.1. Metal Production: Iron and steel production	Steel (integrated production)	CH_4	4.67	0.00%	5.29	0.00%	13.4%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 2	NS	CS
CH_4	Tier 2	NS	CS
N_2O	CS	NS	CS
NO_X, CO, NMVOC, SO_2	Tier 2	NS	CS

The category *Iron and steel production* is a key source of CO_2 emissions in terms of emissions level and trend. Along with carbon dioxide, slight emissions of methane and nitrous oxide also occur in this category. The methane emissions result from production of rolled steel and from production of iron, steel and malleable cast iron. The nitrous oxide originates in primary steel production, in connection with use of blast furnace gas in hot-blast stoves.

Since the CRF-Reporter software does not allow nitrous oxide to be allocated to 2.C.1, it is reported in 2.C.7 instead.

In 2017, a total of 30.4 million t of raw steel, from ore, was produced in Germany in six integrated steel works. Electric steel production amounted to 13.2 million t.

4.4.1.2 Methodological issues (2.C.1)

This sector comprises process-related emissions from primary steel production (via sinter plants, blast furnaces and oxygen-steel plants) and from electric steel plants.

Other structural elements in this category (foundries: iron and steel casting (including malleable casting); steel production: rolled-steel production) are used for calculation of other pollutant emissions (not greenhouse-gas emissions).

Process-related CO_2 emissions from primary steel production in integrated smelters result primarily from use of reducing agents in blast furnaces. CO_2 emissions from limestone inputs in sinter plants and in pig-iron production (including the CO_2 emissions from the lime kilns operated by the steel industry), and CO_2 emissions from electrode consumption in electric steel production, are added to process-related emissions in sector 2.C.1.

Very little direct-reduced iron (DRI; sponge iron) is produced in Germany (only about 0.6 million t. per year). Annual production-quantity data are available for the entire time series, but they are confidential, because they refer solely to a single installation.

The CO_2 emissions that occur in DRI production result from the use of natural gas, i.e. from use of a reducing-agent mixture, comprising H_2 and CO, obtained from natural gas. The relevant quantities of natural gas used are included, throughout the entire time series, in the natural-gas inputs in the steel industry that are reported under 1.A.2.a. Consequently, the CO_2 emissions resulting from DRI production are also included, throughout the entire time series, in the emissions reported under 1.A.2.a.

The process-related CO_2 emissions from DRI production cannot be listed separately under 2.C.1, because a) no separate data on the pertinent natural gas quantities consumed are available, for reasons of confidentiality; and b) because such disclosures could be used to derive the confidential production-quantity data for the relevant installation.

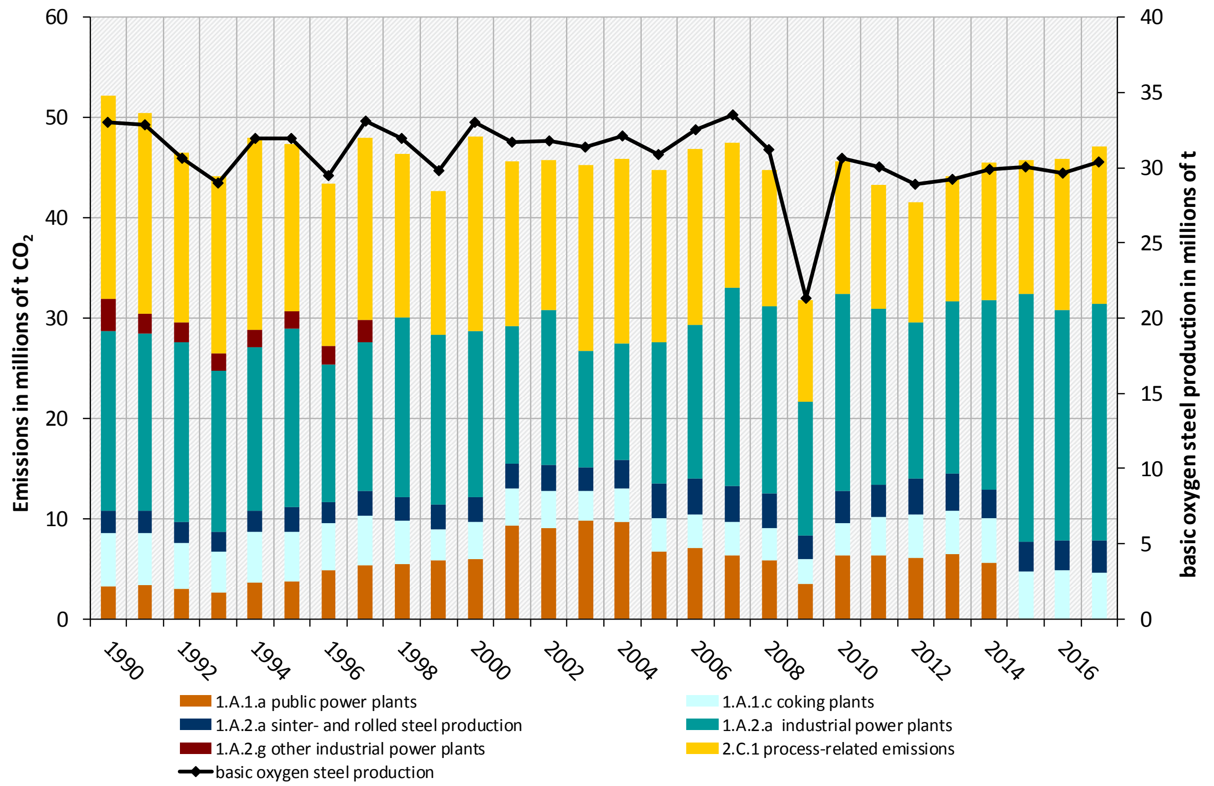
Method for calculating the CO_2 emissions resulting from use of reducing agents in blast furnaces

Pursuant to the IPCC Guidelines, the CO_2 emissions in category 2.C.1 are to be determined via a carbon balance. The reason for this requirement is that virtually all of the carbon used for primary steel production is subsequently released into the atmosphere, as CO^2, in later energy-related use, or in flaring, of the blast furnace gas that forms in the blast furnace or of the basic oxygen furnace gas that forms in the oxygen steel converter. The fraction of pig iron that is not converted into steel is less than 1 %. For this reason, the carbon fraction it contains is not relevant (about 0.1 %) by comparison with the CO_2 emissions tied to inputs of reducing agents. A similar situation applies with regard to the carbon fraction in manufactured steel. A rough calculation places the size of that fraction at about 60,000 t/a, which is equivalent to the carbon inputs via the input raw materials (ores and scrap)[64].

The inputs of reducing agents in blast furnaces, and material inputs in converters, are statistically recorded in great detail. The Steel Institute VDEh provides the relevant data to the Federal Environment Agency annually. The carbon content in the various materials used is calculated from emissions trading data. CO_2 emission factors for use of blast furnace gas and basic oxygen furnace gas are also available from emissions trading. The input gas quantities are taken from energy statistics. Calculation on the basis of a) carbon inputs and of b) carbon removals via use of blast-furnace / basic oxygen furnace gas yields a difference. Those CO_2 emissions are reported in category 2.C.1. Only part of all energy-related use of blast furnace gas and basic oxygen furnace gas takes place in category 2.C.1 (this the energy-related use in hot-blast stoves in blast furnaces). Such gas is also used for other process combustion in the iron and steel industry (1.A.2.a); in coking plants, for bottom heating of coking furnaces (1.A.1.c); and for electricity generation in public power stations (1.A.1.a) and industrial power stations (1.A.2.f). Energy statistics provide data on consumption of blast furnace gas and basic oxygen furnace gas in all of the aforementioned categories. Consequently, the CO_2 emissions resulting from reducing-agent inputs for primary steel production are divided among all categories in which blast furnace gas and basic oxygen furnace gas are burned and, thus, CO_2 is actually emitted (cf. the following figure).

[64] The average carbon fraction in the more than 2000 types of steel produced in Germany is not recorded statistically. According to the steel plants taking part in emissions trading, the average carbon content of manufactured raw steel is estimated to be 0.15 %. A rough calculation indicates that the non-energy-related carbon discharge via the manufactured steel is equivalent to the carbon input via iron ore (which has a carbon content of about 0.1 %) and recycled scrap (a carbon content of about 0.15 %),

Figure 45: CO_2 emissions from use of reducing agents for primary steel production and from use of blast furnace gas – trend, and category allocation



The sum of the CO_2 emissions shown correlates well with the activity data reported for primary steel production (cf. the black line). Annual fluctuations in the individual categories are probably due to changes in allocation of individual plants within official statistics. Such fluctuations have practically no impact on the total sum of reported emissions, however.

Table 199: CO_2 emissions from primary steel production (including use of blast-furnace gas)

Mt CO_2	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1.A.1.a Public power stations	3.244	3.291	3.015	2.631	3.647	3.764	4.816	5.305	5.465	5.808
1.A.1.c Coking plants	5.340	5.251	4.590	4.083	5.066	4.924	4.707	4.969	4.362	3.145
1.A.2.a Sinter and rolled-steel production	2.228	2.256	2.046	1.936	2.081	2.445	2.151	2.419	2.255	2.444
1.A.2.a Industry power stations	17.886	17.660	17.927	16.098	16.326	17.759	13.624	14.935	17.975	16.933
1.A.2.f Other industry power stations	3.206	2.025	1.942	1.707	1.720	1.770	1.932	2.144	0.000	0.000
2.C.1 Process emissions	20.228	19.961	16.942	17.693	19.074	16.736	16.204	18.194	16.255	14.317
Mt CO_2	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
1.A.1.a Public power stations	5.956	9.284	9.030	9.766	9.640	6.738	7.086	6.370	5.851	3.425
1.A.1.c Coking plants	3.652	3.741	3.684	3.029	3.356	3.247	3.281	3.226	3.226	2.500
1.A.2.a Sinter and rolled-steel production	2.520	2.487	2.629	2.265	2.788	3.461	3.603	3.642	3.437	2.315
1.A.2.a Industry power stations	16.573	13.627	15.406	11.709	11.695	14.164	15.351	19.748	18.675	13.429
1.A.2.f Other industry power stations	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.C.1 Process emissions	19.379	16.493	14.979	18.509	18.418	17.154	17.586	14.452	13.614	10.135

Mt CO_2	2010	2011	2012	2013	2014	2015	2016	2017
1.A.1.a Public power stations	6.276	6.258	6.080	6.465	5.533	0.014	0.000	0.000
1.A.1.c Coking plants	3.245	3.895	4.289	4.341	4.554	4.648	4.872	4.618
1.A.2.a Sinter and rolled-steel production	3.198	3.217	3.646	3.715	2.787	3.015	2.912	3.231
1.A.2.a Industry power stations	19.705	17.553	15.512	17.173	18.890	24.735	22.955	23.532
1.A.2.f Other industry power stations	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.C.1 Process emissions	13.144	12.367	12.046	12.429	13.727	13.278	15.103	15.687

In the iron and steel industry, secondary fuels are used only in pig iron production in blast furnaces. To date, these materials have not yet been included in national statistics and the Energy Balance. For this reason, the data used consisted of figures provided by the Wirtschaftsvereinigung Stahl steel-industry association. Since the secondary fuels are used solely as substitute reducing agents, in place of coke, the CO_2 emissions resulting from their use are also included in the CO_2 emissions determined via inputs of blast furnace gas and basic oxygen furnace gas and do not have to be calculated separately.

Determination of CO_2 emissions from limestone inputs in pig iron production

CO_2 emissions from limestone use are determined in accordance with Tier 1 ((Lechtenböhmer et al., 2006a), FKZ 20541217/02). The steel industry uses limestone ($CaCO_3$) in sintering plants and in pig iron production in blast furnaces. In oxygen steel and electric steel mills, burnt lime for steel-mill applications (CaO) is used as a slag former (as a rule, it is purchased from the lime industry sector); the CO_2 emissions released in producing that burnt lime are thus already reported under 2.A.2. Only one steel mill meets its lime requirements with the help of lime kilns of its own whose production quantities, and related CO_2 emissions, are not included in the data reported under 2.A.2. The quantities produced by these lime kilns are estimated on the basis of available figures for the mill's crude-steel production (for a more precise description, cf. the 2016 NIR).

From the so-determined activity data, only the raw-material-related CO_2 emissions, calculated via a stoichiometric EF, are reported in 2.C.1 – in a procedure similar to that used for 2.A.2 (cf. Table 200). The CO_2 emissions from energy inputs in steel mills' own lime kilns, emissions which are not separately listed in the Energy Balance, are included in the emissions reported under 1.A.2.a.

Until 2004, limestone inputs in sinter and pig iron production were published as part of iron and steel statistics ((Statistisches Bundesamt, FS 4, R 8.1)). Since then, they have to be calculated from the production quantities of sinter and pig iron reported by the association, via specific input factors (i.e. kg of limestone per tonne of sinter or pig iron) (reported in the framework of the so-called "BGS form" (Fuel, gas and electricity industries of blast furnaces, steelworks and rolling mills; and forging plants, press works and hammer mills, including the various other plants (without their own coking plants)). Multiplying the activity data for limestone inputs by the stoichiometric emission factor for limestone produces the CO_2-emissions figures given in Table 200.

Table 200: Limestone inputs in the steel industry; and the steel industry's own production of burnt lime, and the resulting CO_2 emissions

Year	Limestone input [t/a]		Own production		CO_2 emissions [t/a]	
	Blast furnaces	Sinter plant	Burnt lime [t/a]	Limestone inputs	Lime production	Total
1990	755,737	4,680,775	153,918	2,392,065	114,823	2,506,888
1991	757,000	4,532,000	147,439	2,327,160	109,990	2,437,150
1992	666,000	4,198,000	136,560	2,140,160	101,874	2,242,034
1993	627,000	3,891,000	129,458	1,987,920	96,575	2,084,495
1994	733,000	4,173,153	140,003	2,158,707	104,443	2,263,150
1995	751,000	4,600,000	139,973	2,354,440	104,420	2,458,860
1996	686,000	4,350,000	129,177	2,215,840	96,366	2,312,206
1997	629,000	4,471,000	145,351	2,244,000	108,432	2,352,432
1998	677,000	4,588,000	140,157	2,316,600	104,557	2,421,157
1999	817,000	4,144,000	130,704	2,182,840	97,505	2,280,345
2000	924,000	4,273,000	144,991	2,286,680	108,163	2,394,843
2001	866,000	4,136,000	138,859	2,200,880	103,588	2,304,468
2002	831,000	3,940,000	139,538	2,099,240	104,096	2,203,336
2003	832,525	4,046,711	137,468	2,146,864	102,551	2,249,415
2004	847,689	4,209,871	140,977	2,225,326	105,169	2,330,495
2005	787,724	4,306,067	134,550	2,241,268	100,374	2,341,642
2006	822,920	4,410,408	162,500	2,302,664	121,225	2,423,889
2007	840,868	4,608,067	149,500	2,397,531	111,527	2,509,058
2008	790,216	4,541,174	136,500	2,345,812	101,829	2,447,641
2009	547,680	3,496,405	97,500	1,779,397	72,735	1,852,132
2010	799,679	4,045,042	130,000	2,131,677	96,980	2,228,657
2011	782,420	3,457,145	123,500	1,865,408	92,131	1,957,539
2012	757,355	3,912,824	117,000	2,054,879	87,282	2,142,161
2013	760,932	3,926,706	130,000	2,062,561	96,980	2,159,541
2014	782,447	3,945,838	130,000	2,080,446	96,980	2,177,426
2015	794,999	3,987,196	149,500	2,104,166	111,527	2,215,693
2016	**780,445**	**3,750,267**	**149,500*)**	**1,993,514**	**111,527*)**	**2,105,041**
2017	**797,856**	**4,120,243**	**149,500*)**	**2,163,964**	**111,527*)**	**2,275,491**

Source: Until 2004: Calculation of limestone inputs by the "limestone balance" project ((Lechtenböhmer et al., 2006a), FKZ 20541217/02);
as of 2005: Calculation via the product-specific factors determined in the aforementioned project
*) Updated via expert judgement, due to a lack of data on raw-steel production of the relevant plant

Determination of CO_2 emissions from electrode consumption in production of electrical steel

In electrical steel production, CO_2 emissions occur directly via consumption of graphite electrodes. These emissions must also be allocated to process-related CO_2 emissions for steel production. They are calculated from the quantity of produced electrical steel, via an emission factor (7.4 kg/t) that was updated in 2009, in a research project (Hensmann et al., 2012), and that is based on the specific electrode consumption per tonne of electrical steel (2.06 kg/t), its carbon content (98%) and the relevant stoichiometric factor (3.667 t CO_2 / t C). The contribution from electrode combustion in electrical steel production, at about 0.2% of total CO_2 emissions in iron and steel production, is insignificant.

Determination of the total CO_2 emissions from iron and steel production to be reported under 2.C.1

The total process-related emissions to be reported under 2.C.1 consist of the following:

10. the CO_2 emissions resulting from use of reducing agents in primary steel production, where the relevant blast furnace gas and basic oxygen furnace gas is not used in other categories and thus reported under other categories as CO_2 emissions,
11. the CO_2 emissions from limestone inputs in pig iron production and from the steel industry's own production of burnt lime, and
12. the CO_2 emissions from electrode consumption in electrical steel production.

The relevant so-determined emissions quantities are shown in Table 202.

Table 201: Total process-related emissions to be reported under 2.C.1

Year	CO_2 emissions from use of reducing agents, where not reported in other categories [t/a]	CO_2 emissions from limestone inputs and from the steel industry's own production of burnt lime [t/a]	CO_2 emissions from electrode consumption [t/a]	2.C.1 total [t/a]
1990	20,228,163	2,506,888	75,242	**22,810,293**
1991	19,960,553	2,437,150	68,464	**22,466,167**
1992	16,942,152	2,242,034	64,358	**19,248,544**
1993	17,692,711	2,084,495	59,840	**19,837,046**
1994	19,074,282	2,263,150	65,783	**21,403,215**
1995	16,736,415	2,458,860	74,794	**19,270,069**
1996	16,204,219	2,312,206	76,291	**18,592,716**
1997	18,193,667	2,352,432	87,552	**20,633,651**
1998	16,255,161	2,421,157	89,196	**18,765,514**
1999	14,316,677	2,280,345	90,457	**16,687,479**
2000	19,378,699	2,394,843	98,251	**21,871,793**
2001	16,493,071	2,304,468	96,961	**18,894,500**
2002	14,978,738	2,203,336	97,381	**17,279,455**
2003	18,508,674	2,249,415	99,048	**20,857,137**
2004	18,418,361	2,330,495	104,984	**20,853,840**
2005	17,153,961	2,341,642	100,780	**19,596,383**
2006	17,586,218	2,423,889	108,206	**20,118,313**
2007	14,451,531	2,509,058	110,721	**17,071,310**
2008	13,614,398	2,447,641	107,945	**16,169,984**
2009	10,134,642	1,852,132	83,587	**12,070,361**
2010	13,144,493	2,228,657	97,446	**15,470,596**
2011	12,367,111	2,239,194	104,741	**14,711,046**
2012	12,046,280	2,142,161	101,675	**14,290,116**
2013	12,428,654	2,159,541	99,245	**14,687,440**
2014	13,726,940	2,177,426	96,314	**16,000,680**
2015	13,277,799	2,215,693	93,401	**15,586,893**
2016	15,103,370	2,085,645	93,193	**17,282,208**
2017	15,687,449	2,275,491	97,530	**18,060,470**

4.4.1.3 Uncertainties and time-series consistency (2.C.1)

The time series is consistent, since the activity data have been determined for all plants and since the same method has been used to determine the emissions for all years concerned. As a result of problems under competition law, the German Steel Federation (WV Stahl) was unable to provide the activity data for the year 2017 as agreed. For this reason, aggregated data from emissions trading have been used as substitutes for the 2017. The consistency of the emissions trading data has been checked against comparable values for previous years. Those checks have shown that the pertinent discrepancies are less than 1%, with the exception of those for sinter production (slightly higher; up to a maximum of + 8%).

Regarding CO_2 emissions from limestone inputs, a discontinuity in methods occurred from 2004 to 2005. It resulted because the data source used until 2004 was no longer available after 2004. The time-series trend seems plausible in spite of this discontinuity. In keeping with the required calculation, the uncertainty for the activity data here is ± 10%. The uncertainty is also relatively high for the activity data for the steel industry's own production of burnt lime, which production has been estimated on the basis of several assumptions. The related CO_2 emissions are comparatively insignificant, however.

The uncertainty of the emission factor for electrode consumption is ± 3 %, while the uncertainty for the other data is ± 5 %. The uncertainties are due solely to imprecision in measurement and analysis.

4.4.1.4 Category-specific quality assurance / control and verification (2.C.1)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

Determining emissions in categories 1.A.2.a and 2.C.1 is a complex task, since the Energy Balance, emissions reporting, emissions trading and association statistics differ widely in terms of their underlying methods. In the interest of data quality assurance, and as the occasion requires, industry experts and experts of the Single National Entity carry out regular experts' discussions for the purpose of comparing and evaluating data. As a result of the methodological differences, plausibility checks of the determined emissions quantities, using data of the German emissions trading authority, are possible only at a highly aggregated level.

The implied emission factors (IEF) obtained by the Climate Secretariat cannot be used to carry out plausibility checks of the emissions determined for this category.

1. The reasons for this include the wide differences, from country to country, in primary steel production's (such production is highly CO_2-intensive) share of total steel production;
2. the differences in the ways that different countries allocate the resulting emissions to categories 1.A.2.a, 2.C.1, and to any other categories in which the process gases occurring in connection with iron and steel production are used for energy generation; and
3. addition of the activity data reported – in different ways, by different countries – under 2.C.1, addition which in some cases

is not justified. The aforementioned factors result in extreme scattering of the IEF obtained for the source categories mentioned, and thus those IEF do not support any conclusions regarding the "correctness" of the determined emissions.

4.4.1.5 Category-specific recalculations (2.C.1)

Slight recalculations have been carried out for the year 2016, to take account of replacement of data from the provisional Energy Balance with data from the final Energy Balance. No other category-specific recalculations were required.

4.4.1.6 Planned improvements, category-specific (2.C.1)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.4.2 Metal production: Ferroalloys production (2.C.2)

4.4.2.1 Category description (2.C.2)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
-/-	2.C.2. Ferroalloys production	Ferroalloys	CO_2	429.00	0.04%	6.07	0.00%	-98.6%
-/-	2.C.2. Ferroalloys production	Ferroalloys	CH_4	8.58	0.00%	1.65	0.00%	-80.7%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS	IS	CS
NO_X, CO, NMVOC, SO_2			NE

The category *Ferroalloys production* is not a key category. Ferroalloys are aggregates that are alloyed with steel. There are five ferroalloy producers in Germany; ferrochromium, ferrosilicon and silicon metal are each produced by only one company, and other ferroalloys are produced only in small quantities. The only process in use since 1995 is the electric arc process, a process that releases only small amounts of process-related CO_2, with such releases occurring in electrode consumption.

Until 1995, the blast-furnace process, which produces relatively higher CO_2 emissions, was used to some extent.

4.4.2.2 Methodological issues (2.C.2)

The **emission factors** for the aforementioned two processes (blast-furnace and electric-arc processes) were determined in the research project "NEW CO_2" ("NEU-CO_2") (FKZ 203 41 253/02; Weiß et al. (2006)).

For the period since 1995, the **activity data** are determined via data of the British Geological Survey (Brown et al., 2017). The currently available data are from 2016. The activity data have been carried forward for 2017.

4.4.2.3 Uncertainties and time-series consistency (2.C.2)

The activity data provided by the British Geological Survey (BGS) Brown et al. (2017) are based partly on estimates and thus are subject to relatively large uncertainties.

The relevant data of the British Geological Survey Brown et al. (2017) were compared with those of the U.S. Geological Survey (USGS). While the USGS data are of the same order of magnitude as the BGS data, they are less detailed and have a higher degree of aggregation. For this reason, we have chosen to use the BGS data.

For the period 2001 – 2006, data of the Federal Statistical Office on sales of ferroalloys are available. Those data are lower, by a factor of 0.7, than the production data of the BGS, however. In the interest of the consistency of the time series, the BGS data have thus also been used for those years.

The considerable decrease in the CO_2 emission factor that took place from 1994 to 1995 does not represent any inconsistency; it is the result of the change in the production process.

4.4.2.4 Source-specific quality assurance / control and verification (2.C.2)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The activity data used, which come from the BGS, have been verified with data of the Federal Statistical Office and the USGS (see above).

4.4.2.5 Category-specific recalculations (2.C.2)

Recalculations were required because the activity data carried forward last year have been updated. Those recalculations led to slight changes in last year's emissions. Such recalculations are carried out every year, since the underlying statistics are provided only at two-year intervals.

4.4.2.6 Planned improvements, category-specific (2.C.2)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.4.3 Metal production: Aluminium production (2.C.3)

4.4.3.1 Category description (2.C.3)

KC	Category	Activity	EM of	1990 / 1995 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990/1995-2017
-/T	**2.C.3 Aluminium production**	**Primary aluminium production**	**PFC**	1,800.71	0.15%	84.17	0.01%	-95.3%
-/-	2.C.3. Aluminium production	Primary aluminium production	CO_2	1,011.92	0.08%	751.84	0.08%	-25.7%
-/-	2.C.3. Aluminium production	Secondary aluminium production	SF_6	11.40	0.00%	10.74	0.00%	-5.8%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 3	AS	CS
CH_4	-	-	NE
PFC	Tier 3	AS	CS
SF_6	CS	NS	CS
NO_X	-	-	NE
CO, SO_2		AS	CS

Primary aluminium – by-product emissions

In keeping with its classification in category 2.C.3 Aluminium production, the category *Primary aluminium production* is a key category for PFC emissions in terms of trend.

In Germany, aluminium is produced at four foundries, in electrolytic furnaces with pre-burnt anodes. The principal emission sources are the waste gases from the electrolytic furnaces and fugitive emissions via the plant roofs. CO, CO_2, SO_2, CF_4 and $C_2F_6$are among the most important climate-relevant substances and air pollutants that are emitted.

Production of primary aluminium continues to be the largest source of PFC emissions in Germany, in spite of the considerable reductions that have been achieved since 1990. Thanks to extensive modernisation measures in German aluminium foundries, and to decommissioning of production capacities, absolute emissions from this sector have fallen by more than 90 % since 1995. As to the future development of PFC emissions, stagnation at a low level can be expected.

Secondary aluminium – use of F gases in foundries

In keeping with its classification in category 2.C.3 Aluminium production, the category *Use of SF_6 in secondary aluminium production* (aluminium foundries) is not a key category for SF_6 emissions.

Generally speaking, inert gases without additives are sufficient for rinsing secondary molten aluminium. A purification system of inert gases, with added SF_6 at a concentration of 1 or 2.5 %, has been used in the past, however, in a few – usually smaller – aluminium foundries and in laboratories. Such purification systems were last used in 1999 (no sales have taken place in

Germany since 2000). From 1990 to 1999, SF_6 consumption remained relatively constant, at 0.5 t/a.

Since 1999, pure SF_6 has been used again as a purification gas, in isolated cases.

4.4.3.2 Methodological issues (2.C.3)

Primary aluminium – by-product emissions

The relevant activity data are reported annually to the Federal Environment Agency by the WirtschaftsVereinigung Metalle metal-industry association. The average anode consumption in production of primary aluminium is 430 kg of petrol coke per tonne of aluminium. Table 202 shows the process-related emission factors.

The total quantity of waste gas incurred per tonne of aluminium during the production of primary aluminium was multiplied by an average concentration value formed from several individual figures, from various different plants, with appropriate weighting. The emission factors also make allowance for fugitive emission sources, such as emissions via plant roofs. The emission figures used for CO are the results of emission measurements within the context of investment projects.

The emission factors for SO_2 and CO_2 were calculated from the specific anode consumption. The anodes consist of petrol coke; this material has specific sulphur concentrations of about 1.2 %, from which an SO_2 emission factor of 10.4 kg/t Al can be calculated. The CO_2-emission factor is calculated on the basis of the specific carbon content of petrol coke, 857 kg per t. (cf. Chapter 18.8). By multiplying the average anode consumption by the mean carbon content and carrying out stoichiometric conversion to CO_2, one obtains a CO_2-emission factor of 1367 kg/t aluminium. Theoretically, the CO_2-emission factor must be reduced by the proportion resulting from a CO fraction of 180 kg/t Al, since CO can also form only via consumption of anodes. The CO_2 factor listed below does not take this into account.

The emission factors shown in Table 202 were compared with the emission data in Best Available Techniques Reference Documents (BREF)[65] and other sources (such as VDI Guideline 2286 (VDI): sheet 1).

Table 202: Activity data and process-related emission factors for primary aluminium production in 2013

	AD		Emission factors				
	Number of smelters	Production [t]	CO_2 [kg/t]	NO_X [kg/t]	SO_2 [kg/t]	C total [kg/t]	CO [kg/t]
Primary aluminium	4	492,368	1367	N. e.	10.4	N. e.	180

Emissions data are available for PFC emissions from primary aluminium smelters, thanks to a voluntary commitment on the part of the aluminium industry. Since 1997, the aluminium industry has reported annually on the development of PFC emissions from this sector. The measurement data are not published, but they are made available to the Federal Environment Agency.

The measurements conducted in all German smelters in the years 1996 and 2001 form the basis for calculation of CF_4 emissions. In this context, specific CF_4 emission figures per anode effect[66]

[65] siehe http://www.bvt.umweltbundesamt.de/kurzue.htm

66 "...Organic fluorides occur only under certain conditions, and such conditions occur in the furnace repeatedly, at intervals of hours to severals days. These conditions are referred to as the "anode effect". ... The gas at the anode changes in composition from CO_2 to CO and 5 to 20 % CF_4...." (Winfried Schwarz, 1996).

were calculated, in keeping with the technologies used. The number of anode effects is recorded and documented in the foundries. The total CF_4 emissions were calculated by multiplying the total anode effects for the year by the specific CF_4 emissions per anode effect determined in 2001. The total emission factor for CF_4 is obtained by adding the CF_4 emissions of the smelters and then dividing the sum by the total aluminium production of the smelters. C_2F_6 and CF_4 occur in a constant ratio of about 1:10. The above-described method was applied to the time series through 2010, and the emissions for the years 1990 to 1996 were filled in via recalculations. For purposes of emissions trading, the aluminium industry has made a transition to the IAI method for calculating PFC emissions (the method is equivalent to UNFCC default Tier 2). The default slope factor used with that method is used by all other European operators, and it is accepted in the framework of European emissions trading. In the interest of consistency, as of 2010 the aluminium industry has also used the IAI method to determine emissions data for purposes of emissions reporting.

Secondary aluminium – use of F gases in foundries

For aluminium foundries, the relevant emission factor has been established more reliably, via plant-specific measurements carried out in 2010. As a result, the relevant emissions figures have been established more reliably as well.

Reports and archived survey records from 1996 have been used as a basis for the reporting years 1990 through 1994.

Emission factor for secondary aluminium

On the basis of confidential measurement records certified by the pertinent permit authority, the SF_6 emission factor for aluminium foundries, for the period 1999 through 2008, has been reduced to 3 %. Via structural conversions, the emission factor has been further reduced, to 1.5%, as of 2009.

Activity data for secondary aluminium

SF_6-consumption data are obtained via surveys of gas sellers. At the same time, the survey for the 2000 reporting year revealed that there have been no sales of this gas mixture since 2000.

Data on the SF_6 used in pure form since 1999 have been obtained via direct surveys of users and have been compared with relevant data of gas sellers.

Since the 2006 reporting year, the data have been obtained by the Federal Statistical Office via surveys of gas sellers with regard to SF_6-sales figures (UStatG 2005).

4.4.3.3 Uncertainties and time-series consistency (2.C.3)

Primary aluminium – by-product emissions

The figures for PFC, CO, CO_2 and SO_2 emissions are in keeping with the Tier 3b approach and thus are considered very accurate. The time series for CO, CO_2 and SO_2 are consistent.

On the other hand, no survey of the plant-specific number of anode effects in 1991, 1992, 1993 and 1995 was conducted, in the framework of voluntary commitments, and no calculation was carried out for those years (cf. 4.4.3.6).

In addition, the years 1991 through 1994 were years of deep crisis for the German aluminium industry, due to sharp drops in the world-market prices for primary aluminium. For this reason, a number of plants were decommissioned. While all smelter types were affected, smelters that had recently been modernised, with point-feeder technology, were most strongly affected. Their capacity decreased by 43 %, with regard to the relevant levels in 1990. This also explains the sudden increase and stagnation in the implied emission factor for CF_4 in these years. In absolute terms, the primary smelters emitted only 26 tonnes of CF_4 in 2007, while they emitted 45 tonnes in 2005. This drop was due to a decrease in production. With regard to 2006, production increased slightly, however, because partial shutdowns of furnaces in the Stade plant were more than offset by production increases at the Hamburg production site. In 2009, the economic crisis and other factors led to drastic reductions of production at the Rheinwerk Neuss site. In the period thereafter, all German primary smelters faced difficult economic situations and had to start up and shut down processes frequently, thereby incurring process instabilities. Those instabilities led to higher numbers of anode effects and, thus, to higher PFC emissions. The economic situation stabilised noticeably in 2010. That made it possible to run continuous, stable processes. As a result, the numbers of anode effects decreased to such a degree that absolute PFC emissions decreased, by comparison to their level in 2009, in spite of the production increases. That trend continued in subsequent years.

Secondary aluminium – use of F gases in foundries

As studies have shown, part of the SF_6 used in aluminium production is broken down during such use. For the aluminium industry, the emission factor has been applied to the highest measured emissions level, and an uncertainty of 50 % has been assumed for lower levels, since measurements have shown that emissions are frequently considerably lower than the maximum levels.

4.4.3.4 Category-specific quality assurance / control and verification (2.C.3)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The activity data for primary aluminium production are based on surveys taken by the WirtschaftsVereinigung Metalle metal-industry association. They are reported to the Federal Environment Agency annually. The relevant time series seems plausible and shows no inconsistencies. It is assumed that such data collection conforms to quality assurance criteria.

4.4.3.5 Category-specific recalculations (2.C.3)

No recalculations are required.

4.4.3.6 Planned improvements, category-specific (2.C.3)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.4.4 Metal production: Magnesium production (2.C.4)

4.4.4.1 Category description (2.C.4)

KC	Category	Activity	EM of	1995 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1995-2017
-/-	2.C.4. Magnesium foundries		SF_6	176.63	0.01%	86.00	0.01%	-51.3%
-/-	2.C.4. Magnesium foundries		HFC 134a	0.0	0.00%	25.76	0.00%	-

Gas	Method used	Source for the activity data	Emission factors used
SF_6	D	PS	D
HFC	D	PS	D

The category *SF_6 and HFC-134a in magnesium production* is not a key category.

No primary magnesium is produced in Germany. Only cast parts made of magnesium alloys are produced. In magnesium casting, since the mid-1970s, SF_6 has been used as a cover (protective) gas over molten magnesium to prevent the magnesium's oxidation and ignition. The amount of SF_6 used per tonne of magnesium (specific SF_6 coefficient) has decreased sharply from its level in 1995. This is due to the fact that HFC-134a has increasingly been used as a substitute since 2003. SF_6 is used in both a) the sand-casting process, for production of prototypes, individual parts and small series, and b) the pressure-casting process, in which it serves as a cover gas.

Pursuant to Article 13 der Regulation (EU) No. 517/2014 on fluorinated greenhouse gases, as of 1 January 2018 use of SF_6 in magnesium pressure die-casting is prohibited even in small production installations. As of 1 January 2008, magnesium die-casting foundries with annual SF_6 consumption exceeding 850 kg were already prohibited from using SF_6 as a cover gas. The German installations affected by this prohibition have gradually switched to HFC-134a.

4.4.4.2 Methodological issues (2.C.4)

Use of SF_6 as a purification and protective gas in magnesium production is an open use, i.e. all of the SF_6 used in the process is emitted into the atmosphere. The practice of assuming the equivalence between consumption (activity data) and emissions conforms to the method set forth in the 2006 IPCC Guidelines (IPCC (2006): Vol. 3, Chapter 4.5).

The 2006 IPCC Guidelines contain no information regarding the emission factor for use of HFC-134a. For this reason, the emission factor previously chosen has been identical with that for use of SF_6 in magnesium production. As of this year, the emission factor has been retroactively set to 50 %, for the entire time series.

Emission factors

For magnesium foundries, a default emission factor of EF_{use} = 100% is assumed for SF_6, due to a continuing lack of precise destruction-rate data that would support a more-precise estimate.

As of reporting year 2017, the emission factor has been retroactively set to 50%, for the entire time series (i.e. for the period as of 2003). In 2017, the IPCC Emission Factor Data Base (EFDB) added "Destruction rates of cover gas HFC-134a," in the amounts of 71% and 77%, as non-binding guidelines for the national emissions inventories. Those values are equivalent to emission rates of 29% and 21%, respectively. In 2007, studies commissioned by the U.S. Environmental Protection Agency (EPA) found that the destruction rates of HFC-134a depend on a range of parameters, including the temperature of the melt, the carrier gas used, the flow rate of the cover gas and the concentration of the HFC-134a. In light of the lack of further studies on this subject, the experts have proposed use of an emission factor of 50%, which would include a safety margin (Gschrey et al., 2018).

Activity data for magnesium production

In 1996, a survey was carried out, under commission to the Federal Environment Agency, of all domestic magnesium foundries that use SF_6. That survey determined the amounts consumed in the years 1990 to 1995.

Until report year 2007, data on the amounts used were obtained directly from users. Since report year 2006, the data have been obtained via surveys of gas sellers with regard to SF_6-sales figures. In report year 2006, the two methods were compared.

Since report year 2007, data of the Federal Statistical Office (UStatG 2005) have been used.

4.4.4.3 Uncertainties and time-series consistency (2.C.4)

As studies have shown, part of the SF_6 and HFC-134a used in magnesium production is broken down during such use. As a result of the assumptions regarding the emission factors, the pertinent emissions of SF_6, and, to some degree, those of HFC-134a, are probably too high.

4.4.4.4 Source-specific quality assurance / control and verification (2.C.4)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

No other data sources, apart from the data provided by the Federal Statistical Office, are available for review of the F-gas quantities determined for emissions reporting purposes, i.e. for review that would serve as a basis for verification. Comparisons with other countries have revealed no requirements for improvements. The emission factor for SF_6 is in keeping with the default emission factor given in the 2006 IPCC Guidelines(IPCC, 2006). To ensure that all emissions are indeed covered, the emission factor for HFC-134a is higher than the corresponding factors in the IPCC Emission Factor Data Base (EFDB).

4.4.4.5 Category-specific recalculations (2.C.4)

Recalculations of the emissions from use of HFC-134a were carried out.

	Units	2003	2004	2005	2006	2007	2008	2009
EF HFC-134a								
2018 Submission	[1]	1	1	1	1	1	1	1
2019 Submission	[1]	0.5	0.5	0.5	0.5	0.5	0.5	0.5
EM HFC-134a								
2018 Submission	t CO_2eq	317.46	337.48	1,731.16	1,212.50	7,779.20	21,746.01	16,905.46
2019 Submission	t CO_2eq	158.73	168.74	865.579	606.249	3,889.60	10,873.01	8,452.73
	Units	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
EF HFC-134a								
2018 Submission	[1]	1	1	1	1	1	1	1
2019 Submission	[1]	0.5	0.5	0.5	0.5	0.5	0.5	0.5
EM HFC-134a								
2018 Submission	t CO_2eq	23,672.22	38,658.62	43,080.18	33,028.71	52,299.39	48,027.98	61,052.42
2019 Submission	t CO_2eq	11,836.11	19,329.31	21,540.09	16,514.36	26,149.70	24,013.99	30,526.21

4.4.4.6 Planned improvements, category-specific (2.C.4)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.4.5 Metal production: Lead (2.C.5)

4.4.5.1 Category description (2.C.5)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
-/-	2.C.5. Lead production		CO_2	157.87	0.01%	77.20	0.01%	-51.1%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1	AS	D/CS

The category *Metal production*: *Lead* is not a key category.

In Germany, lead is produced from primary lead concentrates and secondary raw materials such as lead-containing scrap and lead acid batteries.

All primary lead production in Germany takes place via the direct smelting (DS) process, either in bath smelting furnaces (Isasmelt-Ausmelt) or in QSL reactors. Process-related CO_2 emissions occur primarily via addition of carbon-containing reducing agents (such as coal dust). The imperial smelting process (in imperial smelting furnaces (ISF)) is no longer used in Germany.

Recycling of lead acid batteries is the key factor shaping secondary lead production in Germany. The relevant sector uses both short rotary furnaces and shaft furnaces. Process-related CO_2 emissions occur primarily via addition of carbon-containing reducing agents (for example, coke).

The relevant activity data are reported annually to the Federal Environment Agency by the WirtschaftsVereinigung Metalle metal-industry association.

4.4.5.2 Methodological issues (2.C.5)

The **emission factors** that have been used have been taken from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC (2006): values from Table 4.21). The only lead-production processes used in Germany are the direct smelting (DS) process, for primary lead production, and the secondary lead production (S) process. Uncertainties and time-series consistency (2.C.5)

The default uncertainties set forth in 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) have been used.

4.4.5.3 Category-specific recalculations (2.C.5)

No recalculations are required.

4.4.5.4 Category-specific quality assurance / control and verification (2.C.5)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The activity data are based on confidential surveys taken by the WirtschaftsVereinigung Metalle metal-industry association. They are reported to the Federal Environment Agency annually. The relevant time series seems plausible and shows no inconsistencies. It is assumed that such data collection conforms to quality assurance criteria.

4.4.5.5 Planned improvements, category-specific (2.C.5)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.4.6 Metal production: Zinc (2.C.6)

4.4.6.1 Category description (2.C.6)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
-/-	2.C.6. Zinc production		CO_2	670.80	0.05%	302.51	0.03%	-54.9%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1	AS	D

The category *Metal production*: *Zinc* is not a key category.

In Germany, zinc is produced from primary zinc concentrates and secondary raw materials such as zinc-containing scrap and steel mill dust.

All primary zinc production in Germany takes place via the hydrometallurgical process. The imperial smelting process, a pyrometallurgical process, is not used.

In this sector in Germany, process-related greenhouse-gas emissions occur primarily in secondary zinc production. Process-related CO_2 emissions occur via use of coke as a reducing agent, especially in processing of zinc-containing secondary materials in rotary kilns.

The relevant activity data are reported annually to the Federal Environment Agency by the WirtschaftsVereinigung Metalle metal-industry association.

4.4.6.2 Methodological issues (2.C.6)

The CO_2 emission factor set forth in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC (2006): default factor) has been used.

4.4.6.3 Uncertainties and time-series consistency (2.C.6)

The default uncertainties set forth in 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) have been used.

4.4.6.4 Category-specific recalculations (2.C.6)

No recalculations are required.

4.4.6.5 Category-specific quality assurance / control and verification (2.C.6)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The activity data are based on confidential surveys taken by the WirtschaftsVereinigung Metalle metal-industry association. They are reported to the Federal Environment Agency annually. The relevant time series seems plausible and shows no inconsistencies. It is assumed that such data collection conforms to quality assurance criteria.

4.4.6.6 Planned improvements, category-specific (2.C.6)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.4.7 Metal production: Other (2.C.7)

Since the CRF-Reporter software does not allow nitrous oxide to be allocated to 2.C.1, it is reported in 2.C.7 instead. Otherwise, no emissions are reported in category 2.C.7.

4.4.7.1 Category description (2.C.7)

In Germany, this category primarily includes copper production. The majority of that industry's greenhouse-gas emissions occur in process combustion; those emissions are reported under 1.A.2.b. The greenhouse-gas emissions that do not originate in process combustion are very low by comparison.

4.4.7.2 Methodological issues (2.C.7)

No emission factors are available. In addition, the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) provide no pertinent default factor.

4.4.7.3 Uncertainties and time-series consistency (2.C.7)

No information.

4.4.7.4 Category-specific recalculations (2.C.7)

No recalculations are required.

4.4.7.5 Category-specific quality assurance / control and verification (2.C.7)

The activity data are based on confidential surveys taken by the WirtschaftsVereinigung Metalle metal-industry association. They are reported to the Federal Environment Agency annually. The relevant time series seems plausible and shows no inconsistencies. It is assumed that such data collection conforms to quality assurance criteria.

4.4.7.6 Planned improvements, category-specific (2.C.7)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.5 Use of non-energy-related products from fuels and solvents (2.D)

4.5.1 Lubricant use (2.D.1)

4.5.1.1 Category description (2.D.1)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
-/-	2.D.1. Lubricant use		CO_2	188.10	0.02%	215.43	0.02%	14.5%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 2	NS	CS

The category *Lubricant use* is not a key category for CO_2 emissions.

Lubricants are used to reduce friction and wear in moving machine parts. They can also be used for transmission of power and heat. Furthermore, lubricants are used as sealants, and they are used to prevent build-up of deposits and to guard against corrosion. Process oils, which are also considered to be lubricants, are also used as raw materials and as auxiliary and working materials. In addition, various other industrial oils are used in non-lubrication applications.

The consumption of lubricants in Germany has remained at a relatively constant level since 1990, apart from a sharp decrease in 2009 that was related to the overall economic situation.

4.5.1.2 Methodological issues (2.D.1)

Lubricant use is divided into the two major areas of a) use in motor vehicles, including other mobile sources, and b) use in industry; this is due to the different calculation methods involved.

Lubricant use is divided into the two major areas of a) use in motor vehicles, including other mobile sources, and b) use in industry; this is due to the different calculation methods involved.

The German greenhouse-gas inventory covers CO_2 emissions from co-combustion of lubricants for all mobile sources. In keeping with emissions reporting requirements, emissions from two-stroke petrol engines are allocated directly to the pertinent emission sources, since in those cases lubricants are seen as part of the relevant fuels (fuel mixtures for two-stroke engines). A description of the relevant calculation methods is provided in Chapter 19.1.4. On the other hand, all co-combustion emissions that are not caused by two-stroke engines are considered to result from product use and are reported in section 2.D.1, along with emissions from lubricant use in industrial sectors.

Stationary lubricant use

The activity data for lubricant use in industry consist of domestic delivery data (units: tonnes) given by the "Official Mineral Oil Statistics for the Federal Republic of Germany" ("Amtliche Mineralöldaten für die Bundesrepublik Deutschland" – Mineral Oil Statistics) of the Federal Office of Economics and Export Control (BAFA) (Table 10j). Those statistics differentiate the following groups of lubricant types:

- Motor oils
- Compressor oils
- Turbine oils
- Gear oils
    - Automobile oils
    - Automatic transmission fluid (ATF)
    - Industrial-gear oils
- Hydraulic oils
- Electrically insulating oils
- Machine oils
- Other industrial oils not used for lubrication
- Process oils
- Metal processing oils
    - Hardening oils
    - Water-miscible
    - Not water-miscible
    - Anticorrosive oils
- Greases
    - Among these, for automobiles
- Basic oils
- Extracts from lubricant refining

BAFA regularly publishes sales figures (monthly and annual) for these type groups. The published figures are based on companies' reported data. A list of the companies that report in this framework – the "survey-group list" (Erhebungskreisliste)[67] is available for inspection.

The 2006 IPCC Guidelines do not specify which emission sources the lubricant use category includes. Losses can occur on the input side (filling), during use and on the output side (removal). In the interest of clarity, and to increase the precision of the emission calculation, and a study by an expert was commissioned. In that project, the various lubricant-type groups were considered individually, and emission factors were derived that would permit use of a a Tier 2 method. The study was able to prove that while various types of losses occur, among the different lubricant-type groups, those losses result in emissions into the air only in part.

The typical losses on the input side, i.e. in connection with filling at the planned site of use (for example, the filling of an automobile motor, a transmission, or a machine (machine parts)) include:

- drip losses and other handling-related losses,

67 http://www.bafa.de/SharedDocs/Downloads/DE/Energie/Mineraloel/moel_erhebungskreisliste.xls;jsessionid=8F5CC4170FEBCC89A69DE21218062873.2_cid378?__blob=publicationFile&v=4

- Residues in containers

Many different types of losses can occur during product use. The possible types of losses include:

- evaporation
- (co-) combustion
- leakage
- exports (applies especially to automobile lubricants)
- conversions into products
- adhesion to products

On the output side, i.e. in connection with the removal of used lubricants, the following types of losses can occur:

- drip losses and other handling-related losses,
- residues adhering to some part of the usage site

With respect to *gaseous* emissions, the most significant emissions include releases of greenhouse gases from (co-) combustion of lubricants, the formation of VOC as a result of leakage, and emissions via open applications (which depend on prevailing usage conditions in each case (especially temperature)).

On the basis of the analyses carried out in the project, the following emission factors, oriented to lubricant-type groups, were derived:

Table 203: Emission factors for specific lubricant-type groups, in percent

Lubricant-type group	Share of total sales	NMVOC			CO_2		
		Ø	*Min*	*Max*	Ø	*Min*	*Max*
Motor oils	27 %	1 %	*0 %*	*2 %*	24 %	*23 %*	*25 %*
Compressor oils	1 %	1.5 %	*1 %*	*2 %*			
Turbine oils	0.2 %	0.5 %	*0 %*	*1 %*			
Automobile-transmission oils	9 %	1 %	*0 %*	*2 %*			
Industrial gear oils	2 %	1.5 %	*1 %*	*2 %*			
Hydraulic oils	10 %	1.5 %	*1 %*	*2 %*			
Machine oils	3 %	2.5 %	*0 %*	*5 %*			
Other industrial oils not used for lubrication	6 %	25 %	*0 %*	*50 %*			
Metal processing oils	8 %	5 %	*0 %*	*10 %*			
Basic oils	12 %	10 %	*5 %*	*15 %*			
Electrically insulating oils	1 %						
Process oils	15 %						
Greases	3 %						
Extracts from lubricant refining	2 %						

In this category, greenhouse-gas emissions result solely from co-combustion of motor oils.

The relevant NMVOC emissions are calculated via a Tier 2 method in which the emission factors are applied to the entire time series.

To ensure conformity with the 2006 IPCC Guidelines and the EU's emissions reporting procedures, the NMVOC emissions are converted into CO_2 emissions. The carbon content on which that process is based is the same as that described for 2.D.3.

The area of cooling lubricants, which was previously considered in section 2.D.3.i, is now considered solely in 2.D.1.

For purposes of reporting of air pollutants in the *Informative Inventory Report* (IIR), the NMVOC emissions are allocated to section 2.D.3.i.

In 1995, a number of Mineral Oil Statistics categories were changed. In 1995, three type groups were introduced that had not appeared in the Mineral Oil Statistics prior to that year (four other categories had been used for those purposes). This necessitated a slight adjustment of the procedure for the years 1990-1994. The following table shows the relevant categories for the years 1990-1994, and explains how they were handled in the calculation.

Table 204: Handling of categories in BAFA statistics, 1990-1994

Category	Remarks concerning the procedure	Emission factor
Other lubricating oils, specialty Other lubricating oils, non-specialty	These are handled like the "machine oils" group, which is lacking in the 1990-1994 period. This group includes various specialty and non-specialty lubricating oils.	2.5 %
Other mineral oils for special applications	This category contains no lubricating oils. It is handled like the category "Other industrial oils not used for lubrication," which is lacking in the 1990-1994 period.	25 %
Light-coloured plasticisers and extender oils	Extender oils and plasticisers are classified with the process oils. They are handled accordingly.	0 %

Mobile lubricant use

The data on the total lubricant quantities used in connection with lubricant co-combustion in four-stroke gasoline engines and in other engines in vehicles and mobile sources are very spotty. As a result, the co-combusted quantities are calculated largely on the basis of figures provided by the *Verband Schmierstoff-Industrie* e. V. (VSI; the association of the German lubricant industry) on the relevant fuel quantities Wallfarth (2014).

Pursuant to Wallfarth (2014), the following co-combustion fractions, with respect to the relevant fuel quantities used, are achieved in the various usage areas:

Table 205: Overview of the specific co-combustion fractions used

Sector	Fuel	Fraction	Source / remark
1.A.2.g vii	OK	0.00 %	Assumption, based on Wallfarth (2014)
	DK	0.10 %	
1.A.3.a, 1.D.1.a, 1.A.5.b ii	Ke & FB	0.01 %	Avgas: like kerosene
1.A.3.b	All	-	Calculation via TREMOD
1.A.3.c	DK	0.05 %	
1.A.3.d, 1.D.1.b. 1.A.4.c iii, 1.A.5.b iii	DK & HOS	0.15 %	Heavy fuel oil: like diesel fuel
1.A.4.a ii	DK	0.10 %	Like 1.A.3.b
	LPG	0.10 %	Like 1.A.3.b
1.A.4.b ii	OK	0.00 %	Assumption, based on Wallfarth (2014)
1.A.4.c ii (i)	OK	0.00 %	Assumption, based on Wallfarth (2014)
	DK	0.10 %	Like 1.A.3.b
1.A.4.c ii (ii)	DK	0.10 %	Like 1.A.3.b
1.A.5.b i	OK	0.00 %	Assumption, based on Wallfarth (2014)
	DK	0.15 %	Like 1.A.3.d; takes account of heavy armored vehicles
	HOS	0.15 %	Like diesel fuel

OK: gasolines (including bioethanol), only four-stroke engines; DK: diesel fuel (including biodiesel), Ke: kerosene; FB: avgas; HOS: heavy fuel oil; LPG: LPG

The quantities of co-combusted lubricants are calculated on the basis of the energy quantities used in some sectors in non- two-stroke engines, as well as of the aforementioned co-combustion fractions. Those lubricant quantities are then used, with the help of the unified emission factor of 73,300 kg CO_2 / TJ, to calculate the sector-specific unintended carbon dioxide emissions from lubricant co-combustion.

Table 206: Carbon dioxide from lubricants co-combusted unintentionally in mobile non- two-stroke engines, in kilotonnes

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
1.A.2.g vii	3.47	3.25	3.10	2.46	2.72	2.81	2.78	2.89	3.03	3.12	3.14
1.A.3.a	0.24	0.24	0.28	0.25	0.26	0.26	0.24	0.22	0.22	0.23	0.24
1.A.3.b	86.21	103.61	113.54	117.27	120.43	122.62	122.64	123.64	126.02	128.62	130.45
1.A.3.c	1.41	1.14	0.93	0.68	0.57	0.58	0.53	0.53	0.48	0.51	0.48
1.A.3.d	5.31	4.17	2.99	2.86	2.53	2.60	2.61	2.62	2.78	2.53	2.94
1.A.4.a ii	0.77	0.72	0.78	0.80	0.88	0.89	0.88	0.89	0.91	0.93	0.94
1.A.4.b ii	*here, only use of two-stroke engines (cf. Chapter* **19.1.4**)										
1.A.4.c ii	4.16	3.44	3.41	3.23	3.70	3.78	3.70	3.81	3.98	4.18	4.23
1.A.4.c iii	0.08	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.06	0.12
1.A.5.b i	1.65	0.88	0.15	0.38	0.12	0.07	0.11	0.08	0.08	0.07	0.07
1.A.5.b ii	0.28	0.12	0.07	0.02	0.02	0.03	0.01	0.02	0.02	0.03	0.03
1.A.5.b iii	0.11	0.07	0.06	0.05	0.04	0.04	0.04	0.04	0.04	0.03	0.04
Total	**103.70**	**117.71**	**125.36**	**128.05**	**131.33**	**133.74**	**133.59**	**134.78**	**137.62**	**140.31**	**142.68**
1.D.1.a	1.20	1.48	1.91	2.27	2.40	2.28	2.48	2.53	2.43	2.42	2.62
1.D.1.b	8.93	7.61	8.21	9.91	11.39	11.22	10.31	9.21	8.94	10.05	11.33

Source: own calculations

4.5.1.3 Uncertainties and time-series consistency (2.D.1)

The uncertainties for the specific emission factors for the type groups, for the area of industrial lubricant uses, result from the emission-factor ranges shown in Table 203.

On the basis of an expert judgement, reached via a study of incorrect notifications in the Mineral Oil Statistics, the uncertainties for the activity data are assumed to be 5 %.

4.5.1.4 Category-specific recalculations (2.D.1)

Stationary lubricant use

As a result of the above-described change of methods, extensive recalculations of both the activity data and the emission factors had to be carried out.

Table 207: Revised input quantities, in kilotonnes

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
2019 Submission	668	688	686	619	669	678	679	669	741	694	663
2018 Submission	724	738	738	676	714	730	738	736	811	771	750
Absolute change	57	50	52	57	46	52	59	67	70	77	87
Relative change	7.81%	6.75%	6.98%	8.36%	6.40%	7.18%	7.94%	9.13%	8.69%	9.93%	11.60%

The revised emission factors are not listed here separately. With regard to the specific EF now used, we refer to Table 203.

Table 208: Revised indirect CO_2 emissions from stationary uses, in kilotonnes

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
2019 Submission	85	62	64	57	61	5	60	63	86	76	80
2018 Submission	427	435	435	399	421	430	435	434	478	454	442
Absolute change	342	374	371	341	361	425	375	371	392	378	362
Relative change	80%	86%	85%	86%	86%	99%	86%	85%	82%	83%	82%

Source: Own calculations

The enormous changes in the listed indirect CO_2 emissions result primarily from conversion to specific emission factors.

Mobile lubricant use

With respect to the 2018 Submission, the total annual quantities of lubricants unintentionally co-combusted in mobile sources have changed as follows:

Table 209: Revised unintentionally co-combusted quantities, in terajoules

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
2019 Submission	1,414.6	1,605.6	1,710.0	1,746.7	1,791.3	1,824.2	1,822.2	1,838.5	1,877.2	1,914.7	1,956.1
2018 Submission	1,414.8	1,605.9	1,710.2	1,747.0	1,791.6	1,824.5	1,822.5	1,838.8	1,877.5	1,914.3	1,946.5
Absolute change	-0.2	-0.2	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	0.5	9.6
Relative change	-0.01%	-0.01%	-0.02%	-0.02%	-0.02%	-0.02%	-0.02%	-0.02%	-0.02%	0.02%	0.49%

The most important factor driving the changes in the entire time series consists of reductions of the quantities of kerosene consumed for domestic flights; those reductions have similarly pronounced impacts on the quantities of lubricants co-combusted for such flights. The contrary developments in 2016 and 2017 lead to increases in the fuel inputs for ship transports (2016) and for road transports (2017).

The CO_2 emissions from this unintentional co-combustion have been revised in keeping with the corrected activity data:

Table 210: Revised CO_2 emissions from unintentional co-combustion in mobile sources, in kilotonnes

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
2019 Submission	103.69	117.69	125.34	128.03	131.30	133.71	133.56	134.76	137.60	140.35	143.38
2018 Submission	103.70	117.71	125.36	128.05	131.33	133.74	133.59	134.78	137.62	140.31	142.68
Absolute change	-0.01	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	0.03	0.70
Relative change	-0.01%	-0.01%	-0.02%	-0.02%	-0.02%	-0.02%	-0.02%	-0.02%	-0.02%	0.02%	0.49%

Source: Own calculations

The total quantity of indirect (calculated on the basis of the NMVOC emissions) and direct carbon dioxide emissions (from unintentional co-combustion in vehicles and mobile machinery) has changed as follows with respect to the 2018 Submission:

Table 211: Revised CO_2 emissions from stationary and mobile uses, in kilotonnes

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016
2019 Submission	188	179	190	190	185	192	139	194	198	224	216
2018 Submission	531	553	553	560	527	553	564	569	569	616	595
Absolute change	-342	-374	-363	-371	-341	-361	-425	-375	-371	-392	-378
Relative change	-65%	-68%	-66%	-66%	-65%	-65%	-75%	-66%	-65%	-64%	-64%

Stationary: Own calculations; stationary uses: indirect CO_2 calculated from quantities of released NMVOC

4.5.1.5 Source-specific quality assurance / control and verification (2.D.1)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

Stationary lubricant use

In the aforementioned study, the newly determined emission factors were compared with a) the corresponding emission factors given in the 2006 IPCC Guidelines and the EMEP Guidebook and b) the emission factors used in the Norwegian and Swiss reports.

In order to validate the activity data, the study also looked at the suitability of the Federal Statistical Office's production and foreign-trade statistics. Along with the Mineral Oil Statistics, those statistics periodically contain data on lubricant production in Germany and imports and exports of lubricants. The study found that the data on placing of lubricants on the market that can be derived from the Federal Statistical Office's production and foreign-trade statistics cannot be used either for validation of the Mineral Oil Statistics or for calculation of emissions from lubricant use. This is because those data also include significant quantities of lubricants intended for further processing in companies' own internal operations, and such quantities do not represent lubricant uses within the meaning of emissions reporting.

A detailed description of the these results is provided in the Informative Inventory Report pursuant to the CLRTAP.

4.5.1.6 Planned improvements, category-specific (2.D.1)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.5.2 Paraffin wax use (2.D.2)

4.5.2.1 Category description (2.D.2)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
-/-	2.D.2. Paraffin wax use		CO_2	248.40	0.02%	564.03	0.06%	127.1%
-/-	2.D.2. Paraffin wax use		N_2O	0.61	0.00%	1.38	0.00%	127.1%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1	NS	D
N_2O	Tier 1	NS	D

The category *Paraffin wax use* is not a key category.

The most important use of waxes is in candles. Packaging, synthetic wood and hot melt adhesives also represent significant areas of application.

Surveys of industry experts, carried out in the framework of a research project, have confirmed the assumption that, apart from candles, no other wax uses are of relevance for emissions reporting – because, apart from the burning of candles, no other uses, under normal conditions, can be expected to produce emissions. For this reason, with regard to wax uses, the inventory continues to take account only of uses in candles.

Germany is an important market for candles within the European Union. In 2016, its share of the overall market amounted to nearly 27 % ((European Candle Association, 2017)). In Germany, in contrast to the trend in Europe as a whole, the demand for candles grew from 1990 to 2013. The increasing demand is being met via imports. Since 2013, production has been decreasingly markedly, and the growing imports are not completely offsetting the production decreases.

4.5.2.2 Methodological issues (2.D.2)

The calculation model is based on the assumption that all candles are consumed within a year of their purchase and are burned completely.

The CO_2 and N_2O emissions are calculated via a Tier 1 method.

Activity data

The production-quantity data, and the data on the imported and exported quantities of candles, for the years as of 1996, were obtained from the Federal Statistical Office (Statistisches Bundesamt (FS 4, R 3.1), Produzierendes Gewerbe, Produktion im Produzierenden Gewerbe sowie der Außenhandelsstatistik ("manufacturing industry; production in the manufacturing industry and foreign-trade statistics").

The quantities consumed are calculated in keeping with the formula Production + Imports – Exports.

For the years 1990 through 1995, the quantities consumed are calculated from the per-capita consumption, which has been derived from the data for the years 1996 through 2013. In the process, it is assumed that consumption also grew linearly in those (earlier) years.

Emission factors

The emission factor for CO_2 is 2.9467 t/t product; for N_2O, the factor is 0.024 kg/t product.

The emission factors, which have been applied to the entire time series, have been derived on the basis of standard values (IPCC (2006): Vol. 2, Chapter 1, Table 1.2, and IPCC, 2006: Vol. 2, Chapter 2, Table 2.4).

4.5.2.3 Uncertainties and time-series consistency (2.D.2)

A Tier 1 method and standard values from the 2006 IPCC Guidelines have been used, and thus that source's uncertainties for the activity data and emission factors apply (IPCC (2006): Vol. 3, Chapter 5).

4.5.2.4 Category-specific recalculations (2.D.2)

The CO_2 and N_2O emissions had to be corrected for the year 2016, as a result of adjustments to foreign-trade statistics. The relevant usage quantities – and, thus, the relevant CO_2 and N_2O emissions – increased by only 0.04% for that year, however. Because these changes are so slight, we have opted not to present them in a table.

4.5.2.5 Source-specific quality assurance / control and verification (2.D.2)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

No other national data, apart from the data provided by the Federal Statistical Office, are available for review of the relevant import, export and production quantities, for purposes of verification of the consumption-quantity data. The official Mineral Oil Statistics do not list uses in candles as a separate category. Furthermore, the European Candle Association (ECA) relies on data of EUROSTAT. A comparison with the data of EUROSTAT was carried out.

A comparison with other countries' calculation methods was also carried out. Differences were found only in determination of the applicable wax quantities.

4.5.2.6 Planned improvements, category-specific (2.D.2)

Plans call for discontinuation of inclusion of biogenic wax fractions.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.5.3 Other: Solvents – NMVOC (2.D.3 Solvents)

4.5.3.1 Category description (2.D.3 Solvents)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
-/-	2.D.3. Other		CO_2	2,552.00	0.21%	1,372.53	0.15%	-46.2%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	D	NS	D
NMVOC	Tier 2	NS	CS

The category indirect CO_2 from NMVOC emissions, within the category *Solvent and other product use* (CRF 2.D.3), is not a key category, due to its inclusion within the overarching category *2.D.3 – Other*.

The NMVOC emissions released through use of solvents and solvent-containing products all belong to sub-categories of this category.

The four reporting categories of this category vary widely in structure. To take account of this variation, inventory data were calculated in keeping with the UNECE/EMEP sub-structures based on the CORINAIR97 (CORINAIR: COordination d' INformation Environmentale; sub-project AIR) SNAP system[68].

The categories 2.D.3.a, d, e, f, g, h and i include the following applications and activities:

2.D.3.a: Household use of solvents, including fungicides

i) Residential use of solvents

- **Soaps**
- **Detergents, dishwashing agents and cleansers** (softeners; general-purpose detergents; detergents; auxiliary washing preparations; dishwashing detergents; cleansers for floors and carpets; cleansers for cars; window cleaners; cleaning agents for toilets and bathrooms);
- **Shoe polishes, shoe- and leather-care products, furniture and floor polishes; car-care washes and waxes**
- **Preparations for polishing metal**
- **Fragrances** (for rooms, perfumes, eau de toilette, aftershaves)
- **Cosmetics and make-up** (make-up; preparations for hand, nail and foot care; face-care products; body-care products; sunscreen products and other preparations)
- **Shampoos and hair-care products** (shampoos; perm-care products and hair straighteners; hairsprays; hair cremes and brilliantines; tinting shampoos, hair-colouring agents, hair-bleaching agents and other care products)
- **Other personal care products** (shaving creams; body deodorants and antiperspirants; bath essences; intimate-care products, hair removers, beauty products and other)
- **Anti-freezes for motor vehicles**

ii) Household use of pharmaceutical products

2.D.3.d: Use of paints and lacquers

i) Industrial coatings

- **Motor-vehicle repair**
- **Professional uses of paints and lacquers in structures and buildings** (emulsion paints for interiors; facade paints / silicate; polymer plasters / silicate; architectural paints / glazes; primers / coatings; other applications)
- **Do-it-yourself uses of paints and lacquers in structures and buildings** (emulsion paints for interiors; facade paints / silicate; polymer plasters / silicate; architectural paints / glazes; primers / coatings; other applications)
- **Wood coatings** (wooden interiors; carpentry and cabinet-making)

ii) Industrial coatings

- **Motor-vehicle manufacturing** (primers, fillers, topcoats and clearcoats)
- **Repair of utility vehicles and other vehicles**
- **Coil coatings**
- **Coatings for maritime applications**
- **Wood coatings** (furniture)
- **Other industrial coatings** (spray paints (without propellants); electrical fittings and appliances / household; machine tools; auto accessories/ metal; metal products, sheet metal packaging; wire enamels; impregnation and casting materials; structural elements without strip coatings; plastics; paper / foil; other processing)

[68] In the present area, this involves "SNAP Level 3" detailing.

iii) Other non-industrial colour coatings (marking paints; anti-corrosives; other)

2.D.3.e Degreasing

- **Metal degreasing**
- **Production of electronic components**
- **Other industrial cleaning** (precision mechanics, optics, watch-making)

2.D.3.f Chemical cleaning (dry cleaning)

- **Dry cleaning**

2.D.3.g Production and processing of chemical products

- **Processing of polyester**
- **Processing of polyvinyl chloride**
- **Processing of polyurethane**
- **Processing of polystyrene foam**
- **Rubber processing** (tyre manufacturing)
- **Production of pharmaceutical products**
- **Production of paints and lacquers**
- **Production of printing inks and dyes**
- **Production of glues**
- **Asphalt blowing**
- **Production of adhesives, magnetic tape, films and photographs**
- **Production of products containing solvents**
    - Production of wood preservatives
    - Production of building-material additives
    - Production of consumer goods containing solvents
    - Production of surface-cleaning agents
    - Production of anti-freezes and de-icing agents
    - Production of waxes and wax removers
    - Production of paint strippers

2.D.3.h Printing industry – printing applications

- Coldset-offset printing (newspaper printing)
- Sheet-fed offset printing (conventional, UV-bases)
- Heatset-offset printing
- Endless-offset printing
- Book printing
- Flexographic printing for packaging (solvent-based, water-based)
- Gravure printing for packaging (solvent-based, water-based)
- Illustration gravure printing
- Screen printing
- Other printing applications
- Paints for artists, in sets
- Paints for artists, not in sets
- Inks for writing and drawing, etc., including inks in concentrate or solid form (not including printing inks)

2.D.3.i: Other applications

- **Treatment of glass and rock wool**

- **Extraction of oils and fats**
- **Use of glues and adhesives** (paper and packaging; construction, wood; transport; shoes; do-it-yourself applications; other)
- **Use of wood preservatives**
- **Undersealing and wax treatments for automobiles**
- **Automobile-wax stripping**
- Other
    - Use of pesticides
    - Dichloroethane for paint stripping
    - Paint and varnish removal (improperly coated aluminium components, steel parts and steel hangers)
    - Concrete additives
    - De-icing (aircraft; working spaces; other)
    - Scientific laboratories

In keeping with the results of the recent study (for an expert judgement), NMVOC emissions from use of metal-processing oils (cooling lubricants) and of other lubricants (industrial lubricants) are no longer reported in source category 2.D.3.i. – "Other applications." We have now included these two source categories, along with the emissions from all other lubricant uses – with the exception of transport-related emissions – within source category 2.D.1. "Lubricant use."

"NMVOC" is defined in keeping with the VOC definition found in the EC solvents directive (European Parliament - Council of the European Union, 2010)[69]. For purposes of the definition of solvents, the term "solvent use" is also defined in keeping with the EC solvents directive[70].

It is important to note that some volatile organic compounds are used both as solvents and as chemical reactants – for example, toluene, which is used as a solvent in lacquers and glues and as a reactant for production of toluenediisocyanate (TDI), and methyl ethyl ketone (butanone), which is used as a solvent in printing inks and as a base material for synthesis of methyl ethyl ketone peroxide. Consequently, VOC (either substances or fractions of substances or products) used as chemical reaction components are not included in this category.

Delimitation of this category as outlined above takes a highly diverse range of emissions-causing processes into account. The factors considered with regard to such processes include:

- Concentrations and volatility of VOC used.
  (The relevant spectrum includes use of volatile individual substances as solvents – for example, in cleansing; use of products with solvent mixtures – for example, in paints and lacquers; and applications in which only small parts of mixtures used (also) have solvent properties (as is the case, for example, in polystyrene-foam production)).
- The great differences in emissions conditions.

Solvent uses can be open to the environment – as is the case in use of cosmetics – or largely closed to the environment – as in extraction of essential oils or cleaning in chemical dry-cleaning systems.

[69] In this definition, volatile organic compounds (VOC) include all organic compounds that are volatile at 293.15 K, at a vapour pressure of at least 0.01 kPa or under the usual conditions for their use.

[70] In this definition, an organic solvent is a volatile organic compound that, either by itself or in combination with other raw materials, products or waste substances, and without changing chemically, either dissolves or is used as a cleanser for dissolving dirt accumulations, as a solvent, as a dispersing agent, as an agent for adjusting viscosity or surface tension, or as a softener or preservative.

4.5.3.2 Methodological issues (2.D.3 Solvents)

NMVOC emissions are calculated via an approach oriented to product consumption. In this approach, the NMVOC input quantities allocated to these source categories, via solvents or solvent-containing products, are determined and then the relevant NMVOC emissions (for each source category) are calculated from those quantities via specific emission factors. This method is explicitly listed, under "consumption-based emissions estimating", as one of two methods that are to be used for emissions calculation for this category.

Use of this method is possible only with valid input figures – differentiated by source categories – in the following areas:

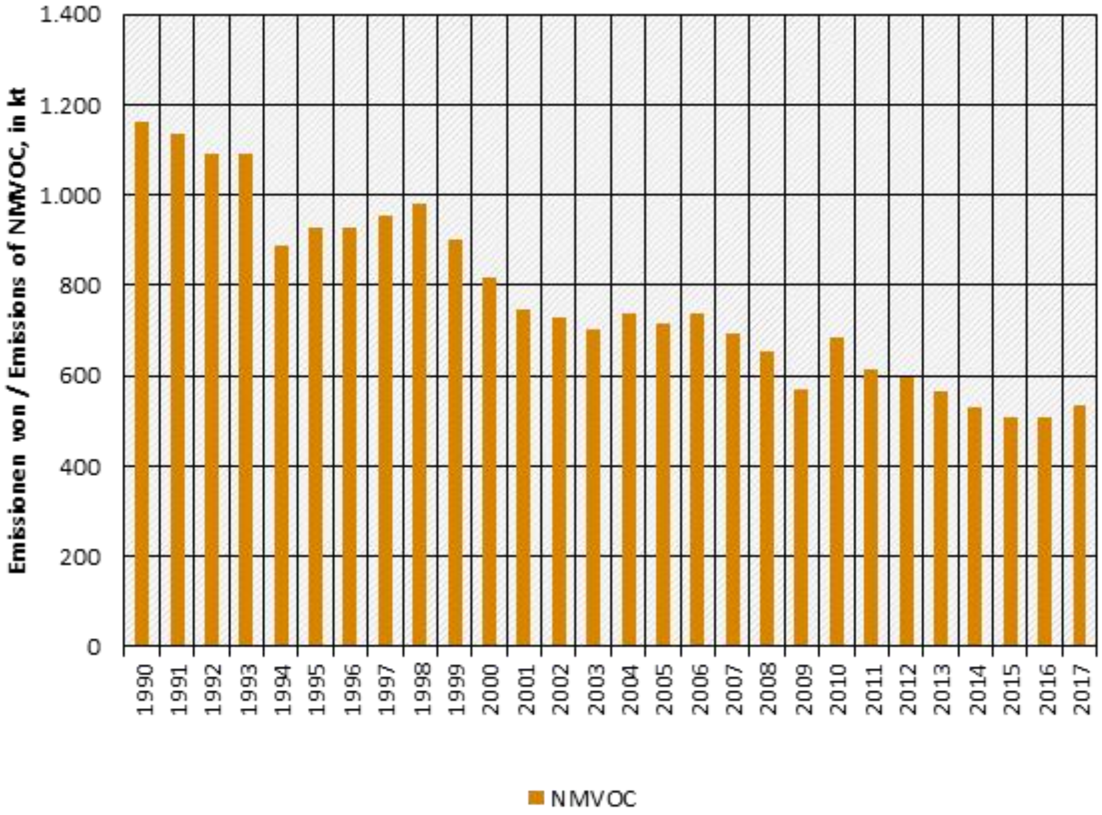
- the quantities of VOC-containing (pre-) products and agents used in the report year,
- the VOC concentrations in these products (substances and preparations),
- the relevant application and emission conditions (or the resulting specific emission factor).

To take account of the highly diverse structures throughout this category, these input figures are determined on the level of 37 differentiated emissions-causing processes (as noted above, in a manner similar to that used for CORINAIR SNAP Level 3), and the calculated NMVOC emissions are then aggregated. The product / substance quantities used are determined at the product-group level with the help of production and foreign-trade statistics. Where possible, the so-determined domestic-consumption quantities are then further verified via cross-checking with industry statistics.

The values used for the average VOC concentrations of the input substances, and the emission factors used, are based on experts' assessments (expert opinions and industry dialog) relative to the various categories and category areas. Not all of the necessary basic statistical data required for calculation of NMVOC emissions for the most current relevant year are available in final form; as a result, the data determined for the previous year are used as a basis for a forecast for the current report. The forecast for NMVOC emissions from solvent use for the relevant most current year is calculated on the basis of specific activity trends. As soon as the relevant basic statistical data are available for the relevant most current year, in their final form, the inventory data for NMVOC emissions from solvent use are recalculated.

Since 1990, NMVOC emissions from use of solvents and solvent-containing products have decreased by 50% overall.

Figure 46: Total NMVOC emissions from solvents-based products and applications (2.D.3.a,d-i)



The greatest part of this emissions reduction has occurred in the years since 1999. This successful reduction has occurred especially as a result of regulatory provisions such as the Ordinance, under chemicals law, for limiting emissions of volatile organic compounds (VOC) through limitations on the placing on the market of solvent-containing paints and varnishes *(Chemikalienrechtliche Verordnung zur Begrenzung der Emissionen flüchtiger organischer Verbindungen (VOC) durch Beschränkung des Inverkehrbringens lösemittelhaltiger Farben und Lacke (Lösemittelhaltige Farben- und Lack-Verordnung - ChemVOCFarbV)*, the 31st Ordinance on the Execution of the Federal Immission Control Act (Ordinance on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain facilities – 31. *BImSchV)*, the 2nd such ordinance *(Ordinance on the limitation of emissions of highly volatile halogenated organic compounds* – 2. *BImSchV)* and the Technical Instructions on Air Quality Control (TA Luft). The German "Blauer Engel" ("Blue Angel") environmental quality seal, which is used to certify a range of products, including paints, lacquers and glues with low solvent concentrations, has also played an important role in this development.

While product sales increased in some areas – even over periods of several years – thereby adding to emissions, the above-described measures have largely offset this trend. These successes, which have occurred especially in recent years, are reflected in the updated emissions calculations – which, thanks to methods optimisation, now feature greater differentiation of VOC concentrations and emission factors.

Since the 2009 report, indirect CO_2 emissions are calculated from NMVOC.

Since compatibility with EU greenhouse-gas reporting is the primary methodological backdrop for conversion of NMVOC emissions into indirect CO_2 emissions, for the current report we have used the Reference Approach proposed in *Vol. 3 Chapter 7 Precursors and Indirect Emissions* of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories:

$$EM_{Indirect\ CO2} = EM_{NMVOC} * \text{molar mass } CO_2 / \text{molar mass } C * 60\ \%$$

In the framework of an expert assessment, and with the help of technical discussions with the affected sectors in the years 2013, 2015 and 2017, the solvent content levels of various paints, coatings and printing inks have been adapted to the current state of the art – and, thus, reduced. In addition, the NMVOC emissions from use of metal-processing oils (cooling lubricants) and of other lubricants (industrial lubricants) have been assigned to another category (2.D.1. "lubricant use") (cf. Chapter 4.5.3.1).

A more-detailed explanation of the methods used to determine and analyse trends for NMVOC emissions from solvents-based products and applications is available in the Informative Inventory Report (IIR)[71].

4.5.3.3 Uncertainties and time-series consistency (2.D.3 Solvents)

At the time of the report, errors had been estimated for NMVOC emissions; this was carried out using the error-propagation method and on the basis of experts' assessments for all input figures (in all 37 differentiated categories). The main source of current uncertainties consists of inadequate precision in separation of basic statistics (production and foreign-trade statistics), with regard to categorisation in VOC-containing and VOC-free products, and with regard to use in different categories with highly differing emissions conditions.

In the framework of an expert judgement, the consistency of the inventory in this area was checked via documentation of the database and the calculation methods for the 33 SNAP codes. The emissions time series from 2005 through 2015 were reviewed with regard to major jumps (>10 % from year to year), and the causes of any jumps were analysed. For all jumps identified, the causes behind the jumps were clarified. As a result, we conclude that there are no inconsistencies in the time series.

4.5.3.4 Category-specific quality assurance / control and verification (2.D.3 Solvents)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

4.5.3.5 Category-specific recalculations (2.D.3 Solvents)

The data used in the emissions inventory for the NMVOC emissions of the previous year are subjected to routine source-specific recalculations. That procedure, which is grounded in the methodology for the product-consumption approach, is required because the relevant final data from foreign-trade statistics do not become available until after the report for the pertinent reported year has been completed.

The NMVOC emissions of the year 2016 had to be slightly corrected, to take account of slight adjustments / updates in foreign-trade statistics. Additional adjustments also resulted in that the NMVOC emissions from use of metal-processing oils (cooling lubricants) and of other lubricants (industrial lubricants) have been assigned to source category 2.D.1 "Lubricant use." Overall, these adjustments and recalculations have led to minor reductions, but they have not brought about any significant changes in the relevant emissions.

[71] Informative Inventory Report – Germany http://iir.umweltbundesamt.de

Table 212: Recalculations for the category "Solvent use"

2019 Submission matter	Category	Units	2013	2014	2015	2016	2017
CO2	2 D 3 a, Domestic Solvent Use Including Fungicides	kt	204.562908	193.238892	198.183216	207.985088	213.313031
CO2	2 D 3 d i, Decorative Coating Application	kt	176.921602	136.460302	150.52081	144.454141	148.251807
CO2	2 D 3 d ii, Industrial Coating Application	kt	280.01468	244.776576	258.049286	253.906168	277.279908
CO2	2 D 3 d iii, Other Coating Application	kt	34.086052	27.880226	30.305242	29.4975837	31.4732101
CO2	2 D 3 d, Coating Applications	kt					
CO2	2 D 3 e, Degreasing	kt	89.38325	84.213734	89.970562	89.5079186	92.1364449
CO2	2 D 3 f, Dry Cleaning	kt	2.601016	2.601016	2.601016	2.60101458	2.60101458
CO2	2 D 3 g, Chemical Products	kt	109.797314	97.64546	94.409788	99.4657481	115.859806
CO2	2 D 3 h, Printing	kt	165.833998	151.365786	140.584026	136.965815	123.802173
CO2	2 D 3 i, Other Solvent Use	kt	183.26143	226.03614	153.833966	156.700919	171.91186
NMVOC	2 D 3 a, Domestic Solvent Use Including Fungicides	kt	92.98314	87.83586	90.08328	94.5386764	96.9604687
NMVOC	2 D 3 d i, Decorative Coating Application	kt	80.41891	62.02741	68.41855	65.660973	67.3871852
NMVOC	2 D 3 d ii, Industrial Coating Application	kt	127.2794	111.26208	117.29513	115.411895	126.036322
NMVOC	2 D 3 d iii, Other Coating Application	kt	15.49366	12.67283	13.77511	13.4079926	14.3060046
NMVOC	2 D 3 d, Coating Applications	kt					
NMVOC	2 D 3 e, Degreasing	kt	40.62875	38.27897	40.89571	40.6854176	41.8802022
NMVOC	2 D 3 f, Dry Cleaning	kt	1.18228	1.18228	1.18228	1.18227936	1.18227936
NMVOC	2 D 3 g, Chemical Products	kt	49.90787	44.3843	42.91354	45.2117037	52.663548
NMVOC	2 D 3 h, Printing	kt	75.37909	68.80263	63.90183	62.2571884	56.2737149
NMVOC	2 D 3 i, Other Solvent Use	kt	83.30065	102.7437	69.92453	71.2276904	78.1417546

2018 Submission matter	Category	Units	2013	2014	2015	2016
CO2	2 D 3 a, Domestic Solvent Use Including Fungicides	kt	204.562908	193.238892	198.183216	203.137791
CO2	2 D 3 d i, Decorative Coating Application	kt	176.921602	136.460302	150.52081	158.046857
CO2	2 D 3 d ii, Industrial Coating Application	kt	280.01468	244.776576	258.049286	265.790756
CO2	2 D 3 d iii, Other Coating Application	kt	34.086052	27.880226	30.305242	32.4266082
CO2	2 D 3 d, Coating Applications	kt				
CO2	2 D 3 e, Degreasing	kt	89.38325	84.473268	89.970562	90.8702754
CO2	2 D 3 f, Dry Cleaning	kt	2.601016	2.601016	2.601016	2.60101458
CO2	2 D 3 g, Chemical Products	kt	109.797314	97.64546	94.409788	95.542699
CO2	2 D 3 h, Printing	kt	165.833998	151.365786	140.584026	142.313212
CO2	2 D 3 i, Other Solvent Use	kt	252.50742	226.03614	225.191494	227.443413
NMVOC	2 D 3 a, Domestic Solvent Use Including Fungicides	kt	92.98314	87.83586	90.08328	92.3353595
NMVOC	2 D 3 d i, Decorative Coating Application	kt	80.41891	62.02741	68.41855	71.8394803
NMVOC	2 D 3 d ii, Industrial Coating Application	kt	127.2794	111.26208	117.29513	120.81398
NMVOC	2 D 3 d iii, Other Coating Application	kt	15.49366	12.67283	13.77511	14.7393673
NMVOC	2 D 3 d, Coating Applications	kt				
NMVOC	2 D 3 e, Degreasing	kt	40.62875	38.39694	40.89571	41.3046706
NMVOC	2 D 3 f, Dry Cleaning	kt	1.18228	1.18228	1.18228	1.18227936
NMVOC	2 D 3 g, Chemical Products	kt	49.90787	44.3843	42.91354	43.4284996
NMVOC	2 D 3 h, Printing	kt	75.37909	68.80263	63.90183	64.6878237
NMVOC	2 D 3 i, Other Solvent Use	kt	114.7761	102.7437	102.35977	103.383369

Difference Gas	Source category	Units	2013	2014	2015	2016
CO2	2 D 3 a, Domestic Solvent Use Including Fungicides	kt	0.00	0.00	0.00	4.85
CO2	2 D 3 d i, Decorative Coating Application	kt	0.00	0.00	0.00	-13.59
CO2	2 D 3 d ii, Industrial Coating Application	kt	0.00	0.00	0.00	-11.88
CO2	2 D 3 d iii, Other Coating Application	kt	0.00	0.00	0.00	-2.93
CO2	2 D 3 d, Coating Applications	kt	0.00	0.00	0.00	0.00
CO2	2 D 3 e, Degreasing	kt	0.00	-0.26	0.00	-1.36
CO2	2 D 3 f, Dry Cleaning	kt	0.00	0.00	0.00	0.00
CO2	2 D 3 g, Chemical Products	kt	0.00	0.00	0.00	3.92
CO2	2 D 3 h, Printing	kt	0.00	0.00	0.00	-5.35
CO2	2 D 3 i, Other Solvent Use	kt	-69.25	0.00	-71.36	-70.74
Total		**kt**	**-69.25**	**-0.26**	**-71.36**	**-97.09**
NMVOC	2 D 3 a, Domestic Solvent Use Including Fungicides	kt	0.00	0.00	0.00	2.20
NMVOC	2 D 3 d i, Decorative Coating Application	kt	0.00	0.00	0.00	-6.18
NMVOC	2 D 3 d ii, Industrial Coating Application	kt	0.00	0.00	0.00	-5.40
NMVOC	2 D 3 d iii, Other Coating Application	kt	0.00	0.00	0.00	-1.33
NMVOC	2 D 3 d, Coating Applications	kt	0.00	0.00	0.00	0.00
NMVOC	2 D 3 e, Degreasing	kt	0.00	-0.12	0.00	-0.62
NMVOC	2 D 3 f, Dry Cleaning	kt	0.00	0.00	0.00	0.00
NMVOC	2 D 3 g, Chemical Products	kt	0.00	0.00	0.00	1.78
NMVOC	2 D 3 h, Printing	kt	0.00	0.00	0.00	-2.43
NMVOC	2 D 3 i, Other Solvent Use	kt	-31.48	0.00	-32.44	-32.16
Total		**kt**	**-31.48**	**-0.12**	**-32.44**	**-44.13**

4.5.3.6 Planned improvements, category-specific (2.D.3 Solvents)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.5.4 Other: Bitumen for roofing (2.D.3 Bitumen)

Gas	Method used	Source for the activity data	Emission factors used
NMVOC	Tier 1	AS	CS
CO_2	NE	NE	NE

As far as is currently known, the category *Bitumen for roofing* produces no greenhouse-gas emissions and thus is not a key category[72].

4.5.4.1 Category description (2.D.3 Bitumen)

Bitumen is used in production and laying of roof and sealing sheeting.

The quantities of roof and sealing sheeting that are produced and used in Germany are shown in Table 213. The discrepancy between the two figures (production and use) is due to an export surplus. In such production, liquid bitumen is applied, at temperatures of 150°C to 220°C, as a saturating or coating agent. This process produces emissions of organic substances (combined here as NMVOC).

Roof and sealing sheeting is laid by means of both hot and cold processes. The hot process, involving welding of sheeting, produces significant emissions of organic substances. The relevant

[72] Cf. the discussion of indirect CO_2 emissions, under "Methodological aspects".

emissions trends depend primarily on trends in quantities of polymer bitumen sheeting produced. Use of solvent-containing primers is not considered here; it is covered via the solvents model – cf. Chapter 4.5.1.

Emissions from production of roof and sealing sheeting have remained about the same, and production quantities have hardly decreased at all. Emissions from laying of roof and sealing sheeting can increase slightly, even when the quantities of sheeting used decrease, because use of bitumen roofing sheets is accounting for a growing share of this sector.

Substances other than NMVOC are of only subordinate relevance in terms of emissions (cf. footnote [72]).

4.5.4.2 Methodological issues (2.D.3 Bitumen)

Data on quantities of roof and sealing sheeting that are produced and used (**activity data**) are provided by the VDD association of the bitumen, roof sheeting and sealing sheeting industry (VDD, 2018), on the basis of a cooperation agreement dating from 2009. At present, no data supplementation or extrapolation is being carried out. To obtain internationally comparable figures, production quantities are converted into quantities of input bitumen (the conversion relationship, depending on the type of sheeting concerned, varies from 1.3 to 3.3 bitumen kg/m^2).

Because of their predominating importance, only NMVOC emissions are considered and taken into account in the emissions inventory. In the process, a distinction is made between emissions from production and emissions from laying of roof and sealing sheeting.

The **emission factor** for production of roof and sealing sheeting was obtained via a calculation in accordance with current technological standards of German manufacturers (VDD, 2009). The emission factor for laying of polymer bitumen sheeting has been taken from an ecological balance sheet (Kreißig, 1996). That emission factor has also been adopted, by analogy, for sheeting glued primarily with hot bitumen. Thin sheeting is not glued; it is attached via nailing and produces no emissions. The implied emission factor for the category has been increasing slightly, as a result of the increasing importance of polymer bitumen sheeting.

NMVOC emissions are calculated in keeping with a Tier 1 method, since no pertinent detailed data are available.

Table 213: Production and laying of roof and sealing sheeting with bitumen, and relevant activity data and emission factors

	Produced or used area in 2017 [millions of m^2]	EF/ IEF [kg/ m^2]
Production of roof and sealing sheeting with bitumen	165	NMVOC 0.000358
Laying of roof and sealing sheeting containing bitumen	141	NMVOC 0.000027– 0.000041

The carbon dioxide emissions, which could be obtained by multiplying the NMVOC emissions by a carbon-content factor of 80% and then converting to CO_2, are negligibly low. For this reason, they are not listed as such; in the CRF tables, they are marked as "NE".

4.5.4.3 Uncertainties and time-series consistency (2.D.3 Bitumen)

Information relative to the uncertainty of the data of the VDD was obtained via consultation between the VDD and the Federal Environment Agency. The total uncertainty for the activity data for production and laying of sheeting is estimated to be about +/-1 %. That figure, in turn, leads to a higher uncertainty, of about +/-2.5 %, for the calculated bitumen consumption.

The uncertainty for the combined emission factors for production and laying of roof and sealing sheeting is estimated to be about +/-5 %.

4.5.4.4 Category-specific quality assurance / control and verification (2.D.3 Bitumen)

Due to resources limitations, and to the area's minimal relevance, no QC/QA is carried out for reporting relative to precursors. A QC/QA checklist was completed and confirmed in the framework of the agreement with the VDD.

The manner in which the activity data were determined is considered to be plausible. The emission factors accord with findings from pertinent Federal Environment Agency research projects and are plausible. In particular, the validity of the emission factors is justified in that no emissions from use of solvent-containing coatings and primers have to be taken into account in this section (that takes place in the solvents model, as noted above).

4.5.4.5 Category-specific recalculations (2.D.3 Bitumen)

No recalculations are required.

4.5.4.6 Planned improvements, category-specific (2.D.3 Bitumen)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.5.5 Other: Road paving with asphalt (2.D.3 Asphalt)

Gas	Method used	Source for the activity data	Emission factors used
NO_X, NMVOC, SO_2	Tier 1	AS	CS
CO_2	NE	NE	NE

As far as is currently known, the category *Road paving with asphalt* produces no greenhouse-gas emissions and thus is not a key category[73].

4.5.5.1 Category description (2.D.3 Asphalt)

Currently, the report tables list produced quantities of mixed asphalt products and NMVOC, NO_X and SO_2 emissions (with regard to CO_2, cf. footnote [73]).

In 2017, a total of about 42 million t of asphalt (DAV, 2018) was produced in Germany, in a total of about 600 asphalt-mixing plants (DAV, 2016). Asphalt is used primarily in road construction, where it competes directly with hydraulically bound concrete. In 1991, total production increased considerably; since 2000 it has been decreasing again.

The relevant emissions trend depends primarily on trends in production quantities, and production has stagnated in recent years.

4.5.5.2 Methodological aspects (2.D.3 Asphalt)

No special calculation procedure is available for calculating fuel inputs in category 1.A.2. Nonetheless, fuel inputs are taken into account via Energy Balance evaluation, and they are coupled with suitable emission factors.

The applicable quantity of mixed asphalt products produced (**activity data**) has been taken from communications of the Deutscher Asphaltverband (DAV; German asphalt association).

[73] Cf. the discussion of indirect CO_2 emissions, under "Methodological aspects".

The **emission factors** were determined country-specifically, in accordance with Tier 2 criteria. Emission factors for substances other than CO_2 were determined on the basis of emissions measurements for over 400 asphalt-mixing plants, for the period 1989 to 2000. The majority of the emissions occur during drying of pertinent mineral substances. Almost all of the NMVOC emissions originate in the organic raw materials used, and they are released primarily in parallel-drum operation, as well as from mixers and loading areas. On average, about 50% of the NO_X and SO_2 involved come from the mineral substances used (proportional process emissions). CO occurs primarily in incomplete combustion processes. CO emissions are calculated solely in connection with fuel inputs.

Table 214: Emission factors for production of mixed asphalt products

	NOx	NMVOC	SO_2
EF [kg/ t]	0.015	0.030	0.030

Only emissions from asphalt production are reported. Figures relative to emissions released during laying of asphalt have not yet been adequately reviewed.

The carbon dioxide emissions, which could be obtained by multiplying the NMVOC emissions by a carbon-content factor of 80 % and then converting to CO_2, are negligibly low. For this reason, they are not listed as such; in the CRF tables, they are marked as "NE".

4.5.5.3 Uncertainties and time-series consistency (2.D.3 Asphalt)

As the extensive measurement data show, the emissions lie within a comparatively narrow range. The large volume of measurement data available makes it possible to form highly reliable mean values. The only large uncertainties are found in breakdown of emissions amounts into fuel-related and process-related emissions.

The production-amount data may be considered very accurate, since the product in question is a sale-ready product, and operators report the relevant amounts to the DAV.

4.5.5.4 Category-specific quality assurance / control and verification (2.D.3 Asphalt)

Due to resources limitations, and to the area's minimal relevance, no QC/QA is carried out for reporting relative to precursors.

4.5.5.5 Category-specific recalculations (2.D.3 Asphalt)

No recalculations are required.

4.5.5.6 Planned improvements, category-specific (2.D.3 Asphalt)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.5.6 CO_2 emissions from use of AdBlue® in road transports and off-road vehicles (2.D.3 Other: AdBlue)

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS / M	CS / M	D

4.5.6.1 Category description (2.D.3 Other: AdBlue)

Since 2004, increasing numbers of vehicles have been in service in Germany that are equipped with SCR catalytic converters. These catalytic converters control NO_x emissions with the help of a liquid-reductant agent, an aqueous urea solution.[74] When the urea solution is chemically converted, carbon dioxide is released. In Germany, virtually the only the product used for this purpose is AdBlue® (VDA, 2013).

4.5.6.2 Methodological issues (2.D.3 Other: AdBlue)

Since no comprehensive statistics or market studies on AdBlue® sales are currently available, the input AdBlue® quantities, and the resulting CO_2 emissions, are calculated within TREMOD (Knörr et al., 2018a) on the basis of data on fuel consumption by vehicles equipped with SCR catalytic converters.

Table 215: Annual fuel consumption of SCR vehicles, in terajoules

	2004	2005	2010	2011	2012	2013	2014	2015	2016	2017
Automobiles	0	0	66,122	137,117	211,359	277,203	337,772	394,934	446,932	486,182
Light duty vehicles	0	0	1,380	5,816	14,317	26,194	38,380	50,688	59,416	67,529
Heavy duty vehicles: trucks	133	5,019	251,942	295,619	316,220	341,339	376,925	416,062	453,258	482,476
Heavy duty vehicles: buses	30	110	10,001	11,993	14,142	16,119	18,278	20,763	23,626	26,292
Σ road	**163**	**5,129**	**329,445**	**450,545**	**556,038**	**660,854**	**771,355**	**882,447**	**983,232**	**1,062,479**
Construction sector	0	0	0	0	0	0	758	3,289	8,169	14,555
Commercial and institutional	0	0	0	0	0	0	107	509	1,331	2,422
Agriculture	0	0	0	0	0	0	434	2,204	5,789	10,085
Forestry sector	0	0	0	0	0	0	18	156	498	997
Σ Offroad	**0**	**0**	**0**	**0**	**0**	**0**	**1,317**	**6,158**	**15,787**	**28,059**
Total quantity	**163**	**5,129**	**329,445**	**450,545**	**556,038**	**660,854**	**772,672**	**888,605**	**999,019**	**1,090,538**

Source: (Knörr et al., 2018a, 2018b)

Table 216: Modelled quantities of AdBlue® used, in tonnes

	2004	2005	2010	2011	2012	2013	2014	2015	2016	2017
Automobiles	0	0	3,216	6,633	10,685	15,668	25,346	49,739	90,654	132,345
Light duty vehicles	0	0	0	0	1	29	136	436	3,086	11,925
Heavy duty vehicles: trucks	162	6,120	304,808	357,486	382,251	412,523	455,552	502,959	547,998	583,397
Heavy duty vehicles: buses	40	149	13,224	15,844	18,644	21,201	24,005	27,238	30,949	34,392
Σ road	**202**	**6,269**	**321,248**	**379,962**	**411,581**	**449,421**	**505,039**	**580,372**	**672,688**	**762,060**
Construction sector	0	0	0	0	0	0	1,619	7,021	17,437	31,071
Commercial and institutional	0	0	0	0	0	0	228	1,087	2,841	5,170
Agriculture	0	0	0	0	0	0	926	4,705	12,358	21,528
Forestry sector	0	0	0	0	0	0	39	334	1,064	2,129
Σ Offroad	**0**	**0**	**0**	**0**	**0**	**0**	**2,811**	**13,146**	**33,700**	**59,898**
Total quantity	**202**	**6,269**	**321,248**	**379,962**	**411,581**	**449,421**	**507,850**	**593,518**	**706,387**	**821,957**

Source: (Knörr et al., 2018a, 2018b)

The resulting CO_2 emissions are calculated in keeping with the following formula, pursuant to ((IPCC, 2006): Volume 2, Chapter 3.2 - Road Transportation, p. 3.12, Formula 3.2.2):

$$EM_{CO_2} = AR_{AdBlue®} \times \frac{12}{60} \times \frac{32{,}5}{100} \times \frac{44}{12}$$

The following table presents the so-determined CO_2 emissions, for the period 2004 through 2017, from use of AdBlue® in vehicles equipped with SCR catalytic converters.

[74] Average urea concentration pursuant to DIN 70070: 32.5 %

Table 217: CO_2 emissions resulting from use of AdBlue®, in kilotonnes

	2004	2005	2010	2011	2012	2013	2014	2015	2016	2017
Automobiles	0.00	0.00	0.77	1.58	2.55	3.73	6.04	11.85	21.61	31.54
Light duty vehicles	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.10	0.74	2.84
Heavy duty vehicles: trucks	0.04	1.46	72.65	85.20	91.10	98.32	108.57	119.87	130.61	139.04
Heavy duty vehicles: buses	0.01	0.04	3.15	3.78	4.44	5.05	5.72	6.49	7.38	8.20
Σ road	**0.05**	**1.49**	**76.56**	**90.56**	**98.09**	**107.11**	**120.37**	**138.32**	**160.32**	**181.62**
Construction sector	0.00	0.00	0.00	0.00	0.00	0.00	0.39	1.67	4.16	7.41
Commercial and institutional	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.26	0.68	1.23
Agriculture	0.00	0.00	0.00	0.00	0.00	0.00	0.22	1.12	2.95	5.13
Forestry sector	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.08	0.25	0.51
Σ Offroad	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.67**	**3.13**	**8.03**	**14.28**
Total quantity	**0.05**	**1.49**	**76.56**	**90.56**	**98.09**	**107.11**	**121.04**	**141.46**	**168.36**	**195.90**

Source: (Knörr et al., 2018a, 2018b)

In the German GHG inventory, these emissions are reported, pursuant to footnote (6) to CRF Table 2(I).A-Hs2, under *2.D.3 – Non-energy products from fuels – Other*.

4.5.6.3 Uncertainties and time-series consistency (2.D.3 Other: AdBlue®)

The underlying uncertainties figures have been obtained from expert judgements. The relevant data sources, methods and emission factors are used consistently throughout the entire time series.

4.5.6.4 Category-specific quality assurance / control and verification (2.D.3 Other: AdBlue®)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The data cannot be verified on the basis of inventories comparable to the German inventory. The last comparison with inventories of other countries was carried out in summer 2018, in the framework of an EU-wide exchange on new emission sources.

4.5.6.5 Category-specific recalculations (2.D.3 Other: AdBlue®)

Table 218: Revised annual fuel consumption of SCR vehicles, in terajoules

	2012	2013	2014	2015	2016
2019 Submission	556,038	660,854	772,672	888,605	999,019
2018 Submission	556,059	660,900	772,554	888,456	997,737
Absolute change	-22	-46	118	149	1,282
Relative change	-0.004%	-0.007%	0.015%	0.017%	0.128%

Source: Own calculations, based on , (Knörr et al., 2018a, 2018b)

The quantities of diesel fuel consumed in vehicles equipped with SCR catalytic converters were upwardly corrected, slightly, for the years 2014 through 2016. For the year 2016, the quantities of AdBlue used in road vehicles were downwardly corrected within TREMOD, however.

Table 219: Revised quantities of AdBlue® used, in tonnes

	2012	2013	2014	2015	2016
2019 Submission	411,581	449,421	507,850	593,518	706,387
2018 Submission	411,582	449,424	507,644	593,320	707,850
Absolute change	-1.001	-2.967	207	198	-1,463
Relative change	-0.0002%	-0.0007%	0.041%	0.033%	-0.21%

Source: Own calculations, based on , (Knörr et al., 2018a, 2018b)

Table 220: Revised CO_2 emissions, in kilotonnes

	2012	2013	2014	2015	2016
2019 Submission	98.0934	107.1120	121.0377	141.4551	168.3557
2018 Submission	98.0936	107.1127	120.9885	141.4078	168.7043
Absolute change	-0.0002	-0.0007	0.0492	0.0473	-0.3486
Relative change	-0.0002%	-0.0007%	0.041%	0.033%	-0.21%

Source: Own calculations

4.5.6.6 Planned improvements, category-specific (2.D.3 Other: AdBlue®)

At present, improvements are planned on top of the general maintenance of the underlying TREMOD and TREMOD MM models that is normally carried out.

4.6 Electronics industry (2.E)

KC	Category	Activity	EM of	1995 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1995-2017
-/-	2.E. Electronics industry		PFC	278.31	0.02%	143.43	0.02%	-48.5%
-/-	2.E. Electronics industry		SF_6	47.28	0.00%	21.98	0.00%	-53.5%
-/-	2.E. Electronics industry		HFC	17.11	0.00%	12.89	0.00%	-24.6%
-/-	2.E. Electronics industry		NF_3	C	C	C	C	C

Gas	Method used	Source for the activity data	Emission factors used
HFC	Tier 3	AS, NS	PS
PFC	CS	AS, NS	CS
SF_6	CS	AS, NS	CS
NF_3	CS	AS, NS	CS

The category *Electronics industry* is not a key category.

4.6.1 Semiconductor and circuit-board production (2.E.1)

4.6.1.1 Category description (2.E.1)

The semiconductor industry currently emits PFCs (CF_4, C_2F_6, C_3F_8, c-C_4F_8), HFC (CHF_3, CH_2F_2), nitrogen trifluoride (NF_3) and sulphur hexafluoride ((SF_6) from production processes. These gases are used for etching structures on thin layers and for cleaning reaction chambers following chemical vapour deposition (CVD). In the production process, some of the PFCs fed into plasma chambers are converted partly into CF_4.

The semiconductor industry's emissions depend partly on the degree to which the industry uses waste-gas-scrubbing equipment. They also depend directly on semiconductor-production levels (in the present case, annual levels). As a result of these dependencies, emissions tend to fluctuate rather strongly from year to year.

4.6.1.2 Methodological issues (2.E.1)

Emission factors

During the etching process, only about 15 % of the added CF_4 reacts chemically. The emission factor, an inverse reaction quota, thus amounts to 85 % of the CF_4 consumption.

The emissions cannot be determined solely on the basis of input quantities (sales by gas vendors), however, because the difference between consumption and emissions depends on a number of factors – especially the effects of downstream waste-gas-scrubbing systems, in addition to only-partial chemical transformation in plasma reactors. The relevant figures are thus aggregated and reported on a plant-specific basis, by the pertinent industrial association.

Activity data

The quantities of SF_6 used (since report year 2006) and NF_3 use (since report year 2015) are determined by the Federal Statistical Office, via surveys of gas sellers (UStatG 2005). The usage-quantity data for the other substances are collected by the Federal Statistical Office, assigned to the semiconductor industry and confirmed by that industry.

Reliable emissions data are available for 1990 and 1995. Linear interpolation was carried out for the years 1991 to 1994.

Until report year 2000, emissions data were based on surveys carried out by the EECA-ESIA (European Electronic Component Manufacturers Association – European Semiconductor Industry Association). National manufacturers were queried regarding production capacities, amounts of substances used and waste-gas treatment equipment.

As the result of a voluntary commitment by the semiconductor industry, emissions figures are available for this sub-category, for all individual substances, from the year 2001 onwards. In keeping with a standardised calculation formula (Tier 2c approach), the emissions data are calculated for each production site, from annual consumption, aggregated and then reported by the German Electrical and Electronic Manufacturers Association (Zentralverband Elektrotechnik- und Elektroindustrie eV. – ZVEI; Electronic Components and Systems Division) to the Federal Environment Agency.

4.6.1.3 Uncertainties and time-series consistency (2.E.1)

The uncertainties have been completely determined. According to the association, the uncertainties for the emissions amount to U_{max}= 12 % and U_{min}= 7 %.

4.6.1.4 Category-specific recalculations (2.E.1)

No recalculations are required. For reasons of confidentiality, emissions of HFC, PFC and NF_3 have to be aggregated and reported in 2.H.3, together with other data. Due to the confidentiality involved, the changes in the emissions cannot be shown.

4.6.1.5 Category-specific quality assurance / control and verification (2.E.1)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The data have undergone the above association's internal quality assurance and quality control process.

Quality control (pursuant to Tier 1) and quality assurance, in conformance with the requirements of the QSE manual and its associated applicable documents, have been carried out.

No other data sources, apart from the data collected by the association, and the data provided by the Federal Statistical Office, are available for review of the F-gas quantities determined for emissions reporting purposes, i.e. for review that would serve as a basis for verification. Comparisons with other countries have revealed no requirements for improvements. The emission factors are of the same order of magnitude as those of other countries.

4.6.1.6 Planned improvements, category-specific (2.E.1)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.6.2 TFT (2.E.2)

No TFT flat screens are produced in Germany.

4.6.3 Photovoltaics (2.E.3)

4.6.3.1 Category description (2.E.3)

In wafer production in Germany, SF_6 and other fluorine compounds have been used for structure etching and for cleaning of reaction chambers during production processes. Since the purity of the process gas is lower than that of the gas used in the similar production process in the semiconductor industry, use for *photovoltaics* is reported separately. In Germany, use of SF_6 in solar technology began in 2003.

The time series shows a continuous emissions increase between 2003 and 2006; this is due to increases in production. A large jump occurred in 2007 and 2008, when quantities of produced wafers and, thus, the quantities of SF_6 used, increased sharply. As of 2010, decreases in produced quantities have led to a new reduction of emissions. From 2014 onward, no wafer production with SF_6 has taken place in Germany.

Beginning 2008, NF_3 substituted for SF_6 in all new production lines for production of Si thin-film cells. Production of the substance was phased out by 2015.

In addition, in 2002/2003 the perfluorinated hydrocarbon CF_4 was introduced for "edge insulation" of crystalline solar cells. The procedure using that substance was soon supplanted by a different procedure that is easier to handle, however. Consumption of CF_4, which peaked in 2004, has been decreasing sharply since then. In 2014, production was largely discontinued.

4.6.3.2 Methodological issues (2.E.3)

Like emissions in the semiconductor industry, emissions in photovoltaics occurred during production. It was not possible to determine the relevant production emissions solely on the basis of the quantities used (sales by the gas trade). The differences between consumption and emissions resulted from a) the fact that chemical conversion in plasma reactors was only partial and b) the effects of downstream waste-gas-scrubbing systems.

Emission factors

In 2009, only one producer in Germany did not have a waste-gas-scrubbing system. For this reason, the IPCC default emission factor of 40 % was used only for the first year of pertinent use, 2003. Thereafter, the emission factor decreased, as the percentage of wafer production connected to downstream waste-gas-scrubbing systems increased. In 2010, it was just less than 6 %. As of 2011, all production facilities that used SF_6 had waste-gas-scrubbing systems in place, and the emission factor has been 4 % since that year.

In wafer production with NF_3, the emission factor had a value of 4 %, since all national production facilities operated waste-gas-scrubbing systems. It was thus considerably lower than the IPCC default emission factor of 20 %.

The emission factor for edge insulation with CF_4 is 7 %.

Activity data

The annual consumption figures were obtained via surveys, carried out by the Federal Statistical Office, of gas suppliers (UStatG 2005), with regard to their domestic sales. In addition, the data have been checked in a separate study (Schwarz 2009).

4.6.3.3 Uncertainties and time-series consistency (2.E.3)

The uncertainties have been completely determined. According to expert judgements, the uncertainties for the emissions (U_{min}/U_{max}) are 10 % for SF_6, 20% for NF_3 and 50 % for CF_4.

4.6.3.4 Category-specific recalculations (2.E.3)

No recalculations are required.

4.6.3.5 Category-specific quality assurance / control and verification (2.E.3)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

No other data sources, apart from the data provided by the Federal Statistical Office and the research contractor, are available for review of the F-gas quantities determined for emissions reporting purposes, i.e. for review that would serve as a basis for verification. Comparisons with other countries have revealed no requirements for improvements. The emission factors are of the same order of magnitude as those of other countries that operate production facilities with waste-gas-scrubbing systems.

4.6.3.6 Planned improvements, category-specific (2.E.3)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.6.4 Heat transfer fluids (2.E.4)

4.6.4.1 Category description (2.E.4)

The PFC C_6F_{14} has been used as a heat transfer fluid in the semiconductor industry and in some ICE power cars. C_6F_{14} was widely used in the semiconductor industry in the 1990s. In 2015, such use was discontinued, and hydrofluoroether has been used instead. Emissions thus occur only from existing applications and in disposal. Until 2009, C_6F_{14} was used in ICE power cars for cooling purposes.

4.6.4.2 Methodological issues (2.E.4)

The emission factors are assumed to be 1 % for filling, 5 % for emissions from existing applications and 15 % for disposal. The 2006 IPCC Guidelines (IPCC, 2006) do not provide default emission factors for a Tier 2 approach.

The quantities used, and the emission factors, were determined via surveys of sector experts (Deutsche Bahn, ZVEI), and via studies of available reference materials, in the framework of a research project (Gschrey et al. 2015).

The average lifetime of installations with heat transfer fluids, in the semiconductor industry, amounts to 12 years.

4.6.4.3 Uncertainties and time-series consistency (2.E.4)

The uncertainties have been completely determined. According to expert judgements, the uncertainties for the emissions (U_{min}/U_{max}) amount to 20 %.

4.6.4.4 Category-specific recalculations (2.E.4)

The C_6F_{14} emissions from filling and disposal in the semiconductor industry have been added.

4.6.4.5 Source-specific quality assurance / control and verification (2.E.4)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

No other data sources, apart from the data collected by the research contractor, are available for review of the F-gas quantities determined for emissions reporting purposes, i.e. for review that would serve as a basis for verification. Comparisons with other countries have revealed no requirements for improvements. The emission factors are of the same order of magnitude as the pertinent factors used in other countries.

4.6.4.6 Planned improvements, category-specific (2.E.4)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.7 Product uses as substitutes for ODS (2.F)

KC	Category	Activity	EM of	1995 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1995-2017
L/T	**2.F Product uses as substitutes for ODS**		**HFC**	**C**	**C**	**C**	**C**	**C**
-/-	2.F. Product uses as substitutes for ODS		PFC	19.91	0.00%	7.69	0.00%	-61.4%

Gas	Method used	Source for the activity data	Emission factors used
HFC, PFC	cf. Table 221/Table 222	cf. Table 221/Table 222	cf. Table 221/Table 222

The category Product uses as substitutes for ODS is a key category for HFC emissions in terms of emissions level and trend.

Category 2.F includes Refrigeration and air conditioning systems (2.F.1), Foam production (2.F.2), Fire extinguishing agents (2.F.3), Aerosols (2.F.4), Solvents (2.F.5) and other applications; ODS substitutes fall under (2.F.6). In the interest of more precise data collection, these sub-categories are broken down further, as described in the following sub-chapters.

Use of relevant substances as refrigerants in stationary and mobile refrigeration applications, which accounts for over three-fourths of relevant emissions, is the largest source of HFC emissions in this category. The remaining emissions are distributed among the sources foams and aerosols and, in small amounts, fire extinguishers and solvents.

The PFC emissions originate in use of refrigerant blends in refrigeration and air-conditioning systems.

Table 221: Overview of methods and emission factors used for the current report year in category 2.F.1 – *Refrigeration and air-conditioning systems*.

	QG	Method	Gas		Lifetime	Production	Application	Waste management	
			HFC	PFC	[years]	Emission factor (dimensionless)	Emission factor (dimensionless)	Residual charge level (dimensionless)	Recovery rate (dimensionless)
Air-conditioning and refrigeration systems	**2.F.1**								
Commercial refrigeration	2.F.1a								
- Plug-in appliances					10 (D)	0.005 (D)	0.01 - 0.014 (D)	0.90 (CS)	0.326 - 0.54 (D)
- Condensing units		Tier 2a	HFC		12 (D)	0.01 (D)	0.055 - 0.097 (CS)	0.85 (D)	0.475 - 0.74 (D, CS)
- Central systems				PFC	10 - 14 (D)	0.01 (D)	0.091 - 0.195 (D, CS)	0.875 (D)	0.429 - 0.774 (D, CS)
Household refrigeration	2.F.1b								
- Household refrigeration appliances		Tier 2a	HFC		15 (D)	NO	0.003 (D)	0.955 (CS)	0.733 (CS)
- Ice cream machines		Tier 2a	HFC		15 (CS)	NO	0.003 (CS)	0.955 (CS)	0.53 - 0.605 (CS)
Industrial refrigeration	2.F.1c								
- Plug-in appliances		Tier 2a	HFC		10 (CS)	0.005 (D)	0.01 - 0.014 (CS)	0.9 (D)	0.337 - 0.54 (D)
- Large refrigeration systems				PFC	10 - 30 (D)	0.01 (D)	0.051 - 0.088 (D)	0.85 (D)	0.45 - 0.785 (D)
Refrigerated transports	2.F.1d								
- Refrigerated vehicles		Tier 2a	HFC	PFC	10 (CS)	5 g/system (CS, D)	0.15 - 0.3 (D)	0.875 (CS)	0.657 (D)
- Refrigerated containers					14 (CS)	NO	0.1 (CS)	0.875 (CS)	0.657 (D)
Mobile air conditioning systems	2.F.1e								
- Trucks					15 (D)	5 g/system (CS, D)	0.15 (D)	0.34 (D)	0.38 - 0.46 (D)
- Automobiles					15 (D)	3 g/system (CS, D)	0.1 (D)	0.34 (D)	0.38 - 0.46 (D)
- Buses					15 (D)	50 g/system (D)	0.15 (D)	0.34 (D)	0.38 (D)
- Ships		Tier 2a	HFC		25 (CS)	0.01 (CS)	0.1 - 0.3 (CS)	NO	NO
- Railway vehicles					25 (CS)	0.005 (D)	0.06 (CS)	0.875 (CS)	0.756 (CS)
- Agricultural machines					10 (CS)	5 g/system (CS)	0.15 - 0.25 (CS)	0.34 (CS)	0.117 (CS)
- Aircraft					-	NO	0.05 (CS)	NO	NO
Stationary air conditioning systems	2.F.1f								
- Large air conditioning systems					15 - 25 (D)	0.005 (D)	0.032 - 0.06 (D)	0.9 (D)	0.658 - 0.785 (D)
- Heat pumps					15 (D)	0.005 (D)	0.02 - 0.025 (D)	0.75 (D)	0.5 - 0.605 (D)
- Heat-pump dryers					15 (CS)	0.005 (CS)	0.003 (CS)	NO	NO
- Dishwashers		Tier 2a	HFC		12 (CS)	0.01 (CS)	0.003 (CS)	0.955 (CS)	0.82 (CS)
- Mobile room air conditioners					10 (D)	NO	0.025 - 0.034 (D)	0.75 (D)	0.242 - 0.355 (D)
- Single-split units					10 (D)	0.1 (CS)	0.05 - 0.069 (D)	0.875 (CS)	0.379 - 0.54 (D)
- Multi-split units					13 (D)	0.01 (D)	0.047 - 0.079 (D)	0.875 (CS)	0.62 - 0.74 (D)
- VRF devices					13 (D)	0.01 (D)	0.055 - 0.081 (D)	0.875 (CS)	0.72 - 0.74 (D)

Table 222: Overview of methods and emission factors used, for the current report year, in categories 2.F.2 (Foam blowing), 2.F.3 (Fire extinguishers), 2.F.4 (Aerosols), 2.F.5 (Solvents) and 2.F.6 (Other applications that use ODS substitutes)

	QG	Method	Gas		Lifetime	Emission factor (dimensionless)		
			HFC	PFC	[years]	Production	Application	Waste management
Foam production	**2.F.2**							
closed-cell	2.F.2a							
- PUR hard foam with 134a					50 (D)	0.1 (D)	0.005 (D)	NO
- PUR hard foam with 227ea/245fa/365mfc		Tier 2a	HFC		50 (D)	0.15 (D)	0.01 (D)	NO
- XPS foam with 134a/1234ze					50 (D)	C	0.0066 (CS)	NO
open-cell	2.F.2b							
- XPS foam with 152a		Tier 2a			-	1 (CS)	NO	NO
- PUR integral foam with 134a, 227ea, 245fa, 365mfc		Tier 2a			-	1 (CS)	NO	NO
- PU one-component foam (134a)		Tier 2a	HFC		-	0.5 g/can (CS)	1 (CS)	NO
- PU one-component foam (152a)					-	0.5 g/can (CS)	1 (CS)	NO
Fire extinguishers	**2.F.3**	CS	HFC		20 (D)	0.001 (CS)	0.01 – 0.04 (CS, D) 0.04 (D)	0.01 (CS)
Aerosols	**2.F.4**							
Metered dose inhalers	2.F.4a	Tier 2a	HFC		-	0.01 (CS)	1 (CS)	NO
Other aerosols / novelties	2.F.4b/c	Tier 2a			-	0.015 (CS)	1 (CS)	NO
Solvents	**2.F.5**	Tier 2a	HFC		-	NO	0.5 (D)	NO
Other applications that use ODS substitutes	**2.F.6**					NO	NO	NO

Halocarbons are used in a number of different applications. Whereas in some, so-called "open" applications, consumed quantities are emitted completely, in the same year in question, in other applications large quantities are stored (stocks). The substances then are emitted, either partially or completely, from such "stocks" throughout the entire usage phase and in relevant waste management. Most of the emission factors (EF) used are either country-specific (CS) or IPCC default (D).

The emissions as listed in the inventory tables consist of the quantities of HFCs and PFCs that, during a report year, slowly escape from "stocks" and are emitted in production and waste management.

In general, the emissions data collected for the various product groups comprise emissions from production, use and waste disposal. Except where indicated otherwise in connection with the pertinent methods, these emissions are calculated as follows:

1. Production emissions are determined via new domestic consumption, as activity data:

   Equation 1:

   $$EM_{production} = \text{New domestic consumption} * EF_{production}$$

2. Application emissions are based on the final stocks of relevant pollutants (the activity data), and they are calculated via the following formula:

   Equation 2:

   $$EM_{use} = \text{Final stocks} * EF_{use}$$

   The final stocks for the current year are calculated by summing annual new additions, from the first reporting year to the current one. The new additions for a given year consist of the new domestic consumption for that year, minus production emissions and losses from removals. The calculation thus requires consideration of foreign trade.

3. Disposal emissions refer to new additions for the year that is x years (depends on product lifetime) prior to the current reporting year n:

Equation 3:

$EM_{disposal}$ = New additions (n-x) * $EF_{disposal}$

4. For refrigeration and air-conditioning systems, the disposal emissions are calculated in keeping with Vol. 3 Equation 7.14 of the 2006 IPCC Guidelines:

Equation 4:

$EM_{disposal}$ = new additions (n-x) * residual charge level * (1 - recovery factor)

In this chapter, the sections *Uncertainties and time-series consistency, Category-specific quality assurance / control and verification, Category-specific recalculations and Planned improvements* vary in their reference – some refer to the entire relevant category, some to the sub-category in question and some to only a part of a sub-category. In each case, the reference involved is apparent from the CRF number in the section heading.

4.7.1 Refrigeration and air conditioning systems (2.F.1)

4.7.1.1 Category description (2.F.1)

This category is divided into the sub-categories of commercial refrigeration, household refrigeration, industrial refrigeration, transport refrigeration, mobile air conditioning systems and stationary air conditioning systems (cf. Table 221).

In Germany, the leading HFC refrigerants, far and away, are HFC-134a and the mixtures R404A, R407C, R410A, R422D and R507A.

For calculation of HFC emissions from the sub-categories of refrigeration and stationary air conditioning systems, individual data are collected, or refrigerant models are used. Any refrigerant models used are described in connection with the relevant method.

The emission factors used are the result of surveys of experts. Disposal emissions in this category first occurred in 2000, in sub-categories 2.F.1.a (commercial refrigeration) and 2.F.1.e (mobile air-conditioning systems).

4.7.1.2 Methodological issues (2.F.1)

4.7.1.2.1 Commercial refrigeration (2.F.1.a)

Commercial refrigeration is the largest and most diverse area of (H)FC application. It is subdivided into the areas of plug-in devices, condensing units and central systems. The great diversity seen in the area of central systems, with regard to model, size, type of refrigerant and emissions-tightness, results from the fact that most relevant systems are customised systems. Less diversity is found in the areas of plug-in devices and condensing units.

Use of (H)FCs as refrigerants grew only gradually. For example, HFC-134a was not used on any significant scale until mid-1993. Use of the refrigerant mixtures R404A and R407C also did not begin until 1993. The various R422 mixtures, which are used as "drop-in" refrigerants in conversions of HCFC-22 systems, have been used only since 2009. In addition, since 1993 small quantities of PFC-containing refrigerant mixtures, such as R403A/B, R413A, Isceon 89 and R508A/B, have also been used, as drop-in refrigerants. Since 2007, R410A has been used in small central systems. For conversions of central systems with R404A, the refrigerant mixture R449A has been used since 2013. R448A has also been used for such conversions since 2014. Since 2002, R744 has also been used as a halogen-free alternative. R290 has been used as such an alternative since 2010.

Today, the mixture R404A is the most important HFC refrigerant for stationary refrigeration systems, ranking ahead of even HFC-134a in this category. The mixtures R407C and R422D are now also of some significance.

In light of the extremely large number of companies specialising in refrigeration, detailed statistical surveys of refrigerant stocks are not practicable. Therefore, a different calculation method is used.

- For calculation of emissions from *central systems* for commercial refrigeration, in the food retail sector, the following refrigerant model is used (Schwarz et al. 2012):
- Foreign trade with locally installed refrigeration systems plays a negligible role, and thus annual HFC consumption for new systems is the same as new HFC additions in new systems.
- The starting point for the calculations is not the number of plants involved or the installed cooling capacity, but the sales floor area of the relevant food retail stores, since that figure is statistically recorded, on an annual basis. Discount stores in Germany have sales floor areas of about 800 m^2, and that figure is a relatively constant one. All such stores are assumed to have basically the same refrigeration requirements and, thus, to use the same quantities of refrigerants. This is why in this case the number of discount stores involved serves as the basis for further calculations. The numbers of discount stores are also statistically recorded on an annual basis.
- On the basis of a study of the EPEE[75] (SKM Enviros 2010), the coefficient "kilograms per square meter of sales floor area" is derived for a typical, average-size supermarket. It has the value 0.23 kg/m^2. For discount stores, the coefficient "kilograms per discount store" is determined. It has the value 80 kg / store. With the help of these coefficients, the annual refrigerant stocks are calculated for the three store classes discount stores, small supermarkets and large supermarkets.
- The refrigerant stocks for the various store formats, subdivided by refrigerant types, are determined with the help of applicable percentage shares for the types of refrigerants that are used. The refrigerant shares are derived with the help of statistical calculation models based on experts' assessments. For this purpose, the following store classes are differentiated: large supermarkets (with sales floor areas greater than 1500 m^2) , small supermarkets (with sales floor areas between 400 and 1500 m^2) and discount stores.
- Division of refrigerant stocks by the systems' average lifetime (10 years for discount stores; 14 years for all other types of stores) yields the HFC additions via new systems.
- The production emissions and emissions from stocks are calculated with Equation 1 and Equation 2. Production normally takes place at the relevant sites.
- Replacement of CFCs and HCFCs in old systems is considered separately.

[75] EPEE: The European Partnership for Energy and the Environment.

- Disposal emissions occurred in connection with central systems for the first time in 2000. Removals of refrigerants are calculated with the help of the average lifetime – 10 years for central systems in discount stores, and 14 years for central systems in all other types of stores. In each case, the nominal quantity for disposal is equivalent to the added new quantity a system had when it was commissioned. In practice, however, the quantities of refrigerants that systems contain when they are disposed of are smaller than the corresponding nominal charges, since systems are normally not recharged before they are decommissioned. For this reason, the actual charge upon disposal, the "effective" quantity for disposal, is determined with the help of applicable percentage values for residual charges. The most important factor that enters into the determination of residual charges is the refrigerant-loss level at which a system has to be recharged in order to maintain its proper function. The effective charge at the end of a device's / system's service lifetime is larger, by half of the difference between that minimum "technical" charge and the nominal charge, than the minimum "technical" charge. For central systems, it amounts to 87.5 % of the nominal charge.
- The disposal emissions are calculated by multiplying the so-determined "effective" quantity for disposal by the inverse of the recovery factor, using Equation 4:
- Emissions of HFC-1234yf and HFC-1234ze from the refrigerant mixtures R448A and R449A, emissions which are not subject to reporting obligations, are voluntarily reported, pursuant to the recommendations of the 2014 UNFCCC Reporting Guidelines (FCCC/CP/2013/10/Add.3, Decision 24/CP.19), as "additional greenhouse gases." The emissions are aggregated with other emissions that are not subject to reporting obligations, and are listed in Chapter 4.9.3 under CRF 2.H.3.

Also in the case of *condensing units* for commercial refrigeration, the refrigerant stocks are the central point of reference for the refrigerant model for emissions calculation:

- The starting point for such calculations consists of the number of operation sites in the numerous sectors in which condensing units are used; the relevant sector selection is based on a study of the German Engineering Federation (2011). Such sectors include cash-and-carry beverage stores, service station shops, nurseries (garden centers), flower shops, flower wholesalers, cafeterias, caterers, hospitals, nursing homes, restaurants and hotels, butcher shops and franchise outlets for meat products, bakeries and franchise bakery outlets, discount stores, small food retailers and specialty food retailers. The number of sites involved is updated annually, from publicly accessible statistics.
- The refrigerant stocks for the various individual sectors are calculated as the product of the relevant number of operational sites, the sector-specific charges (as determined from the literature and via surveys of experts) and the percentage shares for the refrigerant types that are used. The percentage shares for the refrigerants are derived via a static calculation model (Winfried Schwarz et al., 2012).
- Division of total refrigerant stocks by the average lifetime of condensing units (12 years) yields the HFC additions via new systems.
- The production emissions and emissions from stocks are calculated with Equation 1 and Equation 2.
- The disposal emissions are calculated via Equation 4. The nominal quantity for disposal is identical, in terms of both quantity (amount) and refrigerant shares, with the corresponding initial-fill quantity from 12 years earlier. For condensing units, the effective charge at the end of units' service lifetime amounts to 85 % of the nominal charge.

The application sectors for hermetically sealed *plug-in units* are largely the same as those for condensing units. Emissions for such appliances are calculated in keeping with the refrigerant-model approach described for condensing units. Such appliances have an average lifetime of 10 years, and their residual charge upon disposal amounts to 90 % of the nominal charge.

Emission factors

The emission factors used are the result of surveys of experts and literature evaluations.

As a rule, charging of refrigeration systems produces only small quantities of emissions. For "initial emission" in Vol. 3, Table 7.9, the 2006 IPCC Guidelines give values of 0.5 to 3 percent of the initial charge for plug-in devices and for medium-sized and large commercial refrigeration systems. The country-specific $EF_{production}$, at 0.5 % for plug-in devices and at 1 % for central systems and condensing units, lie within this range.

Ongoing (H)FC emissions from stationary refrigeration systems in the *commercial refrigeration* category vary widely in keeping with the type of system concerned. The refrigerant loss ranges from 1 to 1.4 %, for plug-in individual units, to 5.5 to 9.7 %, for condensing units and to 9.1 to 19.5 % for central systems. The emission factors for application have decreased continuously since 1993 for all devices and systems in the area of commercial refrigeration (cf. Table 221), in keeping with the increasing degree of care taken in handling HFC refrigerants. Measured against the value ranges given in 2006 IPCC Guidelines (IPCC (2006): Vol. 3, Table 7.9), 1 to 15 % for individual units and 10 to 35 % for medium-sized and large commercial refrigeration systems, the emission factors either lie within low sections of the ranges (individual units and central systems, until report year 2014) or lie below the ranges (condensing units and central systems, as of report year 2015).

The average lifetimes prior to disposal are 10 years (individual units; central systems in discount stores), 12 years (condensing units) and 14 (central systems in all types of stores other than discount stores). The lifetime-figures used thus lie within the relevant ranges given in the 2006 IPCC Guidelines (IPCC, 2006), 10 to 15 years (individual units) and 7 to 15 years (medium-sized and large commercial refrigeration systems).

The residual charges in the devices and systems, at the end of their lifetimes, and with respect to the initial charge in each case, are 90 % (individual units), 85 % (condensing units) and 87.5 % (central systems). The 2006 IPCC Guidelines give value ranges of 0 – 80 % (individual units) and 50 – 100 % (medium-sized and large commercial refrigeration systems). The residual charge applied for individual units thus lies above the specified value range. All other values are default values.

The recovery factors have been increasing continuously, and thus the losses occurring upon disposal, with respect to initial charge / residual charge, have been decreasing over the years concerned. For plug-in devices, the recovery factor was 32.6 % in 2003 and 54 % in 2017. For condensing units, the recovery factor was 47.5 % in 2005 and 74 % in 2017, while for central systems the recovery factor increased from 42.9 % in 2000 to 77.4 % in 2017. As a result, most of the recovery factors used lie within the range given in the 2006 IPCC Guidelines (IPCC (2006): Vol. 3, Table 7.9), 0 to 70 %. Only the recovery factors used for central systems as of report year 2009, and those used for condensing units as of report year 2016, exceed the IPCC values.

Activity data

The sales floor areas of grocery stores are surveyed annually, by two market-research institutes[76]. The EHI Retail Institute also monitors the numbers of discount stores. In addition, the applicable numbers of commercial sites are updated annually from various publicly available statistics (Winfried Schwarz et al., 2012).

[76] EHI – EHI Retail Institute, Cologne; The Nielsen Company GmbH, Frankfurt am Main.

The annual new additions of PFC-116 (C_2F_6), PFC-218 (C_3F_8), HFC-125 and HFC-23, which are contained in the refrigerant mixtures R508A, R508B, Isceon MO 89 and R413A (HFC-23 is also used as a single-component refrigerant), are obtained from the annual national survey pursuant to the Environmental Statistics Act (Umweltstatistikgesetz) (UStatG, 2005).

The quantities and types of refrigeration and freezer systems typically used by businesses are determined from the literature and via estimation by experts. The coefficients "kilograms per square meter of sales floor area" and "kilograms per discount store" have been determined semiempirically by experts, with the help of the relevant technical literature (SKM Enviros (2010), Clodic and Barrault (2011) and Clodic et al. (2012)). The charges for condensing units and plug-in appliances have been determined via techical discussions with German manufacturers of refrigeration / freezer systems and via study of the relevant literature.

4.7.1.2.2 Household refrigeration (2.F.1.b)

In 1994, domestic producers of household refrigerators and freezers made a changeover from CFC-12 to HFC-134a. In Germany, they then switched to isobutane a short time later. Small numbers of devices containing HFC-134a, representing a small share of all relevant appliances, were imported in between 1993 and 2014. Under the EU F-Gas Regulation (F-Gas R, 2014), imports of household refrigerators and freezers that use refrigerants with GWPs of 150 or higher are prohibited as of 2015 (F-GasV, 2014).

Production losses and new consumption for domestic purposes do not have to be determined, since all filling with HFC took place abroad.

Equation 2 is used to calculate annual HFC emissions on the basis of final stocks. This is done by determining and aggregating the annual HFC new additions since 1993 and then subtracting the aggregated annual removals via disposal.

Disposal emissions occurring as of the year 2008, following an average lifetime of 15 years, are calculated with Equation 4.

In Germany since the end of the 1990s, a number of foreign companies have marketed ice cream machines for home use. Compressor-operated ice cream machines function just like regular refrigeration systems that use refrigerants. Since 1997, the refrigerants used have been HFC-134a and the refrigerant mixture R404A. Since 2015, appliances with R600a have also been sold. Depending on machines' sizes, ice cream machines' HFC-refrigerant charges range from about 30 g to over 100 g. These figures translate into an average HFC charge of about 75 g.

Since no domestic production takes place, no domestic production emissions occur.

The annual HFC emissions are calculated with Equation 2, on the basis of final stocks. The final stocks are calculated from the aggregated annual new HFC additions since 1997, less the aggregated annual removals via disposal.

Units have an average lifetime of 15 years, and thus disposal began in 2012. The resulting emissions are calculated with Equation 4.

Emission factors

Current HFC emissions from household refrigerators and freezers are estimated at 0.3 %, which is within the value range given by the 2006 IPCC Guidelines (IPCC (2006): Vol. 3, Table 7.9), 0.1 to 0.5 %.

The average lifetime prior to disposal is 15 years. The system lifetimes used thus lie within the range given by the 2006 IPCC Guidelines, 12 to 20 years.

The residual charges in devices, with respect to initial charge, average 95.5 %. The relevant values given in the 2006 IPCC Guidelines range from 0 to 80 %. The value used is thus higher than the range given in the 2006 IPCC Guidelines. The value is justified in light of the low refrigerant losses that occur during the use phase (0.3 % per year; 4.5 % throughout the entire use phase); those losses do not substantiate use of lower values for the residual charge level.

The recovery factor is 73.3 %, which is slightly above the range given in the 2006 IPCC Guidelines (IPCC (2006): Vol. 3, Table 7.9), 0 to 70 %. The higher recovery factor has been brought about by legislation (the Electrical and Electronic Equipment Act – Elektrogesetz (ElektroG, 2015)) governing the disposal of household appliances.

The 2006 IPCC Guidelines provide no specifications for ice cream machines (IPCC, 2006). All of the values used for the calculation are thus country-specific. The emissions from stocks are estimated to be 0.3 %. The average lifetime is 15 years. As is the case for household refrigeration appliances, the residual charge, with respect to the initial charge, is 95.5 %. The recovery factor is estimated to range from 53 % (2012) to 60.5 % (2017).

Activity data

The figure of 1 % for annual new additions of household refrigerators and freezers is an estimate of leading refrigerator manufacturers.

With the help of information provided by a leading manufacturer of ice cream machines, the number of ice cream machines in Germany in 2016 was estimated as equivalent to 1.5% of the total number of households in the country. The annual new additions have been at a constant level of 6.7 % (Kristina Warncke, 2018).

4.7.1.2.3 Industrial refrigeration (2.F.1.c)

The industrial refrigeration included in this sector refers to refrigeration for production of products – mostly food and drink – that are refrigerated or frozen. Refrigeration systems in this category, as in the category of *commercial refrigeration*, are usually not purchased directly from series production. They tend to be customised systems, and thus emissions for this category have to be calculated with the help of a refrigerant model.

Use of fluorine-based refrigerants has not yet become standard practice in industry, especially the food industry. In addition, natural refrigerants – primarily ammonia – are used much more frequently in this sector than they are in other sectors. The fluorine-based refrigerants used in industrial refrigeration are R404A, HFC-134a, R407C, R507A and R422D. The last of these serves as a substitute refrigerant for converted HCFC-22 systems. HFC-23 und PFC-116 are also used, in low-temperature systems, while the refrigerant HFC-227ea is used in air-conditioning systems for cranes and in high-temperature heat pumps.

Use of fluorine-based refrigerants began in Germany in 1993. Disposal emissions began occurring in 2002, from converted CFC-12 and HCFC-22 systems.

The following refrigerant model is used for *industrial refrigeration*:

- The refrigerant stocks serve as the central point of reference for the model. It is broken down into twelve major industrial refrigeration sectors: beer breweries, wine production, meat production, dairies, cold-storage facilities, chocolate production, production of frozen foods and of juices, skating rinks, milk refrigeration in the agricultural sector, other industry (80 % chemical industry) and hermetically sealed appliances in manufacturing. The basis for calculation of the refrigerant stocks consists of the quantities of produced goods. They are updated annually via publicly accessible merchandise statistics.

- In the three smaller sectors of industrial refrigeration, air-conditioning for cranes, high-temperature heat pumps and low-temperature refrigeration with HFC-23 (primarily in the plastics industry) and R508A/B, the annual new additions are used as the starting value for calculating stocks and all emissions.
- On the basis of the relevant production quantities, a conversion is made to the installed cooling capacity required for cooling goods and products in the twelve major sectors. The key factors required for that conversion, "installed cooling capacity per units of annual goods production", have been determined empirically, on the basis of the technical literature.
- The refrigerant quantities required for the resulting cooling capacity are estimated on the basis of refrigerant-use rates for plus and minus refrigeration and for direct and indirect refrigeration. The refrigerant-use rates were also determined via study of the literature, including Clodic and Barrault (2011) and Clodic et al. (2012). They range from 2 kg/kW for indirect plus refrigeration to 8.8 kg/kW for direct minus refrigeration. The typical charges per installed unit of cooling capacity are calculated, for the twelve sectors, by combining these values with the applicable sector-specific weightings for the four basic forms of refrigeration.
- Foreign trade with locally installed refrigeration systems plays a negligible role, and thus annual HFC consumption for new systems is the same as new HFC additions in new systems.
- The refrigerant stocks also provide the basis for calculating the quantity for disposal. For each sector, that quantity is calculated by dividing the stocks by devices' service lifetimes. For most sectors, the applicable service lifetime is 30 years. For dairy farms and skating rinks, it is 20 years, and for plug-in appliances, air conditioners for cranes, high-temperature heat pumps and low-temperature applications, it is 10 years.
- The percentage shares for the types of refrigerants that are used, which vary over time for stocks, new additions and quantities for disposal, are derived for each sector via a static calculation model (Winfried Schwarz et al., 2012).
- Replacement of CFCs and HCFCs in old systems is considered separately.
- The production emissions and emissions from stocks are calculated with Equation 1 and Equation 2.
- Disposal emissions are calculated with Equation 4. The nominal quantity for disposal is identical with the initial-fill quantity. The effective charge at the end of devices' service lifetimes is 85 % of the nominal charge, for all sectors except plug-in appliances, for which it is higher – 90 %.

Emission factors

The emission factors on which the emissions data are based are listed in Table 221.

The emission factors used are the result of surveys of experts and literature evaluations.

As a rule, charging of industrial refrigeration systems produces only small quantities of emissions. In Vol. 3, Table 7.9, the 2006 IPCC Guidelines (IPCC, 2006) give for "initial emission" values of 0.5 to 3 percent of the initial charge quantity. The country-specific $EF_{production}$ for the sectoral application areas is 1 %, while it is 0.5 % for plug-in appliances. The EF thus lie within the lower part of the range given by the Guidelines.

In all sectors except hermetically sealed appliances, ongoing HFC emissions from industrial refrigeration systems have been decreasing continually, changing from 8.8 % in 1993 to 5.1 % in 2017. The reason for this trend is that refrigeration systems' capacity for retaining their refrigerants has improved as a consequence of national and European legal regulations. Such emissions now lie within the lower part of the range, or even slightly below the range, given by the 2006 IPCC Guidelines in Vol. 3, Table 7.9 – 7 % to 25 %. For plug-in appliances, the decrease has been comparable to that seen in commercial refrigeration: from 1.4 % in 1994 to 1 % in 2017.

The average applicable lifetimes prior to disposal are as follows: 10 years (plug-in individual units, air-conditioners for cranes, high-temperature heat pumps, low-temperature applications and plastics industry); 20 years (dairy operations, skating rinks); and 30 years (food industry, cold-storage systems, chemical industry). The lifetimes used – with the exception of the 10-year lifetimes for certain application areas – thus lie within the value range given by the 2006 IPCC Guidelines (IPCC (2006): Vol. 3, Table 7.9), 15 to 30 years.

The residual charges in the devices and systems, at the end of their lifetimes, and with respect to the initial charge level in each case, are 90 % (individual units) and 85 % (sectoral application areas). The 2006 IPCC Guidelines (IPCC (2006): Vol. 3, Table 7.9) give values of 50 to 100 % for industrial refrigeration systems. All of the values used are thus default values.

The recovery factors have been increasing continuously, and thus the losses occurring upon disposal, with respect to initial charge / residual charge, have been decreasing over the years concerned. For plug-in individual units, the recovery factor was 33.7 % in 2004 and 54 % in 2017. For refrigeration systems of sectoral application areas, the recovery factor was 45 % in 2002 and 78.5 % in 2017. As a result, the recovery factors used lie within the range given in the 2006 IPCC Guidelines (IPCC (2006): Vol. 3, Table 7.9), 0 to 90 %.

Activity data

The statistics of the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) contain numerous time series for food-production quantities. In addition, data are available from industrial associations such as the German association of cold-storage facilities and cold-chain logistics companies (VDKL) and the Association of the German Confectionary Industry (BDSI), as well as from specialised institutes, such as the German Wine Institute.

The unit-number figures for plug-in appliances have been taken from a study of the German Engineering Federation (VDMA) VDMA (2011) and information provided by industry experts.

The annual new additions of HFC-227ea and HFC-23 (air-conditioning for cranes, high-temperature heat pumps and low-temperature cooling) are obtained from the annual national survey conducted pursuant to the Environmental Statistics Act (Umweltstatistikgesetz) (UStatG, 2005).

The "installed cooling capacity per units of annual goods production" indices, and the refrigerant-use rates for plus and minus cooling and for direct and indirect cooling, were determined on the basis of information provided in the relevant technical literature.

4.7.1.2.4 Transport refrigeration (refrigerated vehicles and containers) (2.F.1.d)

HFCs have been used as refrigerants in *refrigerated vehicles* since 1993. Today, HFC-134a, along with the refrigerant mixtures R404A and R410A, are most commonly used. Since 2015, R452A has also been in common use. The sizes and refrigerant charges of refrigeration systems vary in keeping with the load volumes of the refrigerated vehicles in question.

Refrigerated containers are used primarily for transports of perishable goods by ocean-going ships. Since their emissions take place primarily in international waters, their refrigerant emissions are divided, in each case, in keeping with the relevant country's share of world trade. Germany is assigned 10 % of global emissions from refrigerated containers. Since 1993, the most commonly used refrigerant has been HFC-134a. Since 1997, R404A has also been used.

The following refrigerant model is applied to *refrigerated vehicles* (Kristina Warncke, 2018):

- Refrigerated vehicles are divided into five weight-based size classes: Vans <3.5 t, vans weighing 3.5-7.5 t, trucks weighing 7.5-12 t, trucks > 12 t and trailer > 26 t total weight.

- Refrigerant types, and specific refrigerant charge amounts, are assigned to the various size classes. Each refrigerant is also assigned a percentage share of each size class.
- For a long period, the refrigerant R404A predominated in the class of trailers > 26 t total weight, with annual shares of 95 % (1993-1994) and 85 % (1995-2014). It was then supplanted, as the most commonly used refrigerant, by R452A. In 2015, that refrigerant's share amounted to 13 %, and by 2017 it had reached 65 %. In addition, HFC-134a (5 %) has been used since 1993, and R410A (10 %) has been used since 1995.
- For trucks > 12 t total weight, the shares for R404A were 90 % (1993-1994) and 80 % (1995-2014). Beginning in 2015, that refrigerant's share decreased continuously, and it reached 65 % in 2017. The shares for HFC-134a (as of 1993) and R410A (as of 1995) each amounted to 10 %. Since 2015, R452A has also been used, increasingly. By 2017, its share had reached 15 %.
- Since 1993, R404A and HFC-134a have been used in trucks with 7.5-12 t total weight. From a level of 70 % (1993-1994), the share for R404A decreased to 60 % (1995-2014). As of 2015, it decreased continuously, and it reached 50 % in 2017. As of 1995, R410A was also used; it had a share of 10 %. In 2015, the share for R452A amounted to 1 %. It then increased continuously, and reached 10 % in 2017.
- Since 1993, 70 % R404A and 30 % HFC-134a have been used in vans with 3.5-7.5 t total weight.
- Since 2006, the refrigerant R404A has been used in wurde in 70 % of vans <3.5 t total weight; HFC-134a has been used in the remaining 30 %. From 1993 through 2005, only HFC-134a was used.
- The number of newly licensed refrigerated vehicles, and the number of refrigerated vehicles charged within the country (broken down by refrigerants), are determined for each year.
- The production emissions are calculated using Equation 1, on the basis of the new consumption required for charging domestically produced refrigerated vehicles.
- The annual new additions of refrigerants result from the numbers of newly licensed refrigerated vehicles and the above assumptions.
- From 1996 to 1999, HFCs were substituted for CFC-12 in a certain number of old systems. These amounts have to be included in the annual new additions.
- The year-end final stocks are obtained by aggregating the annual HFC new additions since 1993 and then subtracting the removals via disposal.
- Equation 2 is used to calculate annual HFC emissions on the basis of final stocks.
- Disposal emissions occurred in connection with refrigerated vehicles for the first time in 2003. They are calculated by means of Equation 4. The nominal quantity for disposal is identical to the new additions 10 years earlier (or 7 years earlier in the case of converted CFC-12 systems). The effective charge level at the end of units' service lifetimes amounts to 87.5 % of the nominal charge level.
- Emissions of HFC-1234yf from the refrigerant mixture R452A, emissions which are not subject to reporting obligations, are voluntarily reported, pursuant to the recommendations of the 2014 UNFCCC Reporting Guidelines (FCCC/CP/2013/10/Add.3, Decision 24/CP.19), as "additional greenhouse gases." The emissions are aggregated with other emissions that are not subject to reporting obligations, and they are listed in Chapter 4.9.3 under CRF 2.H.3.

For *refrigerated containers*, the following refrigerant model is used:

- The number of refrigerated containers produced worldwide is determined for each year.
- The worldwide HFC additions for refrigerated containers are determined on the basis of annual unit figures from global production, in combination with the relevant charges and charge percentages for the various relevant refrigerants.
- Germany's HFC additions are determined from worldwide additions, in keeping with Germany's share of global trade, which amounts to 10 %.

- Since refrigerated containers are produced only outside of Germany, no emissions from charging occur in Germany.
- The year-end final stocks are obtained by aggregating the annual HFC new additions since 1993 and then subtracting the removals via disposal.
- Emissions from stocks are calculated with Equation 2.
- Refrigerated containers have an average lifetime of 14 years, and disposal emissions from such containers occurred for the first time in 2007. They are calculated by means of Equation 4.

Emission factors

The emission factors on which the emissions data are based are listed in Table 221.

The emission factors used are the result of surveys of experts and literature evaluations.

As a rule, charging of refrigerated vehicles produces only small quantities of emissions. The losses of refrigerant during charging are estimated at 5 grams per system, regardless of system size. That is a standard value for hose losses during on-site charging. When emissions from charging are calculatorily considered in relation to new consumption, emission factors between 0.06 und 0.25 % result. For "initial emission" in transport refrigeration, the 2006 IPCC Guidelines give figures, in Vol. 3, Table 7.9, of 0.2 to 1 percent of the initial charge. As a result, the great majority of the values used lie below the range recommended in the 2006 IPCC Guidelines (IPCC, 2006).

Since no domestic production of refrigerated containers takes place, no emissions from charging of such containers occur.

The ongoing HFC emissions from new refrigeration units of refrigerated vehicles, for the three size classes trucks with 7.5-12 t, trucks > 12 t and trailers > 26 t (in each case, permissible total weight), are estimated to be 15 %. For vans <3.5 t and 3.5-7.5 t permissible total weight, the emission factor is 30 %. For old units in refrigerated vehicles (converted CFC-12 systems), the emission factor for emissions from stocks is estimated to average 25 %, for all unit size classes. The emission factors for refrigerated vehicles thus lie at the lower end of the range given in Vol. 3, Table 7.9 of the 2006 IPCC Guidelines, 15 to 50 %.

For refrigeration units, the figure for emissions from stocks is 10 %, which is slightly below the range given in Vol. 3, Table 7.9 of the 2006 IPCC Guidelines, 15 to 50 %.

The lifetime of old systems in refrigerated vehicles is 7 years, while that of new systems in refrigerated vehicles is 10 years. The average lifetime for refrigerated containers prior to disposal is 14 years. The lifetimes used – with the exception of those for old systems in refrigerated vehicles – thus lie within the value range given by the 2006 IPCC Guidelines (IPCC (2006): Vol. 3, Table 7.9), 6 to 9 years.

The residual charges in refrigerated vehicles and refrigerated containers, with respect to initial charge, average 87.5 %. The 2006 IPCC Guidelines (IPCC (2006): Vol. 3, Table 7.9) give values of 0 to 50 % for transport refrigeration systems. All of the values used are larger than those given in the Guidelines, since it must be assumed that transport refrigeration systems that only have 50 % of their initial charges left no longer function properly and thus would compromise the cold chain, with the result that the chain would no longer be seamless. The act of allowing that to happen would violate German law.

The recovery factor for refrigerated vehicles and refrigerated containers is 65.7 %. The recovery factors used thus lie within the range given in the 2006 IPCC Guidelines, in Vol. 3, Table 7.9, 0 to 70 %, and thus are default values.

Activity data

Until 2008, and as of 2011, the registration figures for refrigerated vehicles, broken down by weight classes, were taken from statistical reports of the Federal Motor Transport Authority (KBA). Since the Federal Motor Transport Authority did not carry out separate surveys of refrigerated vehicles in 2009 and 2010, the numbers of new refrigerated vehicles for those two years have been determined via extrapolation from the registration figures for utility vehicles. Charges in refrigeration systems, information on refrigerants used, and details on CFC-12 replacement were provided by experts of the leading providers of refrigeration units for refrigerated vehicles.

New additions of refrigerants in the area of refrigerated containers are determined via a refrigerant model based on the numbers of refrigerated containers produced worldwide, with the numbers provided by the "World Cargo News" information service for the industry. A 10 % share is allocated to Germany.

4.7.1.2.5 Mobile air-conditioning systems (2.F.1.e)

The mobile air-conditioning systems category includes air-conditioning systems in/on automobiles, trucks and utility vehicles, buses, agricultural machinery (tractors, combines, field choppers), railway vehicles, ships, aircraft and helicopters. Hydrofluorocarbons (HFCs) have been used in mobile air-conditioning systems since 1991. HFC-134a is a commonly used HFC refrigerant. Since 2012, HFC-1234yf has also been used in automobile air-conditioning systems.

The time series show a significant emissions increase since 1995. This increase, which has occurred in spite of decreases in charge quantities, is a direct result of increased use of mobile air conditioning systems in vehicles.

- For *automobiles*, the following refrigerant model is applied:
- The production figures for German automobile production are available, on an annual basis, from the publicly accessible statistics of the German Association of the Automotive Industry (VDA). Those figures provide the database for calculating consumption data relative to charging.
- The annual percentages of automobiles equipped with air-conditioning systems are obtained via extensive surveys of manufacturers, since they are not provided by any official or publicly available statistics. This also applies to the average refrigerant (charge) quantities, which are determined from the technical data for the various automobile models and from information provided by industry experts.
- The quantities consumed in charging such air conditioners are calculated by multiplying the numbers of automobiles produced by the annual percentages of automobiles equipped with air-conditioning systems and by the average per-unit refrigerant (charge) quantities.
- Production emissions are computed with Equation 1.
- The annual numbers of new vehicle registrations as recorded by the Federal Motor Transport Authority (KBA) are not used in determining annual new additions and the refrigerant stocks in automobile air conditioning systems, since it is not possible to quantitatively estimate early departures of vehicles (i.e. prior to vehicles' reaching the end of their average lifetimes) from the registration cohorts that form the basic fleet. Instead, the refrigerant stocks are determined on the basis of the numbers of registered vehicles on the road, divided according to age since the initial registration. Relevant official data are available from the statistical communications (Statistische Mitteilung) of the Federal Motor Transport Authority (KBA) (KBA, Versch. Jahrgänge), for all required years, i.e. as of 1991. They make it possible to determine, on a continuous, chronological basis, the numbers of vehicles in the total fleet, divided by registration cohorts.

- The annual percentages of automobiles equipped with air conditioning systems, for newly registered vehicles, are also obtained via extensive surveys of manufacturers. Those numbers are not identical with the corresponding percentages of automobiles produced in Germany and equipped with air conditioning systems, since foreign cars also have to be taken into account. The necessary percentages are thus also obtained via surveys of foreign companies. This also applies to strategies for determining the average per-unit refrigerant (charge) quantities in newly registered vehicles.
- The refrigerant stocks in each registration cohort are calculated by multiplying the specific charges for the year in question by the numbers of automobiles equipped with air conditioners. The total stocks are equivalent to the sum of the refrigerant stocks for all registration cohorts since 1991.
- Emissions from stocks are calculated with Equation 2.
- Replacement of CFCs in old systems, and air-conditioner retrofits, are considered separately.
- In determination of quantities for disposal, only the old vehicles are taken into account that are handled each year by German dismantling facilities. Those figures are obtained from the official data on numbers of old vehicles (Statistisches Bundesamt, FS 19, R 1a). The refrigerant model does not take account of exports of used cars and old cars, since the relevant disposal emissions occur in the pertinent destination countries and double-counting has to be avoided.
- An average lifetime of 15 years is assumed for dismantled vehicles. The total quantity of refrigerants that are disposed of can be determined by multiplying the number of dismantled vehicles by the applicable percentage of vehicles equipped with air conditioning systems and the average per-unit refrigerant (charge) quantity for the relevant new-registration cohort of 15 years earlier.
- Disposal emissions occurred for the first time in 2002. They are calculated with Equation 4.
- Pursuant to the recommendations of the 2014 UNFCCC Reporting Guidelines (FCCC/CP/2013/10/Add.3, Decision 24/CP.19), Germany voluntarily reports emissions of HFC-1234yf, which are not subject to reporting obligations, under "additional greenhouse gases." The HFC-1234yf emissions are aggregated with other emissions that are not subject to reporting obligations, and are reported in Chapter 4.9.3 under CRF 2.H.3.

The refrigerant models for *utility vehicles and buses* are structured similarly to the model for automobiles. A detailed description of the models is provided by (Winfried Schwarz et al., 2012).

The refrigerant model used for *agricultural machinery*, *ships and railway vehicles* is as follows:

- For ships and railway vehicles, refrigerant emissions are determined on the basis of annual new installations of air conditioning systems in ships (outset data: newly built ships for the German fleet) and in railway vehicles (outset data: new procurements by German Railways (DB) and private companies), as well as the relevant charges.
- The refrigerant model for air conditioning systems in agricultural machinery is based on the number of new vehicle registrations for each year, the average percentage of vehicles equipped with air conditioning systems and the average charges in the various types of agricultural machinery concerned.
- The annual new additions of HFC-134a, as well as the final stocks, are determined, for each area, from the relevant previous set of data.
- Emissions from stocks are obtained, using Equation 2, by multiplying the final stocks, for each area, by the relevant EF_{use}.
- Domestic consumption of HFC-134a, for production of mobile air conditioning systems, is determined on the basis of unit-number figures for production. Production emissions are computed with Equation 1.

- Disposal emissions are calculated with Equation 4. In the agricultural machinery category, such emissions occurred for the first time in 2004, at the end of the average lifetime for units in the category, 10 years. In the railway vehicles category, disposal emissions occurred for the first time in 2017, at the end of the 25-year average lifetime. For ships, disposal will not begin until 2022, at the end of a 25-year lifetime.

For *Aircraft and helicopters*, the following refrigerant model is applied:

- The refrigerant stocks in air-conditioning systems of medium-sized, multi-engine aircraft (registration class I) and helicopters (registration class H), and in the on-board refrigeration systems of passenger aircraft in registration classes A, B and C, are determined on the basis of the relevant numbers of aircraft and helicopters registered in Germany. The pertient official figures are available, for all required years (i.e. as of 1993), in the statistics annually published by the German Federal Aviation Office (Luftfahrt-Bundesamt) (Luftfahrt-Bundesamt, Versch. Jahrgänge, Bestand an Luftfahrzeugen).
- In passenger aircraft of registration classes A, B and C, an average of three HFC-134a chillers, with per-unit charges of 500 g, are used for on-board refrigeration during flights lasting longer than four hours.
- According to manufacterers, in aircraft of registration classes I and in helicopters, an average of 2 kg of HFC-134a are used, per aircraft/helicopter, for cooling instruments and for air-conditioning.
- The pertinent refrigerant stocks are calculated by multiplying the aircraft-specific charge by the number of registered air-conditioned / refrigerated aircraft involved.
- Emissions from stocks are calculated with Equation 2.
- To date, no disposal emissions have occurred, due to the long lifetimes of the aircraft involved.

Emission factors

The emission factors on which the emissions data are based are listed in Table 221.

The emission factors used have been obtained via: studies of the literature (for example, studies of Winfried Schwarz (2003); Siegl et al. (2002); Clodic and Barrault (2011); Clodic et al. (2012); Winfried Schwarz et al. (2012)), measurements (automobiles), evaluations of records of automotive-service shops, extensive surveys of experts and surveys of automotive-service shops and dismantling facilities. In addition to regular emissions during operation, emissions also arise as a result of accidents and other external influences.

As a rule, charging of mobile air-conditioning systems produces only small quantities of emissions. For automobiles, the refrigerant losses upon charging are estimated as 3 grams per system. For utility vehicles and agricultural machinery, they are placed at 5 grams per system, and for buses they are considered to be 50 grams per system. These figures are standard values for hose leakage in connection with on-site charging. When the emissions from charging are seen, mathematically, in relation to new consumption, the following emission factors result: 0.25 - 0.63 % (automobiles), 0.42 - 0.66 % (utility vehicles), 0.28 - 0.35 % (agricultural machinery) and 0.42 - 0.45 % (buses). The ranges are the result of annual variations in initial charges. For railway vehicles, the emission factor for charging is 0.5 %, while for ships, it is 1 %. For "initial emission" for mobile air-conditioning systems (automobiles, utility vehicles, buses and railway vehicles), the 2006 IPCC Guidelines give figures, in Vol. 3, Table 7.9, of 0.2 to 0.5 percent of the initial charge. The great majority of the values used for the vehicles described in the 2006 IPCC Guidelines (IPCC, 2006) thus lie within the relevant ranges proposed by the Guidelines. The 2006 IPCC Guidelines provide no values for agricultural machinery, ships and aircraft.

Current HFC emissions are estimated at 10 % for automobiles; at 15 % for utility vehicles and buses; at 6 % for railway vehicles; for agricultural machinery, at 15 % (tractors) and 25 % (combines and field choppers); for ships, at 10 % (passenger ships on inland waterways), 20 % (ocean liners) and 30 % (ocean-going cargo ships); and at 5 % for aircraft. The EF_{use} used thus lie largely within the range proposed in Vol. 3, Table 7.9 of the 2006 IPCC Guidelines (IPCC, 2006), 10 to 20 % for air-conditioning systems in automobiles, utility vehicles, buses and railway vehicles. No proposals have been provided for agricultural machinery, ships and aircraft.

The average lifetimes prior to disposal are 15 years (automobiles, utility vehicles, buses), 10 years (agricultural machinery) and 25 years (railway vehicles, ships). With the exception of those for systems in railway vehicles and on ships, the lifetimes lie within the value range given by the 2006 IPCC Guidelines for systems in automobiles, utility vehicles, buses and railway vehicles, 9 to 16 years.

The residual charges remaining in air-conditioning systems, with respect to initial charge, average 34 % (automobiles, utility vehicles, buses, agricultural machinery). They average 87.5 % for railway vehicles, since the maintenance intervals for such vehicles are kept shorter, in the interest of passenger comfort. The 2006 IPCC Guidelines (IPCC (2006): Vol. 3, Table 7.9) give values of 0 to 50 % for this area. All of the values used, with the exception of the value for railway vehicles, are default values.

As a result of the disposal and recycling of end-of-life vehicles as required by the End-of-Life Vehicles Ordinance (Altfahrzeug-Verordnung) since 2002, the recovery factors for automobiles and utility vehicles have been increasing continuously, with the result that losses occurring upon disposal, with respect to initial charge or residual charge, have been decreasing over time. For automobiles and utility vehicles, the recovery factors amounted to 38 % in 2000, and to 46 % in 2017. The estimated recovery factors are as follows: 38 % for buses, 11.7 % for agricultural machinery and 75.6 % for railway vehicles. As a result, the recovery factors used for automobiles, utility vehicles and buses lie within the range given in the 2006 IPCC Guidelines (IPCC (2006): Vol. 3, Table 7.9), 0 to 50 %. The country-specific value for railway vehicles is considerably higher than the default value, because considerably greater care is taken in disposal from railway vehicles. The 2006 IPCC Guidelines provide no proposals for agricultural machinery.

Activity data

The Federal Motor Transport Authority (KBA) reports numbers of registered automobiles, utility vehicles and buses, and new registrations of agricultural tractors. The number of registered aircraft has been obtained from the German Federal Aviation Office (Luftfahrt-Bundesamt). The sources for production figures include the German Association of the Automotive Industry (VDA), the German Engineering Federation (VDMA), other statistics and surveys of manufacturers.

The charges in automobile air conditioners, and the annual percentages of automobiles equipped with air-conditioning systems, are determined via direct surveys of automobile companies. For systems in other types of vehicles, the charges and percentages are obtained by combining official statistics, information from surveys of manufacturers and experts' assessments.

4.7.1.2.6 Stationary air conditioning systems (2.F.1.f)

The area of stationary air conditioning systems includes room air conditioners, chillers for air conditioning of buildings and industrial refrigeration of liquids, heat-pump systems, heat-pump laundry dryers and commercial dishwashers with heat pump systems.

4.7.1.2.6.1 Room air conditioners

Room air conditioners are used to cool the interiors of individual rooms, entire floors or small-to-medium-sized buildings. Their performance levels tend to be lower than those of large air conditioning systems. The following refrigerants are in use: since 1998, the HFC mixture R407C; since 2001, the mixture R410A; and since 2014, HFC-32. Since 1997, R290 has also been used in mobile room air-conditioners, as a halogen-free alternative.

There is no domestic production of room air conditioners. Room air conditioners are normally already filled when imported. Installation of factory-manufactured single-split, multi-split and VRF-multi-split units involves installation of refrigerant lines, and these have to be charged on site, however. Such charging of lines is not required in connection with mobile, plug-in room air conditioners.

The following refrigerant model is used for room air conditioners:

- *Room air conditioners* are divided into four categories. The applicable numbers of new systems produced each year in each category are determined via surveys of manufacturers and via the data published in pertinent international publications. The categories are: small mobile units, single-split units, multi-split units with constant-volume refrigerant flow and VRF-multi-split systems with variable-volume refrigerant flow.
- For each category, the charges, and the percentage shares for the various types of refrigerants used, are determined in keeping with the numbers of new systems sold each year. The annual new consumption, which is identical to annual new additions of refrigerants, is obtained from sales statistics and the above assumptions. The year-end final stocks are obtained by aggregating the annual HFC new additions since 1993 and then subtracting the removals via disposal.
- No production emissions occur. Charging losses do occur, however, in installation of stationary single-split units, multi-split units and VRF multi-split systems. Surveys of experts have indicated that the applicable losses during installation are 5 g per unit (10 % of the initial charge) for single-split units, 20 g per unit (1 % of the initial charge) for multi-split units and 45 g per system (1 % of the initial charge) for VRF multi-split systems.
- Emissions from stocks are calculated with Equation 2.
- Disposal emissions occurred for the first time in 2008. The average lifetime of mobile units and single-split units is 10 years, while the average lifetime of multi-split units and VRF multi-split systems is 13 years. Disposal emissions are calculated with Equation 4.

Emission factors

The emission factors used have been obtained via surveys of experts and evaluations of the literature; they are listed in Table 221.

The country-specific $EF_{production}$ = 1 % for multi-split units and VRF multi-split units lies within the value range given by the 2006 IPCC Guidelines, in Vol. 3, Table 7.9 – 0.2 to 1 %. For single-split units, the emission factor is 10 %, which corresponds to a loss of 5 g of refrigerant per 50 g charge, and which is above the range given in the Guidelines.

For all devices, the emission factors for use decrease continually throughout the time series, beginning with the first year of use (cf. Table 221). For mobile room air conditioners, they range from 3.4 % (1999) to 2.5 % (2017); for single-split units, they range from 6.9 % (1998) to 5 % (2017); for multi-split units, they range from 7.9 % (1998) to 4.7 % (2017); and for VRF multi-split units, they range from 8.1 % (2003) to 5.5 % (2017). The emission factors for use thus lie within the range given in Vol. 3, Table 7.9 of the 2006 IPCC Guidelines, 1 to 10 %.

The estimated lifetimes for such units, 10 years (mobile room air-conditioners, single-split units) and 13 years (multi-split units, VRF multi-split units), lie within the value range given in Vol. 3, Table 7.9 of the 2006 IPCC Guidelines, 10 to 20 years.

The residual charge upon disposal is 75 % for mobile room air-conditioners and 87.5 % for all other types of units. The 2006 IPCC Guidelines (IPCC, 2006), in Vol.3, Table 7.9, recommend values ranging from 0 to 80 %. The residual-charge figure used for mobile room air-conditioners is thus a default value, while the values used for the other types of units lie above the range given in the Guidelines.

The recovery factors have been increasing continuously, and thus the losses occurring upon disposal, with respect to initial charge / residual charge, have been decreasing over the years concerned. For mobile room air-conditioners, the recovery factor was 24.2 % in 2009 and 35.5 % in 2017; for single-split units, it was 37.9 % in 2008 and 54 % in 2017; while for multi-split units, it was 62 % in 2011 and 74 % in 2017. For VRF multi-split units, it was 72 % in 2016 and 74 % in 2017. As a result, the recovery factors used lie within the range given in the 2006 IPCC Guidelines (IPCC (2006): Vol. 3, Table 7.9), 0 to 80 %.

Activity data

The numbers of units sold in Germany, of the various types of units and systems involved, are determined on an annual basis via technical publications(JARN, Versch. Jahrgänge) and surveys of sellers.

4.7.1.2.6.2 Chillers

Chillers for air-conditioning of buildings and industrial refrigeration of liquids are divided into three performance categories: chillers with a cooling capacity of less than 100 kW, chillers with a cooling capacity of more than 100 kW and turbo-compressor systems (with cooling capacities above 1500 kW). The types of compressors used in chillers include piston, scroll and screw compressors.

HFC-134a has been used in turbo-compressor systems since 1993. In the years 1995 through 1999, HFC-134a was also used for conversions of CFC-12 turbocompressor systems. The most important refrigerants used in chillers include HFC-134a (used as of 1993), R407C (as of 1998) and R410A (as of 2004). HFC-1234ze has also been used since 2013.

The following refrigerant model is applied to *chillers*:

- Chillers are divided into three categories. The number of new systems in each of the following categories is determined each year via surveys of experts and international sales statistics: chillers ‹100 kW cooling capacity; chillers ›100 kW cooling capacity; and turbo-compressor systems in the performance range above 1500 kW.
- For each category, the average charge, and the percentage shares for the various types of refrigerants used, are determined. The applicable charges are 10 kg for chillers ‹100 kW, 95 kg for chillers ›100 kW and 630 kg for turbo-compressor systems.
- Data on annual HFC additions to domestic stocks are obtained from the numbers of new systems, in connection with the above assumptions. Consumption for CFC replacements in old systems has to be taken into account.
- The year-end refrigerant stocks can be calculated from the previous-year stocks, the new additions and the removals.
- Production emissions are calculated by multiplying the quantities consumed in charging by the $EF_{production}$, pursuant to Equation 1.
- Emissions from stocks are calculated with Equation 2.

- Disposal emissions occurred for the first time in 2003 (in conversion of systems for CFC substitutes). They are calculated with Equation 4.
- Pursuant to the recommendations of the 2014 UNFCCC Reporting Guidelines (FCCC/CP/2013/10/Add.3, Decision 24/CP.19), emissions of HFC-1234ze , which are not subject to reporting obligations, are voluntarily reported under "additional greenhouse gases." The emissions are aggregated with other emissions that are not subject to reporting obligations, and they are listed in Chapter 4.9.3 under CRF 2.H.3.

Emission factors

The emission factors used have been obtained via surveys of experts. They are listed in Table 221.

The loss from charging, at 0.5 %, lies within the range given in the 2006 IPCC Guidelines ((IPCC, 2006): Vol. 3, Table 7.9), 0.2 to 1 %. To take account of the fact that large numbers of chillers are imported as pre-filled units, $EF_{production}$ = 1 %, the actual $EF_{production}$, is not used.

The ongoing HFC emissions through 2000 are estimated at 6 % for all cooling-capacity classes / compressor models, age classes and refrigerant types. Thereafter, the EF_{use} decreases continuously, to 3.2 % (2017). All of the values used thus lie within the lower part of the range proposed by the 2006 IPCC Guidelines (IPCC (2006): Vol. 3, Chapter 7.9), 2 to 15 %.

The 2006 IPCC Guidelines, in Vol. 3, Table 7.9, give a service lifetime of 15 to 30 years for liquid chiller systems. The values used in the present case lie within that range: 15 years for chillers with cooling capacities either less or more than 100 kW, and 25 years for turbo-compressor systems.

The residual charge upon disposal is 90 %, for all chiller types. The 2006 IPCC Guidelines, in Vol. 3, Table 7.9, recommend values ranging from 80 to 100 %. The residual-charge figures used are thus default values.

The recovery factors have been increasing continuously, as a result of technical progress and greater care taken in handling refrigerants, and thus the losses occurring upon disposal, with respect to initial charge / residual charge, have been decreasing over the years concerned. The recovery factor for chillers, including units with cooling capacity less than 100 kW and greater than 100 kW, was 65.8 % in 2003 and 78.5 % in 2017, while the factor for turbo-compressor systems was 69.5 % in 2003 and 78.5 % in 2017. The recovery-factor figures used thus lie within the range given in Vol. 3, Table 7.9 of the 2006 IPCC Guidelines, 0 to 95 %.

Activity data

The numbers of new systems are determined annually via surveys of experts and consultation of international sales statistics (for example, BSRIA Limited (Versch. Jahrgänge)).

The average charges, and the percentage shares for the various types of refrigerants used, were determined in the framework of expert consultations with industry representatives.

4.7.1.2.6.3 Heat-pump systems

Via a refrigeration cycle, heat pumps draw heat from the air, ground or groundwater and make it available for heating or cooling indoor areas or for heating water. Devices that directly use heat from the outdoor environment to warm indoor air fall within the category of room air conditioners. Since 1995, HFC-134a and the HFC mixtures R404A and R407C have been used as refrigerants in heat pumps; since 2001, R410A has been used as well.

Methodologically, the refrigerant model for *heat pumps* is structured like the model for room air conditioners.

- Three categories of heat pumps for heating are differentiated: air – water; ground (groundwater) – water; ground (brine) – water. Heat pumps for pumping hot process water are treated as a fourth category.
- The starting and reference point for calculations consists of the annual numbers of newly installed heat-pump units in each of the four categories. These data are published annually by the German heat-pump association (BWP). The numbers of newly installed heat pumps for hot process water are also used as production quantities. The produced quantities of heat pumps for heating are larger, by a factor of 2, than the numbers of newly installed pumps. On the basis of the data for new additions, the various heat-pump types are assigned average HFC charges and percentage shares of the various types of HFCs. The model also includes service-life and emissions-rate figures.
- Production emissions are calculated by multiplying the quantities consumed in charging by the $EF_{production}$, pursuant to Equation 1, while emissions from stocks are calculated with Equation 2.
- Heat pumps with HFCs have been produced and sold since 1995. Since the units have an average service life of 15 years, disposal-related emissions began occurring in 2010. They are calculated with Equation 4.

Emission factors

The emission factors (EF) on which the emissions data are based are listed in Table 221.

The emission factors used are the result of surveys of experts.

The charging loss is 0.5 %. As a result, the $EF_{production}$ lies within the range proposed by the 2006 IPCC Guidelines (IPCC (2006): Vol. 3, Table 7.9), 0.2 to 1 %.

The annual HFC emissions for heating-system heat pumps are estimated at 2.5 %, while the emissions for water-heating heat pumps are placed at 2 %. The EF_{use} used thus lie within the range proposed by the 2006 IPCC Guidelines (IPCC (2006): Vol. 3, Table 7.9), 1 to 10 %.

The average lifetime prior to disposal is 15 years. The system lifetimes used thus lie within the range given in the 2006 IPCC Guidelines (Vol. 3, Table 7.9), 10 to 20 years.

The residual charges in heat pumps, with respect to initial charge, average 75 %. The 2006 IPCC Guidelines (IPCC (2006): Vol. 3, Table 7.9) give values of 0 to 80 % for this area. The value used is thus a default value.

The recovery factor for heat pumps has been increasing continuously, as a result of the greater care taken in handling refrigerants, and thus the losses occurring upon disposal, with respect to initial charge / residual charge, have been decreasing over the years concerned. The recovery factor was 50 % in 2010, and 60.5 % in 2017. As a result, all of the recovery-factor figures used lie within the range given in the 2006 IPCC Guidelines (IPCC (2006): Vol. 3, Table 7.9), 0 to 80 %.

Activity data

Each year, the Bundesverband Wärmepumpe (BWP) national heat-pump association publishes the numbers of new heat pumps installed domestically. Those figures serve as the basis for the relevant emissions calculation.

The production / installation ratio used is based on information provided by heat-pump producers.

4.7.1.2.6.4 Heat-pump clothes dryers

Heat-pump clothes dryers with HFC refrigerants have been sold on the German market since 2008. The refrigerants they use are HFC-134a and the refrigerant mixture R407C. The charges in hermetically sealed units range from 220 g to 485 g. In heat-pump clothes dryers, R290, a halogen-free alternative, has also been used since 2015.

From 2008 to 2012, one domestic company produced heat-pump clothes dryers charged with the refrigerant HFC-134a. At the end of 2012, that company transferred its production abroad.

The refrigerant model for *heat-pump clothes dryers* is structured similarly to the models for room air conditioners:

- The most important starting values are a) the unit-number figures for domestic sales and domestic production, and b) the split applied to the two refrigerants used (the refrigerant-use figures are tied to the domestic-sales figures). The total numbers of devices are calculated from the sums of new additions.
- Production emissions are calculated by multiplying the quantities consumed in charging by the $EF_{production}$, pursuant to Equation 1, while emissions from stocks are calculated with Equation 2.
- Heat-pump dryers with HFCs have been produced and sold since 2008. Since the units have an average service life of 15 years, disposal-related emissions will begin occurring in 2023.

Emission factors

The emission factors used are based on information from experts. They are listed in Table 221.

The charging loss is 0.5 %. The $EF_{production}$ is country-specific, since the 2006 IPCC Guidelines do not cover these appliances.

The ongoing HFC emissions of these hermetically sealed units are estimated at 0.3 %. In this area as well, the 2006 IPCC Guidelines provide no specifications.

Activity data

Heat-pump dryers are a relatively new product for which little statistical data and technical information are available. The pertinent refrigerant model is thus based almost exclusively on information provided by manufacturers (Winfried Schwarz et al., 2012).

4.7.1.2.6.5 Dishwashers with heat-pump systems

Since 2005, a number of commercial dishwashers with heat-pump systems have been available on the German market. Such systems, intended for large, commercial kitchens, make use of the dishwashers' waste heat. The only refrigerant used by such units is HFC-134a. The average charge is 2.5 kg.

In Germany, there are two producers of commercial dishwashers with heat-pump systems. Production of the dishwashers began in 2005 and now serves nearly the entire national market. While the dishwashers themselves are built in Germany, their heat-pump systems are imported, pre-charged, from external suppliers located abroad. When the heat-pump systems are fitted to the dishwashers, in production located in Germany, additional charges of about 200 g per unit are added.

The national market for commercial dishwashers is quite stable. It has remained at a relatively constant level for a number of years now.

The refrigerant model for *Dishwashers with heat-pump systems* is structured like the model for room air conditioners (Kristina Warncke, 2018):

- The most important outset values are the unit-number figures for domestic sales and domestic production. The stocks (pool of relevant devices) are calculated from the sum of new additions, less the removals via disposal.

- Production emissions are calculated by multiplying the quantities consumed in charging by the $EF_{production}$, pursuant to Equation 1, while emissions from stocks are calculated with Equation 2.
- Commercial dishwashers with heat-pump systems have been produced and sold since 2005. Since the units have an average service life of 12 years, disposal-related emissions began occurring in 2017. They are calculated with Equation 4.

Emission factors

The emission factors used are based on information from experts. They are listed in Table 221.

The charging loss is 1 %. The $EF_{production}$ is country-specific, since the 2006 IPCC Guidelines do not cover these appliances.

The ongoing HFC emissions of dishwashers with heat-pump systems are estimated to be 0.3 %. In this area as well, the 2006 IPCC Guidelines provide no specifications.

The average lifetime prior to disposal is 12 years. The 2006 IPCC Guidelines provide no information on this point.

The residual charges in dishwashers, with respect to initial charge, average 95.5 %. The 2006 IPCC Guidelines (IPCC, 2006) provide no values in this regard. The value used is thus also a country-specific value.

The recovery factor was 82 % in 2017. No comparisons with corresponding figures in the 2006 IPCC Guidelines (IPCC, 2006) are possible.

Activity data

Very little statistical data and technical information are available for the area of commercial dishwashers with heat-pump systems. The pertinent refrigerant model is thus based almost exclusively on information provided by manufacturers (Kristina Warncke, 2018).

4.7.1.3 Uncertainties and time-series consistency (2.F.1 all)

The emission factors are subject to considerable uncertainties. The broad range of emission factors found in the literature (see the refrigerant models) for identical applications is only partly a consequence of technical modifications, of how well systems are sealed or of national differences. To a large extent, it also results from real uncertainties, since too little solid empirical study of such factors has been carried out (Schwarz, 2007).

As a result of the aforementioned uncertainty with regard to emission factors, and to the large number of individual applications (systems) involved, the emissions data are considered to be too imprecise. In order to improve the quality of the data, the data were compared with manufacturers' (substance-oriented) sales data.

Until the 2001 reporting year, Germany reported only aggregated emissions, covering all sub-source categories. Within the context of emissions surveys for the years 1999 to 2001, and the emissions survey for the 2002 reporting year, the emissions for the reported years 1995 to 1998 were reviewed and updated on the basis of new findings on input quantities and emission factors. All data are thus being improved on an ongoing basis. A comprehensive review of the currentness of the refrigerant models, outset data and emission factors used was carried out in 2012. Additional areas of HFC-refrigerant use continue to be added on an ongoing basis. Most recently, in 2018, the categories of ice cream machines and commercial dishwashers were added to the national inventory.

The quality of the data on emissions from mobile air conditioning systems is good. The reason for this is that annual HFC consumption can be precisely determined via statistics on registered vehicles and new registrations, and on production, imports and exports of automobiles, which account for the largest part of this sector, as well as via annual model-specific figures on air-conditioner-installation rates and the pertinent charges. Only in the area of commercial vehicles are the data subject to major uncertainties.

The emission factors have been updated on the basis of the results of a study of the Federal Environment Agency (UBA) (Winfried Schwarz et al., 2012). In many application areas, the factors show a continuous development within the time series. Overall, the EF are considered to be accurate. In the study, the residual charges and recovery factors were determined for all areas of application of refrigeration and air-conditioning systems, in order to achieve conformance with the 2006 IPCC Guidelines.

The uncertainties for the entire sub-category of refrigeration and air conditioning systems have been quantified for the 2015 report.

4.7.1.4 Category-specific recalculations (2.F.1 all)

The unit-number figures for plug-in units and condensing units in the area of commercial refrigeration (sub-category 2.F.1.a), for retail businesses selling food, were corrected on the basis of figures of the Federal Statistical Office (Series 45341-0001) for the years 2005, 2006, 2009, 2010, 2015 and 2016. This led to changes in emissions from production and use of HFC-125, HFC-134a, HFC-143a and HFC-32 in the years 2005 through 2016.

In the area of low-temperature applications in commercial refrigeration and of systems converted to HCFC-22 (sub-category 2.F.1.a), data collected by the Federal Statistical Office, pursuant to the Environmental Statistics Act (UStatG, 2005), are used with regard to initial charges of new systems, and to initial charges of systems converted to R413A, R508A, R508B, Isceon 89 and HFKW-23. Since the UStatG data on HFC did not become available until December of the following year, the figures for 2016 had to be recalculated. This led to changes in the emissions of PFC-116, PFC-218, HFC-125 and HFC-23 in connection with production and use in 2016.

The percentage shares of halogen-free and HFC refrigerants in central systems of discount stores and small supermarkets in the food retail sector (sub-category 2.F.1.a) were reassessed, for the years 2015 and 2016, on the basis of new findings. This led to changes in emissions, from production and use, of HFC-125, HFC-134a, HFC-143a and HFC-32 in the years 2015 and 2016.

Ice cream machines for home use were included in the inventory for the first time, in sub-category 2.F.1.b (residential refrigeration). This led to changes in use-related emissions of HFC-125, HFC-134a and HFC-143a in the years 1997 through 2016, and to changes in disposal-related emissions of those substances in the years 2012 through 2016.

In the area of industrial refrigeration (sub-category 2.F.1.c), data collected by the Federal Statistical Office, pursuant to the Environmental Statistics Act (UStatG, 2005), have been used with regard to initial charges of new systems, and to initial charges of systems converted to HFC-23 and HFC-227ea. The figures for new additions in 2016 also had to be recalculated, since the relevant data collected pursuant to (UStatG, 2005) did not become available until December of the following year. This led to changes in emissions from production and use of HFC-23 and HFC-227ea in 2016.

In the area of refrigerated containers (sub-category 2.F.1.d), the number of containers produced worldwide in 2016 was corrected. Emissions from pertinent use of HFC-125, HFC-134a and HFC-143a decreased in 2016 as a result.

In the area of refrigerated vehicles (sub-category 2.F.1.d), the applicable size classes, charges and refrigerant shares were reassessed. This led to changes in production-related and use-related emissions of HFC-125, HFC-134a, HFC-143a and HFC-32 in the years 1993 through 2016, and to changes in disposal-related emissions of those substances in the years 2003 through 2016.

In the area of utility vehicles (sub-category 2.F.1.e), the number of light utility vehicles disposed of in 2016 was downwardly corrected in keeping with the pertinent figure reported in the 2018 waste statistics of the Federal Statistical Office. This led to a decrease in the disposal-related emissions of HFC-134a in 2016. In addition, the numbers of domestically produced utility vehicles fitted with air-conditioning systems were corrected for the years 2013 through 2016. This led to changes in production-related emissions of HFC-134a in the years 2013 through 2016. Furthermore, the change in the climate quota for new registrations in the years 2013 through 2016 led to a change in the HFC-134a emissions from stocks in the years 2013 through 2016.

In the area of automobiles (sub-category 2.F.1.e), the number of vehicles disposed of in 2016 was updated in keeping with the waste statistics of the Federal Statistical Office. This led to a decrease in the disposal-related emissions of HFC-134a in 2016. Also, the charges for automobiles newly registered in 2016 were upwardly corrected. This led to an increase in the HFC-134a emissions from stocks in 2016.

For ships (sub-category 2.F.1.e), the number of ocean-going cargo ships domestically produced in 2016 was downwardly corrected. The HFC-134a emissions from charging in 2016 decreased as a result.

In the area of chillers (sub-category 2.F.1.f), and on the basis of new sales statistics, the number of new chillers with cooling capacity >100 kW was updated for the year 2016, and the numbers of new turbo-compressor systems in the years were updated for 2015 and 2016. This led to a change in the production-related and use-related emissions of HFC-125, HFC-134a and HFC-32 in 2016 and to a change in the HFC-134a emissions in 2015.

In sub-category 2.F.1.f, commercial dishwashers with heat-pump systems were included in the inventory for the first time. This led to changes in HFC-134a emissions from charging, and from stocks, in the years 2005 through 2016.

The emissions changes in the sub-category refrigeration and air-conditioning systems (2.F.1), with regard to emissions from production, use and disposal of PFC-116, PFC-218, HFC-125, HFC-134a, HFC-143a, HFC-227ea, HFC-23 and HFC-32, in the years 1993 through 2016, are listed in Table 223.

Table 223: Overview of the recalculation-related changes in emissions (EM) in the sub-category refrigeration and air-conditioning systems (2.F.1), with regard to emissions from production, use and disposal of PFC-116, PFC-218, HFC-125, HFC-134a, HFC-143a, HFC-227ea, HFC-23 and HFC-32, in the years 1993 through 2016

	Units	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
EM production, HFC-125													
2019 Submission	t CO_2eq	337.87	2,408.98	4,823.71	9,520.87	9,849.87	10,408.85	9,670.59	10,930.83	11,718.53	10,726.27	11,047.61	11,620.61
2018 Submission	t CO_2eq	337.39	2,409.05	4,823.58	9,520.34	9,848.41	10,406.69	9,667.00	10,926.51	11,716.26	10,724.33	11,047.00	11,619.15
Difference	**t CO_2eq**	**0.47**	**-0.06**	**0.13**	**0.53**	**1.47**	**2.17**	**3.59**	**4.33**	**2.27**	**1.93**	**0.60**	**1.46**
EM production, HFC-134a													
2019 Submission	t CO_2eq	2,919.80	5,820.69	10,357.44	17,953.79	21,646.37	27,278.51	30,248.45	29,056.47	29,880.85	28,522.48	29,265.33	30,384.19
2018 Submission	t CO_2eq	2,920.88	5,820.54	10,357.34	17,954.32	21,648.75	27,282.26	30,254.96	29,064.38	29,884.99	28,526.04	29,266.39	30,386.93
Difference	**t CO_2eq**	**-1.08**	**0.15**	**0.10**	**-0.54**	**-2.38**	**-3.75**	**-6.51**	**-7.91**	**-4.14**	**-3.56**	**-1.05**	**-2.75**
EM production, HFC-143a													
2019 Submission	t CO_2eq	171.01	702.26	2,544.92	8,793.36	9,214.73	10,531.94	11,690.54	13,979.24	15,166.47	13,689.24	13,764.67	13,992.60
2018 Submission	t CO_2eq	170.30	702.35	2,545.14	8,793.26	9,213.52	10,529.89	11,686.85	13,974.75	15,164.11	13,687.20	13,764.09	13,991.00
Difference	**t CO_2eq**	**0.71**	**-0.09**	**-0.22**	**0.10**	**1.21**	**2.05**	**3.69**	**4.49**	**2.35**	**2.04**	**0.58**	**1.60**
EM production, HFC-32													
2019 Submission	t CO_2eq			35.12	134.01	142.86	180.37	248.52	259.59	290.83	288.56	343.58	422.34
2018 Submission	t CO_2eq			35.06	133.92	142.73	180.21	248.30	259.33	290.69	288.45	343.54	422.27
Difference	**t CO_2eq**			**0.05**	**0.09**	**0.13**	**0.16**	**0.22**	**0.26**	**0.14**	**0.11**	**0.04**	**0.08**
EM use, HFC-125													
2019 Submission	t CO_2eq	10,698.78	58,401.98	145,105.88	304,987.55	463,777.16	620,619.02	744,259.89	839,934.21	940,840.78	1,031,797.77	1,118,839.31	1,192,432.14
2018 Submission	t CO_2eq	9,543.64	56,728.85	142,735.15	301,735.05	459,378.53	614,828.38	736,433.05	829,827.38	929,366.00	1,019,246.90	1,107,087.70	1,180,582.86
Difference	**t CO_2eq**	**-1,155.14**	**-1,673.13**	**-2,370.73**	**-3,252.50**	**-4,398.62**	**-5,790.64**	**-7,826.84**	**-10,106.83**	**-11,474.78**	**-12,550.87**	**-11,751.61**	**-11,849.28**
EM use, HFC-134a													
2019 Submission	t CO_2eq	67,597.80	176,648.41	339,791.76	631,221.78	974,987.91	1,388,983.24	1,815,096.41	2,180,644.02	2,486,879.30	2,773,270.64	3,054,841.58	3,335,549.40
2018 Submission	t CO_2eq	67,633.31	176,673.41	339,847.27	631,372.63	975,489.98	1,390,069.31	1,817,085.27	2,183,668.16	2,490,549.14	2,777,547.74	3,059,439.12	3,340,740.33
Difference	**t CO_2eq**	**35.51**	**25.00**	**55.51**	**150.85**	**502.06**	**1,086.08**	**1,988.87**	**3,024.15**	**3,669.85**	**4,277.10**	**4,597.54**	**5,190.93**

	Units	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
EM use, HFC-143a													
2019 Submission	t CO_2eq	9,782.49	26,102.70	68,852.36	213,212.65	358,247.72	514,093.63	667,712.77	792,676.99	933,083.63	1,053,910.08	1,165,827.74	1,290,243.31
2018 Submission	t CO_2eq	8,038.98	23,577.36	65,531.33	208,882.17	352,570.57	506,765.68	657,907.57	780,078.73	918,834.45	1,038,374.38	1,151,664.60	1,276,156.98
Difference	**t CO_2eq**	**-1,743.51**	**-2,525.34**	**-3,321.03**	**-4,330.48**	**-5,677.14**	**-7,327.96**	**-9,805.20**	**-12,598.26**	**-14,249.18**	**-15,535.71**	**-14,163.14**	**-14,086.33**
EM use, HFC-32													
2019 Submission	t CO_2eq			721.97	2,623.83	4,529.38	6,788.66	9,645.77	11,953.16	13,930.62	16,447.38	20,066.68	24,807.09
2018 Submission	t CO_2eq			689.11	2,549.89	4,406.47	6,608.22	9,389.16	11,613.73	13,538.31	16,011.93	19,609.99	24,321.75
Difference	**t CO_2eq**			**-32.87**	**-73.94**	**-122.91**	**-180.44**	**-256.60**	**-339.43**	**-392.31**	**-435.45**	**-456.69**	**-485.34**
EM disposal, HFC-125													
2019 Submission	t CO_2eq											88,613.25	163,230.06
2018 Submission	t CO_2eq											87,140.17	162,893.97
Difference	**t CO_2eq**											**-1,473.07**	**-336.09**
EM disposal, HFC-134a													
2019 Submission	t CO_2eq											85,324.43	93,285.44
2018 Submission	t CO_2eq											85,775.83	93,564.39
Difference	**t CO_2eq**											**451.40**	**278.95**
EM disposal, HFC-143a													
2019 Submission	t CO_2eq											106,756.59	87,746.87
2018 Submission	t CO_2eq											104,533.20	87,239.60
Difference	**t CO_2eq**											**-2,223.38**	**-507.28**

Continued

	Units	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
EM production, PFC-116													
2019 Submission	t CO_2eq												37.80
2018 Submission	t CO_2eq												25.62
Difference	**t CO_2eq**												**12.18**
EM production, PFC-218													

	Units	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
2019 Submission	t CO_2eq												7.22
2018 Submission	t CO_2eq												5.30
Difference	**t CO_2eq**												**1.92**
EM production, HFC-125													
2019 Submission	t CO_2eq	12,215.81	13,477.68	14,328.19	18,175.25	22,422.88	25,075.63	24,262.49	18,813.40	16,742.22	16,551.94	16,088.38	16,004.85
2018 Submission	t CO_2eq	12,215.45	13,495.36	14,347.05	18,194.03	22,415.47	25,058.63	24,278.23	18,827.11	16,757.02	16,567.12	16,046.22	15,993.35
Difference	**t CO_2eq**	**0.36**	**-17.67**	**-18.86**	**-18.78**	**7.41**	**17.00**	**-15.74**	**-13.70**	**-14.81**	**-15.18**	**42.16**	**11.50**
EM production, HFC-134a													
2019 Submission	t CO_2eq	31,624.09	32,676.58	33,673.22	34,246.48	30,492.37	34,948.75	36,634.53	33,654.98	34,248.14	36,437.31	36,790.29	35,128.14
2018 Submission	t CO_2eq	31,624.24	32,681.64	33,678.68	34,251.45	30,477.03	34,922.73	36,637.92	33,658.52	34,268.30	36,250.53	36,517.58	34,765.97
Difference	**t CO_2eq**	**-0.16**	**-5.06**	**-5.46**	**-4.98**	**15.34**	**26.02**	**-3.39**	**-3.54**	**-20.16**	**186.78**	**272.71**	**362.17**
EM production, HFC-143a													
2019 Submission	t CO_2eq	14,068.04	14,419.04	14,511.76	15,329.20	16,164.86	16,109.87	15,304.99	13,186.48	11,138.83	10,358.36	9,304.32	7,380.51
2018 Submission	t CO_2eq	14,067.73	14,445.91	14,540.38	15,357.62	16,159.59	16,092.91	15,328.82	13,207.21	11,161.24	10,381.35	9,256.76	7,389.45
Difference	**t CO_2eq**	**0.31**	**-26.87**	**-28.63**	**-28.42**	**5.27**	**16.96**	**-23.84**	**-20.73**	**-22.41**	**-22.99**	**47.56**	**-8.94**
EM production, HFC-227ea													
2019 Submission	t CO_2eq												37.87
2018 Submission	t CO_2eq												38.64
Difference	**t CO_2eq**												**-0.77**
EM production, HFC-23													
2019 Submission	t CO_2eq												1,005.69
2018 Submission	t CO_2eq												1,110.00
Difference	**t CO_2eq**												**-104.31**
EM production, HFC-32													
2019 Submission	t CO_2eq	523.30	713.51	861.41	1,040.83	935.52	1,042.93	1,181.91	1,227.89	1,301.20	1,414.79	1,503.83	1,806.04
2018 Submission	t CO_2eq	523.27	713.48	861.39	1,040.82	934.82	1,041.90	1,181.90	1,227.88	1,301.20	1,414.78	1,501.89	1,804.56
Difference	**t CO_2eq**	**0.03**	**0.02**	**0.02**	**0.01**	**0.70**	**1.03**	**0.01**	**0.01**	**0.01**	**0.01**	**1.94**	**1.48**

	Units	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
EM use, PFC-116													
2019 Submission	t CO_2eq												1,863.51
2018 Submission	t CO_2eq												1,713.73
Difference	**t CO_2eq**												**-149.77**
EM use, PFC-218													
2019 Submission	t CO_2eq												2,443.60
2018 Submission	t CO_2eq												2,420.01
Difference	**t CO_2eq**												**-23.59**
EM use, HFC-125													
2019 Submission	t CO_2eq	1,236,194.65	1,286,780.88	1,363,568.37	1,473,607.49	1,622,488.57	1,767,128.76	1,888,096.39	1,911,355.84	1,902,004.83	1,905,204.15	1,887,481.85	1,844,631.54
2018 Submission	t CO_2eq	1,224,742.83	1,276,022.11	1,353,864.91	1,465,249.25	1,614,119.29	1,759,598.06	1,884,653.40	1,908,966.71	1,900,032.63	1,903,929.57	1,886,165.92	1,842,290.52
Difference	**t CO_2eq**	**-11,451.83**	**-10,758.77**	**-9,703.46**	**-8,358.25**	**-8,369.28**	**-7,530.70**	**-3,442.99**	**-2,389.13**	**-1,972.20**	**-1,274.58**	**-1,315.93**	**-2,341.02**
EM use, HFC-134a													
2019 Submission	t CO_2eq	3,622,344.88	3,914,835.27	3,858,823.01	4,048,549.79	4,256,106.34	4,418,161.75	4,566,234.21	4,668,624.81	4,739,546.04	4,816,973.97	4,878,237.77	4,831,663.17
2018 Submission	t CO_2eq	3,627,843.90	3,920,691.25	3,864,876.57	4,054,484.78	4,260,176.72	4,420,917.17	4,570,953.36	4,673,073.47	4,743,243.52	4,820,472.35	4,880,760.88	4,831,866.56
Difference	**t CO_2eq**	**5,499.03**	**5,855.98**	**6,053.56**	**5,934.99**	**4,070.38**	**2,755.42**	**4,719.15**	**4,448.66**	**3,697.48**	**3,498.38**	**2,523.11**	**203.39**
EM use, HFC-143a													
2019 Submission	t CO_2eq	1,389,149.75	1,486,529.48	1,608,352.30	1,736,191.43	1,825,363.95	1,882,746.27	1,923,655.85	1,925,702.36	1,891,270.55	1,837,730.17	1,736,734.89	1,594,876.46
2018 Submission	t CO_2eq	1,375,567.66	1,473,809.81	1,596,987.32	1,726,550.45	1,815,811.30	1,874,390.79	1,920,572.13	1,923,921.07	1,890,028.95	1,837,407.96	1,736,354.39	1,591,000.41
Difference	**t CO_2eq**	**-13,582.09**	**-12,719.67**	**-11,364.97**	**-9,640.98**	**-9,552.65**	**-8,355.48**	**-3,083.72**	**-1,781.29**	**-1,241.61**	**-322.21**	**-380.50**	**-3,876.04**
EM use, HFC-227ea													
2019 Submission	t CO_2eq												2,700.88
2018 Submission	t CO_2eq												2,705.00
Difference	**t CO_2eq**												**4.12**
EM use, HFC-23													
2019 Submission	t CO_2eq												55,882.55
2018 Submission	t CO_2eq												56,546.88

	Units	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Difference	**t CO_2eq**												**664.33**
EM use, HFC-32													
2019 Submission	t CO_2eq	30,148.78	36,667.14	44,775.53	53,441.56	60,553.61	68,234.84	76,664.76	84,286.89	91,494.89	99,734.45	107,869.01	116,964.12
2018 Submission	t CO_2eq	29,675.66	36,217.52	44,356.30	53,061.49	60,164.17	67,856.41	76,394.77	84,053.73	91,273.18	99,529.81	107,654.37	116,776.76
Difference	**t CO_2eq**	**-473.12**	**-449.63**	**-419.22**	**-380.07**	**-389.44**	**-378.42**	**-269.98**	**-233.16**	**-221.71**	**-204.64**	**-214.64**	**-187.37**
EM disposal, HFC-125													
2019 Submission	t CO_2eq	229,974.33	227,706.51	222,152.86	181,479.72	107,330.84	117,652.08	131,909.69	246,548.13	260,003.32	289,363.91	319,561.82	387,734.81
2018 Submission	t CO_2eq	229,387.72	226,874.51	220,932.29	180,022.25	104,617.56	114,358.16	130,345.14	245,227.99	260,129.64	289,048.17	319,951.75	354,226.98
Difference	**t CO_2eq**	**-586.61**	**-832.00**	**-1,220.57**	**-1,457.47**	**-2,713.28**	**-3,293.92**	**-1,564.55**	**-1,320.14**	**126.32**	**-315.74**	**389.93**	**-33,507.83**
EM disposal, HFC-134a													
2019 Submission	t CO_2eq	126,899.68	146,060.61	145,562.25	145,345.72	367,165.15	202,438.92	239,855.70	297,910.94	326,502.20	335,423.91	350,499.39	356,681.43
2018 Submission	t CO_2eq	127,224.69	146,508.03	146,244.04	146,262.67	368,345.86	203,718.16	240,730.68	297,533.23	325,935.05	335,085.02	350,022.25	394,486.43
Difference	**t CO_2eq**	**325.01**	**447.41**	**681.79**	**916.95**	**1,180.71**	**1,279.24**	**874.98**	**-377.71**	**-567.15**	**-338.89**	**-477.14**	**37,805.00**
EM disposal, HFC-143a													
2019 Submission	t CO_2eq	108,545.19	110,360.96	108,169.79	91,430.44	107,616.10	135,827.70	156,658.59	196,610.02	196,134.40	248,238.15	288,158.30	340,550.72
2018 Submission	t CO_2eq	108,174.19	109,747.95	107,093.89	90,130.90	104,712.79	132,152.30	155,124.59	195,292.68	196,657.42	248,209.98	289,070.28	290,246.29
Difference	**t CO_2eq**	**-371.01**	**-613.01**	**-1,075.90**	**-1,299.54**	**-2,903.31**	**-3,675.40**	**-1,534.01**	**-1,317.34**	**523.02**	**-28.17**	**911.97**	**-50,304.43**
EM disposal, HFC-32													
2019 Submission	t CO_2eq	1,645.70	1,754.61	1,751.95	1,564.94	2,233.60	3,346.53	4,790.16	8,849.66	13,183.91	17,199.74	23,108.82	29,204.49
2018 Submission	t CO_2eq	1,579.97	1,672.48	1,654.03	1,449.90	2,081.30	3,180.90	4,684.44	8,763.38	13,141.45	17,142.45	23,067.49	29,169.91
Difference	**t CO_2eq**	**-65.73**	**-82.13**	**-97.92**	**-115.04**	**-152.31**	**-165.63**	**-105.73**	**-86.28**	**-42.47**	**-57.29**	**-41.33**	**-34.58**

4.7.1.5 Planned improvements, category-specific (2.F.1 all)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.7.2 Foam blowing (2.F.2)

Since 1993, hydrofluorocarbons (HFCs) have also been used in foam blowing, as blowing agents substituting for ozone-depleting, climate-damaging CFCs and HCFCs.

A useful distinction can be made between open-cell and closed-cell foam products. In the case of open-cell foam products, the blowing-agent emissions occur only during the production process or immediately after it. The open-cell foam products that are produced and used in Germany include polyurethane integral foam, one-component polyurethane foam and extruded polystyrene hard foam (XPS) blown with HFC-152a. In the case of closed-cell foam products, emissions occur throughout products' entire lifetimes: in production, during use and upon disposal. The products in this category include rigid polyurethane foam, as well as extruded polystyrene hard foam (XPS) blown with HFC-134a or HFC-1234ze. Both types of closed-cell foam products are produced and used in Germany.

4.7.2.1 Closed-cell polyurethane hard foam products (2.F.2 PU hard foam)

4.7.2.1.1 Category description (2.F.2 PU hard foam)

Closed-cell polyurethane (PU) hard foam products are used in many different kinds of products, including household appliances, refrigerated vehicles, insulating boards with flexible laminates and sandwich elements with rigid laminates. HFC-134a was used as a blowing agent from 1998 to 2003. Since 2002, HFC-365mfc (with small quantities of added HFC-227ea) has also been used as a blowing agent, and HFC-245fa has also been used as such an agent since 2004. HFC-245ca is not used in Germany. Use of HFC has been decreasing; it is being supplanted by hydrocarbons, such as pentane, and by CO_2 (in small amounts).

The time series, which does not begin until 1998, shows a small increase in emissions until 2003. A larger increase occurred in 2004. These results agree with the historical development of HFC use in this application area, an area which emerged only slowly, in keeping with the long period in which HCFCs were used. Emissions from PUR hard foam products decreased again from 2005 through 2009. A slight increase occurred in 2010, and since then the emissions have remained at a relatively constant level.

4.7.2.1.2 Methodological aspects (2.F.2 PU hard foam)

The production emissions are calculated, using Equation 1, by multiplying the quantity of HFC that is emitted no later than one year after the time of production (the first-year loss) by the $EF_{production}$. The emissions from stocks are calculated with Equation 2.

Given the products' average lifetime of up to 50 years (sandwich elements), disposal of PU hard foam products will not begin until a few years from now.

Emission factors

The emission factors used are shown in Table 222.

The emission factor for production with HFC-134a is 10 %. That figure is equivalent to the standard value given in the 2006 IPCC Guidelines (IPCC (2006), Vol. 3, Table 7.6) for "polyurethane continuous panels."

The emission factors for all other HFCs have been approved by national experts and adjusted where necessary. For example, the emission factor for production of PU hard foam, with use of HFC-365mfc/HFC-227ea as of 2004, was increased from 10 % to 15 %, because that HFC mixture has been used increasingly in open on-site applications, especially in spray foams. The emission factor for production with HFC-245fa is also 15 %. These values lie within the standard-value range proposed by the 2006 IPCC Guidelines (IPCC (2006): Vol. 3, Table 7.7) for "first-year losses" for the various PUR-hard-foam applications.

For PU hard foam blown with HFC-134a, the annual HFC emissions from the "stock" are estimated at 0.5 %. That figure is equivalent to the default value in the 2006 IPCC Guidelines (IPCC (2006): Vol. 3, Table 7.6) for "polyurethane continuous panels." The products blown with HFC-365mfc/HFC-227ea and HFC-245fa emit 1 % annually, and thus lie within the default-value ranges given by the 2006 IPCC Guidelines (IPCC (2006): Vol. 3, Table 7.7), for various PUR-hard-foam applications. The emission factor used for HFC-365mfc/HFC-227ea emissions from stocks was taken from an estimate based on test products.

Activity data

The figures for new domestic consumption, for each blowing agent and each product group, are based on the amounts of foam products produced in Germany. The data for products in service are based on the amounts of foam products used in Germany (sales in Germany) since the introduction of HFCs. Given a product lifetime of up to 50 years, removals from products in service do not yet play any significant role.

New domestic consumption and domestic sales of foam products are determined annually via surveys of manufacturers, users and blowing-agent suppliers, and via information from the relevant industry association (IVPU[77] – the polyurethane-foam industry association).

4.7.2.2 Closed-cell and open-cell XPS hard foam (2.F.2 XPS)

4.7.2.2.1 Category description (2.F.2 XPS)

Extruded polystyrene hard foam (XPS) is used in insulating boards that need to be highly moisture-resistant. HFC consumption and emissions from production of XPS insulation boards have occurred only since 2001, since HCFCs or CO_2 / ethanol were used in this area prior to that time. Since 2001, both HFC-152a and HFC-134a have been used as blowing agents, either singly or in mixtures. Since 2012, HFC-1234ze has also been used as a blowing agent. The emissions behaviour of XPS insulating boards varies in keeping with the blowing agents used to produce them. When HFC-152a is used, HFC emissions occur only during production, and thus the resulting XPS insulating boards can be considered "open-cell" products. When HFC-134a or HFC-1234ze are used, closed-cell XPS hard foam products result that also release HFC emissions during use and disposal.

The relevant time series begins in 2001 and exhibits a slight initial emissions increase until 2002. As of 2003, the emissions decrease continuously; this is related to the increasing use of non-halogenated blowing agents in production of XPS hard foam products in Germany.

[77] IVPU – Industrieverband Polyurethan-Hartschaum e. V.

4.7.2.2.2 Methodological issues (2.F.2 XPS)

The production emissions are calculated by multiplying the production-related new HFC consumption by the $EF_{production}$, pursuant to Equation 1.

The use emissions are calculated, in keeping with Equation 2, from the domestic final HFC stocks in XPS insulating materials. Those stocks increase annually solely through new additions of insulating boards containing HFC-134a and HFC-1234ze. Given a product lifetime of 50 years, removals from products in service do not yet play any significant role. The new HFC additions are not equivalent to annual new consumption, minus production emissions. The reason for this is that, as a result of foreign trade, especially exports of XPS products with HFC-134a or HFC-1234ze, only 25 % (the complementary value for the export rate) of the HFC-134a or HFC-1234ze contained in products amounts to new additions to domestic HFC stocks.

Given that XPS insulating boards have an average lifetime of 50 years, disposal will not begin until 2051 at the earliest. Disposal emissions thus play no significant role to date.

HFC-1234ze is not subject to reporting obligations. Germany voluntarily reports emissions of this substance pursuant to the recommendations of the 2014 UNFCCC Reporting Guidelines (FCCC/CP/2013/10/Add.3, Decision 24/CP.19), under "additional greenhouse gases". For reasons of confidentiality, the HFC-1234yf emissions are aggregated with other emissions that are not subject to reporting obligations and are reported in Chapter4.9.3 under CRF 2.H.3.

Emission factors

The emission factors used are shown in Table 222.

The production emissions (HFC first-year losses) for HFC-152a are practically 100 % ($EF_{production}$ = 1), since the substance is used solely as a blowing agent in production. With HFC-134a, only part of consumption is emitted upon blowing; most of the substance enters into the product. The $EF_{production}$ for HFC-134a is determined empirically and communicated by the CEFIC[78] association or by its EXIBA[79] industry association. It is subject to confidentiality requirements. Until experimental measurements become available, the same $EF_{production}$ will be used for XPS insulating boards blown with HFC-1234ze that is used for insulating boards blown with HFC-134a.

Trials with HFC collection and recovery in the production process have been conducted, but to date no relevant systems have been implemented, for both technical and economic reasons.

The 2006 IPCC Guidelines (IPCC, 2006) give the following default values, in Vol. 3, Table 7.6, for insulating boards blown with HFC-134a and HFC-152a: The "first year loss" is 25 % for HFC-134a and 50 % for HFC-152a. The corresponding values used in Germany, especially that for HFC-152a, differ widely from these figures. At the same time, they are considered to be representative, since they are based on information provided by industry experts.

A representative of the FPX extruded-polystyrene-foam association estimated the annual releases from enclosed HFC-134a cell gas as being less than 1 % in 2002. That figure is based, inter alia, on an internal study of BASF regarding the half-lives of various cell gases, including HFC-134a (Weilbacher, 1987). The EF_{use} from that laboratory study has been used for HFC-134a. Fugitive emissions from boards depend on board thickness, and they can be given only as average values, or as values for specific board thicknesses. The value used, EF_{use} = 0.66 %, is based on a medium board thickness, and it lies below the value proposed in the 2006 IPCC Guidelines (IPCC (2006): Vol. 3, Table 7.6), 0.75 %. The 2006 IPCC Guidelines do not provide any default values for insulating

[78] CEFIC – The European Chemical Industry Council

[79] EXIBA – European Extruded Polystyrene Insulation Board Association

boards blown with HFC-1234ze. The same EF_{use} is used for such boards as is used for boards blown with HFC-134a.

Activity data

The data on new domestic consumption of HFC-134a and HFC-152a are obtained from data collected pursuant to the Environmental Statistics Act (Umweltstatistikgesetz; (UStatG, 2005)) and from surveys of manufacturers.

The data on new domestic consumption of HFC-1234ze are obtained from data collected via surveys pursuant to the Environmental Statistics Act (Umweltstatistikgesetz; (UStatG, 2005)) and via information provided by the pertinent propellant manufacturer.

All of the data required for emissions calculation, including new domestic consumption, loss rate in production and the foreign trade balance for insulation boards containing HFC-134a, are provided by the relevant European industry association (CEFIC or EXIBA).

4.7.2.3 Open-cell polyurethane integral foam (2.F.2 PU integral foam)

4.7.2.3.1 Category description (2.F.2 PU integral foam)

Open-cell polyurethane (PU) integral foams are foams with a porous core and a compact, tough skin. They are produced via reaction injection moulding. In that process, the reaction mixture, including the blowing agent, is injected in liquid form into a cold injection mould. All of the blowing agent is emitted during the foaming action that ensues. PU integral foams are used in the soles of athletic and leisure shoes, in car-body parts and in window profiles. HFCs have been used as blowing agents for production of PU integral foams since 1996.

Along with HFC-134a, which has been used since 1996, the blowing agents used in Germany also include HFC-365mfc (since 2002; and with minor additions of HFC-227ea) and HFC-245fa (since 2004). HFC-245ca is not used in Germany.

The time series begins in 1996. From then until 2001, the emissions remained relatively constant. As of 2002, the emissions increase continuously. HCFCs were long used in production of PU integral foams in Germany, and this delayed the phasing-in of HFCs. A sharp emissions reduction occurred in 2012. It was due to intensified use of hydrocarbons (such as pentane), as blowing agents, in place of HFCs. The emissions increased again thereafter, however.

4.7.2.3.2 Methodological aspects (2.F.2 PU integral foam)

Pursuant to the 2006 IPCC-Guidelines (IPCC (2006): page 7.34, equation 7.8), the emissions in this open application are considered to be the same as the HFC quantity used in production (new HFC consumption).

The production emissions are calculated by multiplying the production-related new HFC consumption by the $EF_{production}$, pursuant to Equation 1.

No use emissions or disposal emissions occur, since all of the blowing agent is emitted completely in production.

Emission factors

The emission factor used is shown in Table 222.

For PU integral foams blown with HFC-134a, HFC-245fa or HFC-365mfc (with additions of HFC-227ea), the 2006 IPCC Guidelines give a default value of 95 % for the first-year loss. The annual loss is given as 2.5 %, with the result that emissions occur over three years.

According to the in-country experts consulted, all of the blowing agent – except for small residual quantities – escapes during the blowing process. The small residual quantities are then emitted over a period of no longer than two years. For this reason, in a departure from the 2006 IPCC Guidelines, Germany considers an emission factor of 100 % to be appropriate for production.

Activity data

The figures for new domestic consumption, for each blowing agent and each product group, are based on the amounts of integral foam products produced in Germany.

The new domestic consumption is determined annually via surveys of manufacturers, users and blowing-agent suppliers, and via information from the relevant industry association (IVPU – the polyurethane-foam industry association).

4.7.2.4 Open-cell one-component polyurethane foam (2.F.2 one-component PU foam)

4.7.2.4.1 Category description (2.F.2 one-component PU foam)

The term "one-component foam" refers to open-cell polyurethane foam (PU foam) that is sprayed, on site, from pressurised containers (cans). Such foam is used, for example, in installation of windows and doorframes. The blowing agents now used for such foam, following the prohibition of HCFCs, include mixtures of HFCs and propane, butane or dimethyl ether (DME). At the same time, the HFC quantities in such cans have been continually reduced since 1996.

HFC-134a has been used in Germany since 1992, in production of PU one-component foam (in cans). HFC-152a was used from 2002 to 2004. Imported cans of PU foam sealant used in Germany contain HFC-134a (since 1992) or HFC-152a (since 1995).

The emissions of PU one-component foam increased sharply from 1992 through 1994; thereafter, they decreased continuously. Since 4 July 2008, a ban has been in force in the EU, with a few permitted exceptions, on sale of one-component-foam products filled with fluorinated greenhouse gases with a global warming potential (GWP) greater than 150. For that reason, future emissions can be expected to remain relatively constant, at low levels.

4.7.2.4.2 Methodological aspects (2.F.2 one-component PU foam)

The production emissions are calculated from the number of cans filled per year in Germany and the blowing-agent loss per can.

Pursuant to the 2006 IPCC-Guidelines (IPCC (2006): p. 7.34, equation 7.8), in each case the emissions for this open use are considered the same as the HFC quantity sold with the can. Emissions from use are calculated, with Equation 2, via the HFC quantities sold in cans.

No disposal emissions occur, since all of the HFCs in cans of one-component foam are emitted when the cans are used.

Emission factors

The emission factors used are shown in Table 222.

The $EF_{production}$ was determined via surveys of experts and of manufacturers. From 1992 to 2002, it amounted to 1.5 g/can, while since 2003 it has been only 0.5 g/can, since the total fill quantities in cans have decreased.

The 2006 IPCC Guidelines (IPCC, 2006), in Vol. 3, Table 7.6, give a first-year loss of 95 % and an annual loss of 2.5 % for one-component foams, with the result that the relevant emissions are distributed over a total of three years in each case. In contrast to the IPCC method, for the German inventory, it is assumed that all emissions occur in the year of sale (EF_{use} = 100 %), since use and disposal occur promptly. At the same time, used cans are not completely empty when they go to waste management; they still contain about 8 % of their original foam contents, including the relevant blowing agent. The majority of that blowing agent eventually also enters the atmosphere, after a certain delay.

Activity data

The data required for determination of losses from charging (production emissions) – the numbers of cans filled annually in Germany with HFC-134a or HFC-152a; the quantity of HFC per can, in grams; and the specific loss from charging – are obtained via surveys of experts and from information provided by manufacturers.

The data required for determination of the emissions from use – the numbers of cans sold annually in Germany with the propellants HFC-134a or HFC-152a, and the HFC quantity per can, in grams – are obtained from the manufacturers of spray cans with one-component-foam.

The pre-1995 data for foam sealants were obtained via discussion, in 2006, with leading foreign sellers of one-component foam products and from older publications.

4.7.2.5 Uncertainties and time-series consistency (2.F.2 all)

The uncertainties for the "foams" sub-category have been systematically quantified.

The emissions data for prior years, for PU foam products, are considered fairly accurate, since the quantities of HFCs used are rather small.

Because it includes only a small number of manufacturers, the German XPS market is not complex. Since the EF and AD were prepared in co-operation with manufacturers, they are considered sufficiently precise.

Since 2001, the relevant industry association has determined, via research, the input quantities of HFC-152a and HFC-134a in production of XPS hard foams. Since 2006, data collected pursuant to the Environmental Statistics Act (Umweltstatistikgesetz; (UStatG, 2005)) have also been available. Since only three manufacturers use HFC for XPS blowing, there is little reason to doubt the reliability of the activity data. This also applies to the export rate and the HFC production emissions determined for use of HFC-134a.

The production emissions in use of HFC-152a, 100 %, do not agree with the existing IPCC estimates. Nonetheless, the industry association considers them to be realistic.

The value for the emissions rate from current stocks, as determined by a laboratory study, will be used as long as no reliable measurements with insulation boards in actual service have been carried out; such measurements would be considered more conclusive than laboratory values.

4.7.2.6 Category-specific recalculations (2.F.2 all)

The figures for domestic consumption of HFC-152a for production of XPS hard foam, for the years 2007 through 2011, were corrected on the basis of data collected pursuant to the Environmental Statistics Act (2005). In addition, the figures for domestic consumption of HFC-134a for production of XPS hard foam were corrected – also on the basis of data collected pursuant to the Environmental Statistics Act – for the years 2009 through 2011 and 2013 through 2016.

The figures for domestic consumption of HFC-365mfc, HFC-227ea and HFC-245fa for production of PU hard foams and PU integral foams were corrected, for the years 2007 through 2016, on the basis of new findings.

For reasons of confidentiality (there are only a few producers of foam products in Germany), the emissions changes are not quantified in this context.

4.7.2.7 Planned improvements, category-specific (2.F.2 all)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.7.3 Fire extinguishers (2.F.3)

4.7.3.1 Category description (2.F.3)

Halons, which until 1991 were permitted fire extinguishing agents, have since been largely supplanted by ecologically safe substances – especially inert gases, such as nitrogen and argon, for systems for flooding rooms; and by powder, CO_2 and foams in handheld fire extinguishers.

In 1998, HFC-227ea was certified in Germany as a halon substitute. In 2001, HFC 236fa also received such certification. That substance is used solely in the military sector, however. HFC-23, while certified since 2002, did not begin to be used until 2005. While certification of fire extinguishing agents is no longer required, the list of fire extinguishing agents in use has nonetheless not grown, since all application areas can be covered with halogen-free agents and with the aforementioned HFCs (especially 227ea and 236fa).

HFC-based fire extinguishing agents are imported and filled into fire extinguishing systems in Germany. Virtually no foreign trade with charged systems takes place. The time series do not begin until 1998.

4.7.3.2 Methodological issues (2.F.3)

The annual new HFC additions in domestic systems are identical with the amounts added to new systems within the country (new HFC consumption).

Since activity data are available in Germany for HFC-227ea and HFC-236fa, a bottom-up approach is used. The approach used differs from the top-down approach given by the 2006 IPCC Guidelines (IPCC (2006): Vol. 3, Chapter 7.6) in that emissions from charging have been taken into account.

Due to a lack of pertinent data, the installed quantities of HFC-23 are estimated by the Federal Environment Agency. As of report year 2016, it has been asssumed that, as a result of the provisions of Regulation (EU) No 517/2014 (F-GasV, 2014), no further new systems have been installed.

The average lifetime of fire extinguishing systems is estimated to be 20 years, a period on the same order as the duration range proposed by the 2006 IPCC Guidelines (IPCC (2006): Vol. 3, Chapter 7.6.2.2), 15 to 20 years.

Disposal emissions occurred for the first time in 2018, at the end of the average lifetime for the category, 20 years.

Emission factors

The emission factors used are shown in Table 222.

The $EF_{production}$ are based on experts' assessments.

The EF_{use} for HFC-236fa and HFC-23 is 4 %. The 4 % figure conforms to the 2006 IPCC Guidelines. With regard to HFC-227ea, concrete figures are available relative to installed and recharged quantities. They were obtained via up-scaling from the pertinent company's market share (as estimated by the company) to the German market as a whole.

For all HFCs, the emission factor for disposal is 1 %. Experts of the environmental research institution Öko-Recherche recommended this value, which differs from the value specified by the 2006 IPCC Guidelines (IPCC (2006): Vol. 3, Chapter 7.6.2.2), in light of the fact that, in practice, the gas cylinders used in such systems are normally reused (i.e. they are separated from the systems for recharging and reusing).

Activity data

The figures for HFC 227ea emissions are based on statistical surveys by one company, covering the aspects of input quantities, recharge quantities, accidental releases, releases in cases of fire, and flooding tests in Germany (by analogy to Tier 2). Up-scaling was carried out on the basis of the market shares estimated by the company. The data for HFC-236fa are based on company information provided on a voluntary basis. The figures for HFC-23 are based on estimates of the Federal Environment Agency.

4.7.3.3 Uncertainties and time-series consistency (2.F.3)

The uncertainties for the "fire extinguishing agents" sub-category have been systematically quantified.

4.7.3.4 Category-specific recalculations (2.F.3)

No recalculations are required.

4.7.3.5 Planned improvements, category-specific (2.F.3)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.7.4 Aerosols (2.F.4)

This area includes metered-dose inhalers (MDI), which are used in medical applications, as well as general-purpose aerosols and so-called "novelty aerosols".

4.7.4.1 Metered-dose inhalers (2.F.4.a)

4.7.4.1.1 Category description (2.F.4.a)

Metered-dose inhalers are used in the medical sector, primarily for treatment of asthma. Metered-dose inhalers with an HFC propellant first reached the German market in 1996. They contained the propellant HFC-134a. Beginning 1999, metered dose inhalers with the propellant HFC-227ea were also sold. Since then, the number of available preparations has grown continually. Charging of inhalers with HFC-134a has taken place in Germany since 2001.

From 1996 through 2002, the time series shows a sharp emissions increase that correlates with increasing use of HFCs as CFC substitutes. A large change occurred in 2001. As of that year, CFCs were prohibited for the largest group of active ingredients, the short-acting betamimetics. Since 2003, the emissions have remained at a relatively constant high level.

4.7.4.1.2 Methodological issues (2.F.4.a)

Since 98 % of the contents of metered dose inhalers consist of propellant, their contents are considered to consist solely of HFCs.

The production emissions are calculated from the number of metered dose inhalers charged per year in Germany and the propellant loss per can. Part of the propellant emissions are collected with cold traps and then incinerated. Without such collection, the emissions would be higher.

Emissions from use are calculated, with Equation 2, via the HFC quantities sold in metered dose inhalers. The great majority of metered dose inhalers used in Germany are sold in pharmacies. An estimated 10 percent are used by hospitals, for their own needs, while 3 percent are samples, "not for sale", for doctors and pharmaceutical representatives. These two shares are taken into account by adding 13 % to sales by pharmacies.

The time period between pharmacy sales and use is short. In a departure from the recommendation in the 2006 IPCC Guidelines (IPCC (2006): Vol. 3, Equation 7.6), the reference figure for the emissions from use is thus not the sum of half the purchases (sales) of the previous year and half the purchases (sales) of the current year, but all purchases (sales) for the current year. The approach in the 2006 IPCC Guidelines would be a useful choice if the available data covered produced inhalers – rather than sold inhalers – since considerable time, for transport and storage, indeed can pass between production and use.

No disposal emissions occur, since all of the HFCs in metered dose inhalers are emitted when the cans are used.

Emission factors

The emission factors used are shown in Table 222.

The $EF_{production}$ on which production-emissions data are based is itself based on very precise determination of charging emissions, in actual operations, by the only German company that charges such inhalers. These amount to about 1 %, with respect to new consumption for charging. This translates to about 0.15 g per 10 ml inhaler.

In agreement with IPCC specifications (2006 IPCC Guidelines, Vol. 3, p. 7.28), a 100 % emissions level in use (EF_{use} = 1) is assumed. Inhaled HFCs are not broken down in bronchial passages; they are released into the atmosphere, without undergoing any changes, upon exhalation. In a departure from the Guidelines, Germany uses a lifetime of only one year for metered dose inhalers. The emission factor has thus been classified as "country-specific".

Activity data

The emissions data for the period until reporting years 2005 (production) and 2006 (use) are based on sales figures (sales in pharmacies) for metered-dose inhalers in Germany, as obtained via surveys of producers. The total unit numbers, the average fill quantity in ml and the propellant used have all entered into relevant calculations. As of report year 2006, the activity data for production are based on experts' estimates. As of report year 2007, the activity data for use are also based on such estimates. In the category "metered dose inhalers", the results of the Federal Statistical Office's annual surveys of certain climate-relevant substances (UStatG, 2005) normally do not become available on time for the corresponding current report year. Retroactive data cross-checking is carried out when necessary, however.

4.7.4.2 Other aerosols (2.F.4.b)

4.7.4.2.1 Category description (2.F.4.b)

In Germany, six types of general-purpose aerosols (includes neither medical metered dose inhalers nor novelties) containing HFC are sold:

- compressed-air sprays,
- cooling sprays,
- drain-opener sprays,
- lubricating sprays,
- insecticides, and
- self-defence sprays.
- Production and use of general-purpose aerosols with HFC-134a began in 1992; production and use of such aerosols with HFC-152a began in 1995. Since 2013, HFC-1234ze has also been used as a propellant in cooling sprays and cleaning sprays. From 1992 through 1996, the time series shows a sharp emissions increase that correlates with increasing use of HFCs as CFC substitutes. The emissions remained at a constant level between 1996 and 2005. The emissions then decreased sharply in 2009. Since that year, emissions from general-purpose aerosols have been increasing slightly.

Other aerosols include "novelty" aerosols (artificial snow, "silly string", etc.). Such products are not produced in Germany, however. Use of novelty sprays with HFC-134a began in 1995, while use of sprays with HFC-152a began in 2000. As of 2004, the emissions from such sprays decreased sharply. Since 2010, they have remained at a constant low level. That trend is the result of a EU ban, in force as of 4 July 2009, on sale of novelty aerosols filled with hydrofluorocarbons (HFCs) with a Global Warming Potential (GWP) greater than 150. Producers were quick to respond by choosing other propellants for their products.

4.7.4.2.2 Methodological issues (2.F.4.b)

In the case of general-purpose aerosols, imports and exports are roughly in balance, and thus the domestic market can be considered equivalent to consumption for domestic filling. Domestic consumption refers to spray cans filled in Germany, regardless of where the cans are ultimately used. The production emissions are calculated, pursuant to Equation 1, from the HFC consumption for in-country filling of general-purpose aerosols and the propellant loss in production.

No novelty aerosols are produced in Germany. The basis for calculating the HFC quantities sold in novelty-aerosol cans consists of the German market's share of the EU market.

Emissions from use are calculated, using Equation 2, via the HFC quantities sold in "other aerosols".

Since the calculations are oriented to the numbers of aerosol cans sold – and not to the numbers produced – the average time period between the sale and use of such cans may be assumed to be very short. The reference figure for calculating the emissions from use – in contrast to the recommendation in the 2006 IPCC Guidelines (Vol. 3, Equation 7.6) – is thus not the sum of half the purchases (sales) of the previous year and half the purchases (sales) of the current year, but all purchases (sales) for the current year.

Since the HFCs contained in such aerosols are emitted completely when the aerosols are used, no disposal emissions have to be reported.

HFC-1234ze is not subject to reporting obligations. Germany voluntarily reports emissions of this substance pursuant to the recommendations of the 2014 UNFCCC Reporting Guidelines (FCCC/CP/2013/10/Add.3, Decision 24/CP.19), under "additional greenhouse gases". For reasons of confidentiality, the HFC-1234yf emissions are aggregated with other emissions that are not subject to reporting obligations and are reported in Chapter4.9.3 under CRF 2.H.3.

Emission factors

The emission factors used are shown in Table 222.

The $EF_{production}$ = 1.5 % on which production-emissions data for other aerosols are based is itself based on experts' assessments.

A 100 % emissions level in use of other aerosols (EF_{use} = 1) is assumed. This assumption is appropriate, and it accords with the IPCC specifications (IPCC (2006), Vol. 3, p. 7.28). In a departure from the Guidelines' relevant proposal, it is assumed that all of the cans sold in Germany are used completely in the same year in which they are sold. The emission factor has thus been classified as "country-specific".

Activity data

The data for the period prior to 1995 are based on estimates of experts. In keeping with a bottom-up approach, all quantity data as of 1995 are provided directly by producers, fillers and operators, propellant manufacturers and the relevant industry association. Emissions data for general-purpose aerosols also include filling emissions (= production emissions). Estimates are based on EU-wide data.

4.7.4.3 Uncertainties and time-series consistency (2.F.4 all)

The uncertainties for the "aerosols" sub-category have been systematically quantified.

In the case of metered dose inhalers, the surcharge factor for hospitals and doctors' samples can vary, by ± 3 %, from the above-cited 13%.

In comparison to the emissions data for metered dose inhalers, the data for other aerosols are considered not as good, since the large number of products involved makes it difficult to obtain an overview of the market. Large quantities of imports, especially in the area of "novelties", also complicate the situation. The uncertainties are thus considerably higher (more than 20 %).

Since the shift from CFCs to chlorine-free propellants had already been completed by the beginning of the 1990s, the time series for the period 1995-2005 showed virtually no changes. Slight emissions decreases have been seen since 2006.

4.7.4.3.1 Category-specific recalculations (2.F.4 all)

The quantities of HFC-134a used for production of general-purpose aerosols, which agree with the quantities sold in Germany, were corrected for the years 2011 through 2016. As a result, the emissions from charging and use of general-purpose aerosols changed in those years. In addition, the HFC-152a activity data for production and use of general-purpose aerosols were corrected for the year 2016. This led to a decrease in the HFC-152a emissions from charging and use in 2016.

Table 224: Overview of the recalculation-related changes, in the sub-category Aerosols (2.F.4), in emissions (EM) from production and use of HFC-134a and HFC-152a in the years 2012 through 2016

	Units	2012	2013	2014	2015	2016
EM production and use, HFC-134a						
2019 Submission	t CO_2eq	513,304.59	530,636.11	519,212.53	581,490.62	605,175.79
2018 Submission	t CO_2eq	510,313.69	528,554.90	517,678.31	582,070.88	574,177.98
Difference	**t CO_2eq**	**2,990.90**	**2,081.21**	**1,534.22**	**-580.26**	**30,997.81**
EM production and use, HFC-152a						
2019 Submission	t CO_2eq					245.81
2018 Submission	t CO_2eq					857.61
Difference	**t CO_2eq**					**-611.80**

4.7.4.3.2 Planned improvements, category-specific (2.F.4 all)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.7.5 Solvents (2.F.5)

4.7.5.1 Category description (2.F.5)

Use of HFCs as solvents was banned in Germany until the year 2001 (2nd Ordinance on the Implementation of the Federal Immission Control Act – 2. BimSchV) and remains heavily restricted to this day. A separate permit has to be applied for for every surface-treatment facility that uses HFCs either in a pure form or in mixtures with trans-1,2-dichloroethene, and such permits are granted only in special cases. In addition to HFC-43-10mee, which has already been reported, the following substances are now also used, in very small quantities: HFC-365mfc (since 2013), HFC-245fa (since 2010) and C_6F_{14} (since 2006).

4.7.5.2 Methodological issues (2.F.5)

Emissions are calculated in keeping with Tier 2a as described in the 2006 IPCC Guidelines (IPCC (2006): Vol. 3, Chapter 7.2). Emissions occur only during use.

Emission factors

In an objectively correct approach that is keeping with the IPCC specifications (IPCC (2006): Vol. 3, Equation 7.5), emissions from a given solvent use are assumed to amount to 100 % within 2 years (EF_{Use} = 1).

Activity data

The consumption figures for HFC-43-10mee are based on the sales data of an authorised dealer. The quantities of HFC-245fa and of HFC-365mfc used are based on information provided by industry experts. The data on domestic consumption of C_6F_{14} was obtained from data collected pursuant to the Environmental Statistics Act (UStatG, 2005).

Since the data are confidential, they are reported under CRF 2.H.3.

4.7.5.3 Uncertainties and time-series consistency (2.F.5)

The uncertainties for the "solvents" sub-category have been systematically quantified. The figures on solvents consumption are obtained directly from the individual firms concerned. The uncertainties for the emissions (U_{min}/U_{max}) are thus very low. They are assumed to be 2 %. C_6F_{14} is an exception. According to expert judgements, the uncertainties for the emissions (U_{min}/U_{max}) of that substance amount to 20 %.

Prior to 2006, the emissions stayed at a constantly low level. Between 2006 and 2008, a sudden sharp emissions increase occurred, triggered in part by the onset of use of C_6F_{14}. Since 2009, the quantities used – and thus the emissions – have remained at a relatively constant low level.

4.7.5.4 Category-specific recalculations (2.F.5)

No recalculations are required.

4.7.5.5 Planned improvements, category-specific (2.F.5)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.7.6 Other applications that use ODS substitutes (2.F.6)

Germany reports no emissions in this category.

4.7.7 Category-specific QA/QC and verification (2.F all)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The data for the 2003 report year, like the data for most of the previous years, were collected by an external expert working in the framework of a research project under commission to the Federal Environment Agency.

For the most part, quality assurance was carried out by an external expert. In addition, the data are checked by the relevant Federal Environment Agency specialists upon receipt.

In 2011, the entire sector of F-gas emissions was subjected to voluntary trilateral review. Experts from England, Germany and Austria reviewed "each other's" F-gas inventories. The aims of the review were to exchange information regarding country-specific methods for preparing F-gas inventories; to learn about the institutional and legal regulations for F-gas inventories in each country; to identify obstacles for the preparation of complete, precise inventories; and to discuss differences and similarities between the various methods used to prepare F-gas inventories. The meeting helped all three countries to review their methods for relevant emission calculation. In addition, the transparency, completeness and precision of the various inventories were assessed. That review had a positive outcome, namely that Germany has a good F-gas inventory. As a result, no recommendations were issued for improvements of the German F-gas inventory.

No other data sources, apart from the data provided by the Federal Statistical Office, the data collected by the research contractor and the data reported by the pertinent companies, are available for review of the F-gas quantities determined for emissions reporting purposes, i.e. for review that would serve as a basis for verification. Comparisons with other countries have revealed no requirements for improvements. The emission factors either are in keeping with the default emission factors given by the 2006 IPCC Guidelines or are of the same order as the values used by other countries.

4.8 Other product manufacture and use (2.G)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
L/T	**2.G Other product manufacture and use**		**SF_6**	**C**	**C**	**C**	**C**	**C**
-/T	**2.G. Other product manufacture and use**	**includes 2.B.10. Other N-dodecanedioic acid**	**N_2O**	2,029.49	0.17%	382.93	0.04%	-81.1%
-/-	2.G. Other product manufacture and use		CH_4	4.53	0.00%	33.28	0.00%	634.9%
-/-	2.G. Other product manufacture and use		HFC	C	C	C	C	C
-/-	2.G. Other product manufacture and use		PFC	C	C	C	C	C

Gas	Method used	Source for the activity data	Emission factors used
CO_2, CH_4, N_2O, SF_6, PFC, HFC	cf. Table 225	cf. Table 225	cf. Table 225

The category *Other product manufacture and use* is a key category for SF_6 emissions in terms of level and trend. For N_2O emissions, it is a key category only in terms of trend.

The category 2.G includes SF_6 from electrical equipments (2.G.1), SF_6 and PFC from other product use (2.G.2), use of N_2O (2.G.3), other ORC systems (2.G.4 ORC) and CO_2, CH_4, N_2O and particulate emissions from use of charcoal (2.G.4 Charcoal). With regard to use of cigarettes (2.G.4) and fireworks (2.G.4), emissions of particulates, precursor substances and heavy metals are reported. In the interest of more-precise data collection, these sub-categories are further divided, to some extent, in the following section.

The methods, emission factors and applicable lifetimes on which the emission calculation is based are listed in Table 225.

Table 225: Overview of the methods and emission factors used, for the current report year, in the categories 2.G.1 (Electrical equipments), 2.G.2 (SF_6 and PFC from other product use) and 2.G.4 (ORC systems & charcoal use)

	QG	Method	Gas			Lifetime	Emission factor (dimensionless)		
			SF_6	HFC	PFC	[years]	Production	Application	Waste management
Electrical equipments	**2.G.1**								
Switchgear and controlgear	2.G.1a	Tier 3	SF_6			40	0.02 (CS)	0.001 – 0.01 (CS)	0.015 (CS)
SF_6 and PFC from other product use	**2.G.2**								
AWACS	2.G.2a	CS					NO	1 (CS)	NO
Particle accelerators	2.G.2b	CS	SF_6				0.15 - 1 (CS)	0.006 – 0.003 (CS)	NO
Insulated glass windows	2.G.2c	Equ. 3.24 ff					0.33 (D)	0.01 (D)	1 (D)
Adiabatic behaviour	2.G.2d								
- Automobile tyres		Equ. 3.23	SF_6				NO	NO	1 (D)
- Athletic shoes		Equ. 3.23	SF_6		PFC		NO	NO	1 (D)
Other	2.G.2e								
- Trace gases		Equ. 3.22	SF_6				NO	1 (D)	NO
- Welding		CS	SF_6				NO	1 (CS)	NO
- Optical glass fibre		CS	SF_6				0.001 (CS)	NO	NO
- Medicines and cosmetics		CS			PFC	-	NO	1 (D) 0.95 – 0.998 (CS)	NO
Semiconductor manufacturing		D					C		
Narcotic applications		D						1	
Explosives		D						0.1036 kg/t	
Spray cans		D						1	
Other	**2.G.4**								
ORC systems	2.G.4a	CS		HFC	PFC	20 – 30 (CS)	0.02 (CS)	0.04 (CS)	0.2 (CS)
Charcoal use	*2.G.4b*	Tier 1	CO_2-, CH_4-, N_2O- and particulates				C	C	

4.8.1 Electrical equipments (2.G.1)

This category consists primarily of use of electrical equipments (2.G.1), which is further subdivided into high-voltage (HS – Hochspannungs-), medium-voltage (MS – Mittelspannungs-) and other electrical equipments.

4.8.1.1 Category description (2.G.1)

In electricity transmission and distribution, SF_6 is used primarily in switchgear and controlgear and equipment in high-voltage (52-380 kV) and, increasingly, medium-voltage (10-52 kV) networks. It serves as an arc-extinguishing and insulation medium (in the latter function, in place of air). In addition, it is used in production of components installed in gas-insulated indoor switchgear and controlgear (instrument transformers, bushings) or supplied directly to operators (high-voltage instrument transformers for outdoor installations).

As a result of first-time inclusion, in report year 2002, of additional SF_6 applications, the time series shows a marked jump in emissions in 2002. In report year 2005, new companies were included in reporting, especially in the new category "Other electrical equipments." For reasons having to do with the economy as a whole, more systems were sold in 2005 and 2006. Nonetheless, absolute emissions are falling overall, due to considerable reductions in the area of "other" equipments and as a result of again-lower rates of emissions from switchgear and controlgear. In 1996, industry, represented by producers' and operators' associations and the SF_6 producer, committed itself to reducing emissions in life cycles of switchgear and controlgear and to provide annual progress reports. In 2005, this voluntary commitment was extended, in co-operation with the Federal Environment Agency and the Federal Ministry for the Environment, Nature

Conservation and Nuclear Safety (BMU), to include additional energy-transmission and energy-distribution installations above the 1 kV level. In addition, specific reduction targets were added to the commitment. The scope of voluntary reporting was enlarged and refined accordingly. In subsequent years, manufacturers and the gas producer made further investments in reduction measures. Substitutes for SF_6 foams were introduced in some sub-areas of bushings. This brought about further reductions in specific emissions rates and absolute emissions, even though production continued to increase.

4.8.1.2 Methodological issues (2.G.1)

The emission factors used are shown in Table 225.

The emissions figures are based largely on a mass balance. Increasingly, they are also being combined with emission factors for sub-areas in which the technical measurement limits for mass-balancing have been reached or in which mass-balancing would necessitate unreasonably high costs.

The method used is based on the "Tier 3 Hybrid Life-Cycle Approach" described in the 2006 IPCC Guidelines (IPCC (2006): Vol. 3, Chapter 8.2.2).

Usage emissions

Ongoing emissions from stocks are based on the stocks of SF_6 that have accumulated since 1970, via annual additions of switchgear and controlgear, and that are in place as of the middle of a relevant year n.

The final stocks of SF_6 in all electrical equipments for a given year n change annually by the balance of new additions and removals. Some removals (high voltage) have been registered since 1997; large-scale removals of first-generation high-voltage switchgear and controlgear and equipment cannot be expected until after 2015, in light of the products' estimated service lifetime of at least 40 years.

Three special aspects must be taken into account in reporting relative to switchgear and controlgear:

- Calculation of the final stocks for a given year n is based on the final stocks for the previous year (n-1); this does not extend back to the first year of service, however. Such backward extension, an otherwise customary procedure, is not used for switchgear and controlgear, because operators/manufacturers estimated the SF_6 stocks in service for 1995. Their estimate was broken down into high-voltage and medium-voltage categories (770 t and 157.6 t, respectively).
- In the area of high-voltage switchgear and controlgear, stocks and emissions are determined via direct surveys of the some 100 operators. In such surveys, the operators are asked to provide data on their current stocks of SF_6 in electrical equipments (gas-insulated HV switchgear (GIS), circuit breakers, outdoor instrument transformers). Emission factors determined on the basis of reference systems are then applied to such stocks data.

- The group of operators of medium-voltage switchgear is very numerous and highly diverse. It is thus not feasible to conduct direct surveys. Manufacturers of medium-voltage switchgear have themselves taken responsibility for updating their domestic stocks data on the basis of their sales data. The emissions can be determined in that the systems are practically maintenance-free and, by definition (IEC 62271-1), require no refilling throughout their entire lifetimes. The emissions are minimal (usually, they occur only as a result of external influences), and they can be accounted for via a lump-sum emission factor (obtained via surveys of experts); the emissions rate has been set at a constant 0.1 % since 1998, since virtually all of the systems added to domestic stocks since the mid-1990s are systems that are "sealed for life" (hermetically sealed pressurised systems pursuant to IEC). In their voluntary commitment of 2005, the operators also promised to use only such systems. As a result, the impact of the few older systems that have emissions rates greater than 0.1 % has diminished. The stocks are calculated on the basis of the previous year's stocks, plus new deliveries and less decommissioned systems.

Disposal emissions

Because switchgear and controlgear have long service lifetimes (40 years), and because the first use of SF_6 dates from the late 1960s, disposal emissions were very low until 2004. For the period until 2004, therefore, the quantities of SF_6 (AD), in old switchgear and controlgear (high-voltage and medium-voltage), that were slated for disposal have been roughly estimated (at a constant 3 t/a). As of the 2005 report year, amounts for disposal from systems removal were determined precisely for the first time, by the relevant associations. This also applies to emissions from disposal, which prior to 2005 were estimated at 0.06 t.

Activity data

In the framework of the manufacturers' voluntary commitment, annual consumption by manufacturers of electrical equipments, and stocks of medium-voltage switchgear and controlgear, are reported to the Federal Environment Agency by the German Electrical and Electronic Manufacturers' Association (ZVEI), while stocks of high-voltage switchgear and controlgear, outdoor-mounted instrument transformers, gas-insulated lines and transformers are reported by the Forum network technology / network operation (FNN) in the Association for Electrical, Electronic & Information Technologies (VDE) and, since 2004, by the Association of the Energy and Power Generation Industry (VIK). Participants in the voluntary commitment jointly determine quantities of decommissioned units.

Table 226 shows the inventory data for the current year, broken down by sub-categories and with explanatory remarks. The sum total for electrical equipments for energy transmission and distribution agrees with the data in Table 2 (II)F, Sheet 2, category 2.G.1 in the CRF.

Table 226: 2017 inventory data for category 2.G.1, including relevant sub-categories

Category 2.G.1: Electrical equipments for energy transmission and distribution	Activity data			Emissions	
	Annual consumption, production	Stocks	Decommissioned	Production	Operation
			(tonnes of SF_6)		
Electrical equipments for energy transmission and distribution 2.G.1 (total), including:	**734**	**2712**	**8.0**	**6.4**	**6.2**
MV switchgear and controlgear *	166	1258	1.2	0.3	1.2
HV switchgear and controlgear **	502	1160	6.8	1.7	4.1
Other electrical equipments ***	66	293	0	4.3	0.8

IE= included in "HV switchgear and controlgear; marginal

Explanatory remarks:

* Hermetically sealed pressurised systems pursuant to IEC 62271-1 for the range 1kV through 52 kV; also known as "sealed for life" systems

** Sealed pressurised systems pursuant to IEC 62271-1 for the range above 52 kV

*** Gas-insulated transformers: marginal residual stocks in the network; (no production emissions) + high-voltage instrument transformers for outdoor installation (all emissions categories) + gas-insulated lines (GIL) (all emissions categories) + high-voltage bushings (only production emissions) + medium-voltage cast-resin instrument transformers (only production emissions) + testing of medium-voltage components (only production emissions) + 1000V capacitors (only production emissions)

4.8.1.3 Uncertainties and time-series consistency (2.G.1)

Since there are only about ten different manufacturers of electrical equipments (including bushings and instrument transformers), the consumption data, and the new-additions and decommissioned-units figures, are highly reliable. This holds all the more in that such data and figures are based on internal accounting, and that fill amounts are determined with great precision and then noted on devices' name plates. The pertinent uncertainty is in the area of ± 5 %.

Determination of emissions is more difficult, since the plants typically concerned have several different emissions sources, each quite small. Gas losses occur in filling of devices, in testing, in opening of products that fail to pass quality inspections, in product development, etc.. On the other hand, all domestic plants proceed in accordance with a standardised questionnaire that lists all possible emissions sources and that is checked for correctness during surveys. For this reason, and because there are few manufacturers (see above), the precision of data collection ultimately depends on the precision of the relevant measurements. The resulting figures lie within ±10 % of estimates.

Emissions from operations in the high-voltage sector are determined by selected operators, via monitoring of annual refilling of reference systems (refills are carried out when levels fall below 90 % of the desired charge, and the devices themselves normally display such fill requirements as soon as they occur). This method can be considered very reliable, i.e. the deviations from the actual value are about ±5 %. All surveys to date have produced similar results for emissions rates; all results are within a range from 0.55 to 0.88 %. The one-time emissions-rate peak for high-voltage switchgear and controlgear that occurred in 2004 is the result of special events. In the main, it was due to simultaneous refilling of old, older-model systems that were less well-sealed.

In the year 2000, a decrease with respect to the previous year occurred in high-voltage in-service stocks and, thus, in emissions, both of which had been increasing since 1995. For in-service stocks, the decrease amounted to over 25 t, while for emissions it amounted to 0.85 t. That decrease, which was due to trends in gas-insulated HV switchgear (GIS) (600 to 567 t), cannot be explained as the result of decommissioning removals, since the role of such removals is still insignificant.

According to the association of network operators (VDN), which carried out the surveys at the time, the underlying problem is both statistical and organisational in nature. At the end of the 1990s, electricity-market liberalisation led to profound operator regrouping (through mergers and changes in ownership of various parts of companies). Along with those changes, personnel assignments relative to electrical equipments in service were repeatedly changed. As a result, it is possible that double-counting occurred in 1999, and that some operating equipment was not counted in 2000. In light of experience gained in recent years, the uncertainty today can be assumed to lie in the range of ± 5 % for high-voltage stocks.

Pursuant to the IEC, the emissions rate of 0.1 % in the medium-voltage sector is a normal rate for hermetically sealed pressurised systems.

4.8.1.4 Category-specific recalculations (2.G.1)

No recalculations are required.

4.8.1.5 Category-specific quality assurance / control and verification (2.G.1)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

As in previous years, the data for the current reporting year were reported to the Federal Environment Agency, in the framework of a voluntary agreement, by the relevant producer and operator associations and the pertinent SF_6 producer.

For the most part, quality assurance was carried out by the associations. In addition, the data are checked by the relevant Federal Environment Agency specialists upon receipt.

In 2011, the entire sector of F-gas emissions was subjected to voluntary trilateral review. Experts from England, Germany and Austria reviewed "each other's" F-gas inventories. The aims of the review were to exchange information regarding country-specific methods for preparing F-gas inventories; to learn about the institutional and legal regulations for F-gas inventories in each country; to identify obstacles for the preparation of complete, precise inventories; and to discuss differences and similarities between the various methods used to prepare F-gas inventories. The meeting helped all three countries to review their methods for relevant emission calculation. In addition, the transparency, completeness and precision of the various inventories were assessed. That review had a positive outcome, namely that Germany has a good F-gas inventory. As a result, no recommendations were issued for improvements of the German F-gas inventory.

No other data sources, apart from the data reported by the associations, are available for review of the F-gas quantities determined for emissions reporting purposes, i.e. for review that would serve as a basis for verification. Comparisons with other countries have revealed no requirements for improvements. The emission factors are of the same order of magnitude as the pertinent factors used in other countries.

4.8.1.6 Planned improvements, category-specific (2.G.1)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.8.2 SF_6 and PFC from other product use (2.G.2)

This category comprises the applications *Military AWACS* (2.G.2.a), *Particle accelerators* (2.G.2.b), *Sound-proof glazing* (2.G.2.c), *Adiabatic properties: Automobile tyres* and *athletic shoes* (2.G.2.d), Other: *Trace gas, welding, optical glass fibres* and medical and cosmetic applications (2.G.2.e).

4.8.2.1 Military AWACS maintenance (2.G.2.a)

4.8.2.1.1 Category description (2.G.2.a)

SF_6 is used as an insulating medium for radar in Boeing E-3A (NAEWF; formerly, AWACS) aircraft, which are large military surveillance aircraft. It is used to prevent electrical arcing, towards the antenna, in waveguides with high voltages in excess of 135 kV. Ongoing emissions are relatively high, since SF_6 is released to equalize pressure as aircraft climb.

4.8.2.1.2 Methodological issues (2.G.2.a)

The emissions data for report years until 2001 are based on estimates that are themselves based on a survey from the year 1996. For this reason, the precision of the emissions data for the years 1997 to 2001 is lower than it is in subsequent years. For report year 2002, a new survey of consumed quantities was carried out. This showed a significant increase over relevant quantities in report year 2001. As of report year 2006, the quantities used are determined by the Federal Statistical Office (UStatG, 2005), via surveys. The pertinent quantities are added to aircraft, in Germany.

For the SF_6 emissions of AWACS, an emission factor of 100 % of consumption is assumed.

The pertinent emissions have been decreasing in recent years.

Data on AWACS maintenance are reported under CRF 2.H.3, since the data are confidential.

4.8.2.2 Particle accelerators (2.G.2.b)

4.8.2.2.1 Category description (2.G.2.b)

The insulating gas SF_6 is used to protect human safety and to safeguard equipment parts (to guard against burning of insulators). In relevant applications, high-voltage parts are insulated by being enveloped with the gas (which guards against electrical arc flashes between high-voltage parts and equipment walls).

In some cases, such protection can also be achieved by using other gases (such as nitrogen, nitrogen/CO_2 mixtures), by providing adequate physical distance (air insulation) or by enclosing equipment in concrete walls. The criteria entering into decisions for or against SF_6 as an insulating gas for equipment (either by itself or as an additive) include technical circumstances, design considerations and voltage levels. For this reason, the quantities of SF_6 that non-standardised equipment and components require will vary. The SF_6 charge in any given unit or system thus depends on the unit's/system's setup, and not on its size class (measured in MV, for example).

The SF_6-insulated particle accelerators in use differ in terms of size, design and function. High-voltage accelerator systems (0.3 to more than 23 MV) are used by university institutes, research groups and industry. In such high-voltage systems, the accelerator and the high-voltage source (Van de Graaff generator, or a more-compact high-voltage generator with cascaded diodes) sit within a tank that is insulated with SF_6 or an SF_6-containing mixture. In some cases, such tanks are also pressurised. Such tanks often have to be opened when equipment has to be adjusted or repaired. In such cases, the insulating gas is pumped into reserve tanks. SF_6 losses occur during such pumping, and they occur whenever overpressure valves of accelerator or reserve tanks are activated. Research accelerators, which are operated under varying conditions, have to be opened more frequently than industrially used electron accelerators do.

In industry, low-voltage devices with less than 0.3 MV are also used. In low-voltage systems, the depth to which electrons penetrate materials being processed is considerably lower than the depths occurring in connection with high-voltage systems. In industry, "electron-beam tools" are used for cross-linking of polymers, primarily polymers in cable and wire insulation. Low-voltage systems, with lower accelerator voltages, require less shielding (= smaller quantities of SF_6) than high-voltage systems do.

Yet another relevant category consists of radiation-therapy devices in medical facilities. In cancer treatments with electron or photon radiation, industrially pre-set particle accelerators are used. Such accelerators accelerate particles within waveguides that are filled with the insulating gas SF_6, which guards against electrical flashovers. Prior to 1996, CFCs were used in such equipment.

SF_6 is also used as an insulating gas in large electron microscopes (with accelerator voltages >100 kV) and in electron-beam lithography systems. Such devices, which are combined within the category "other equipment, have now been covered for the first time – for the year 2010.

In general, the following applies: The SF_6 consumption tied to initial charging and recharging of equipment, and to replacements of emission, depends on equipment size, pressure conditions and operating conditions.

4.8.2.2.2 Methodological issues (2.G.2.b)

In early 2004, Öko-Recherche, working under commission to the Federal Environment Agency, carried out a complete survey of particle accelerators within the country, with the aim of updating pertinent data, some of which date from 1996. In the process, both users and producers of the devices/systems were queried. The questions posed had to do with the quantities of SF_6 in their devices and with refills of SF_6 carried out during the last seven years.

The CSE assumes responsibility for structuring the survey. For all five relevant categories, it contains annual data on SF_6 stocks and on replacements to compensate for emissions. The emissions in question include both ongoing emissions and filling and disposal losses.

For the 2011 report year, another exhaustive survey was carried out out. For the first time, data on electron microscopes were gathered (Winfried Schwarz et al., 2012). Only small numbers of equipment changes – additions or removals, depending on the application – were seen. For this reason, constant levels of usage are assumed. Radiation therapy is an exception. In this area, the quantities used have been increasing slightly.

Table 227: SF_6 stocks in particle accelerators, in 5 application sectors, 1995-2015, in t

User category	1995	2001	2003	2010	2015
(1) University institutes	30.571	28.067	28.317	32.090	32.090
(2) Research institutions	19.555	19.305	19.555	13.531	13.531
(3) Industry (high-voltage)	13.750	24.422	24.422	26.575	26.575
(4) Industry (low-voltage)	1.600	1.600	1.600	1.425	1.425
(5) Institutions for radiation therapy	0.156	0.173	0.157	0.106	0.118
Total (1-5)	**65.632**	**73.817**	**73.801**	**73.727**	**73.739**

In most high-volume particle accelerators used for research or industrial purposes (the first three user categories), the recharge quantities, which serve as indicators of the ongoing emissions, amounted to 4.1-4.5 t per year in the years 1995 through 2003. The ongoing emissions were considerably lower in 2010. That decrease is more pronounced than is the decrease in the charges.

Table 228: SF_6 emissions from particle accelerators, broken down by five areas of application, from 1995 through 2015, in t

User category	1995	2001	2003	2010	2015
(1) University institutes	1.853	1.508	1.558	1.582	1.582
(2) Research institutions	1.259	1.246	1.196	0.886	0.886
(3) Industry (high-voltage)	0.958	1.722	1.710	1.155	1.155
(4) Industry (low-voltage)	0.020	0.020	0.020	0.017	0.017
(5) Institutions for radiation therapy	0.345	0.384	0.395	0.491	0.503
Total	**4.435**	**4.880**	**4.879**	**4.131**	**4.143**

When tanks of high-volume high-voltage systems are opened, the SF_6 in the tanks is pumped out and then later returned to the tanks. This can entail considerable gas losses. The reported recharges also include compensations for emissions due to accidents. As a result, the emission factors in lines 1-3 fluctuate (Table 229).

Table 229: SF_6 emission factors of particle accelerators, in five areas of application, 1995-2015, in % of SF_6 stocks

User category	1995	2001	2003	2010	2015
(1) University institutes	6.1	5.4	5.5	4.9	4.9
(2) Research institutions	6.4	6.2	6.2	6.5	6.5
(3) Industry (high-voltage)	7.0	7.1	7.0	4.3	4.3
Subtotal (1-3)	**6.4**	**6.2**	**6.2**	**5.0**	**5.0**
(4) Industry (low-voltage)	1.3	1.3	1.3	1.2	1.2
(5) Institutions for radiation therapy	222	222	252	463	426

According to information provided by producers, the emissions rate for small low-voltage systems in industry, in the years 1995-2003, was 1.3%. Producers also report that the emissions rate was 1.2 % in 2010, meaning that it had changed very little.

From 1995 through 2003, the radiation therapy units used in medical settings had annual emissions rates of 220 – 250 %. The high recharge requirements for such units result in that such units are opened an average of two to four times per year, for maintenance and repairs by producers, and the insulating gas escapes every times the units are opened. Service personnel regularly recharge the units in connection with maintenance and repairs. The differences in the emissions rates (annual losses per unit), for the three producers, form a factor-of-10 spread. The smaller the charge, the greater the recharge requirements – and, thus, the greater the emissions rate. For units of two of the three producers, the per-unit recharge rate remained constant between 2003 and 2010, while the rate decreased considerably for the third producer's units. In keeping with the fact that the share of small, highly emissive units, with respect to the overall unit pool, has increased markedly, the total loss rate for radiation therapy units increased considerably between 2003 and 2010, from about 250 % to about 460 %. One maker of radiation therapy units has reported having introduced a service tool, in 2006, for recycling SF_6 in the maker's units (for pumping SF_6 out of units, storing it temporarily and then re-adding it to units). According to that producer, this has considerably reduced SF_6 consumption.

4.8.2.3 Sound-proof glazing (2.G.2.c)

4.8.2.3.1 Category description (2.G.2.c)

Since 1975, SF_6 has been used to enhance the soundproofing properties of multi-pane windows. In such use, the gas is inserted into the spaces between the panes. The disadvantages of such use are that it reduces windows' thermal-insulation performance and that SF6is a potent greenhouse gas. The higher priority given to thermal insulation – e.g. by the Thermal Insulation Ordinance (Wärmeschutzverordnung) – along with improved SF_6-less window technologies, have led to a reduction in use of SF6 in this application since the mid-1990s.

In Germany, sound-proof windows have been produced by numerous companies and filled with gas. Exports of assembled windows play no significant role.

Since 4 July 2007, a ban has been in force in the EU on sale of windows, for residential uses, that are filled with fluorinated greenhouse gases. As of 4 July 2008, that ban also applies to other windows. Current and future emissions in this category thus come primarily from open waste management of old windows, which is assumed to occur an average of 25 years after the windows were filled. For this reason, total emissions are expected to continue growing until the year 2020.

4.8.2.3.2 Methodological issues (2.G.2.c)

Emissions occur during filling of spaces between panes, as a result of overfilling (production emissions), during use (use emissions) and in disposal (disposal emissions). Emissions are calculated in keeping with with equations 3.24 – 3.26 of IPCC-GPG ((Penman et al., 2000)) on the basis of new domestic consumption, average annual stocks and remaining stocks 25 years ago.

The time series for sound-proof glazing begin in 1975, since the filling quantities of the year 1975 are of relevance for emissions from stocks in 1995. These data, which were reconstructed with the help of industry experts in 1996, were published in 2004 for the first time.

Emission factors

According to expert-level information from manufacturers of windowpanes and gas-filling equipment, provided to industry experts and to a scientific institute, one-third of the SF_6 used in the process of pumping SF_6 into spaces between windowpanes escapes. The $EF_{production}$ is thus 33 %, with respect to new annual consumption.

This emission factor is obtained in the following manner: In use of both manual filling devices and automatic gas-filling presses, gas-swirling in the space between the panes cannot be avoided. As a result, the escaping gas consists not only of the air originally between the panes, it also includes an air-SF_6 mixture. More and more mixed gases escape as the filling process progresses. The gas loss, the "overfill", ranges from 20 to 60 % of the amount filled. The smaller the window concerned, the greater the overfill's relative importance. On average, i.e. throughout the entire spectrum of filled windows, of all shapes and sizes, the overcharge amounts to 50 % of the amount actually contained between the panes. This corresponds to one-third (33 %) of the relevant consumed amounts. This emission factor continues to be used, since neither filling technologies nor the range of window geometries have changed.

A DIN standard (DIN EN 1279-3, DIN 2003) specifies an upper limit of 10 per mil for annual losses of filled gas from panes' peripheral seals. This value also takes account of gas losses resulting from glass breakage in transport, installation and use, as well as from age-related increasing leakage from peripheral seals. The result is an emission factor EF_{use} of 1 % with respect to the average SF_6 stocks that have accumulated since 1975 and that are in place in year n.

Finally, disposal losses are incurred at the end of windows' service lifetimes (utilisation periods), or an average of 25 years after the windows were filled. For this reason, emissions from disposal do not have to be taken into account until the year 2000.

Since each year a window loses 1 % of its gas, with respect to the previous year's value, only part of a window's original quantity of gas is emitted when the window undergoes disposal. Since no gas collection upon disposal takes place, however, the emissions level is 100% ($EF_{disposal}$ = 1).

Activity data

The new annual consumption was determined via top-down survey (domestic sales by the gas industry).

Since the 2006 reporting year, the new-consumption data have been determined by the Federal Statistical Office via surveys of gas sellers with regard to SF_6-sales figures (UStatG, 2005).

4.8.2.4 Adiabatic behaviour – Automobile tyres (2.G.2.d)

4.8.2.4.1 Category description (2.G.2.d)

Beginning in 1984, automobile tyres were filled with SF_6 for reasons of image (the resulting improved pressure constancy is not relevant in practice). The peak consumption year was 1995. In that year, over 500 of the some 3,500 tyre-sales outlets in Germany had equipment for filling tyres with SF_6 gas. Because SF_6 is a powerfully acting greenhouse gas, many tyre dealers began filling tyres with nitrogen instead. This practice led to a considerable reduction in use of SF_6. Since 4 July 2007, a ban has been in force in the EU on sale of new automobile tyres filled with fluorinated greenhouse gases. No further emissions occur.

4.8.2.4.2 Methodological issues (2.G.2.d)

For the sake of simplicity, gas emissions during tyres' service lifetimes are not taken into account; as a result, emissions occur only when tyres are dismantled. Given an intended service lifetime of about 3 years, and the fact that there is no foreign trade with filled types, emissions follow domestic consumption for filling with a three-year time lag (Winfried Schwarz, 1996). The emissions are calculated using equation 8.19 of the 2006 IPCC Guidelines (Vol. 3).

Emission factors

The very small losses incurred in filling of tyres are not taken into account. Since SF_6 escapes completely when tyres are dismantled, $EF_{disposal} = 1$.

Activity data

Annual sales have been determined via surveys, carried out by the Federal Statistical Office (UStatG, 2005), of gas suppliers, regarding their domestic sales to tyre dealers and automobile service centres.

4.8.2.5 Adiabatic behaviour – Athletic shoes (2.G.2.d)

4.8.2.5.1 Category description (2.G.2.d)

SF_6 was inserted into the soles of sport shoes in order to enhance cushioning. 2003 was the last year in which this practice occurred anywhere in Europe. As of 2004, PFC-218 (C_3F_8) was used in this application. Use of that gas was then discontinued in 2006. Today, nitrogen is usually used for this purpose. The sale of footwear produced with fluorinated greenhouse gases has been prohibited in the EU since 4 July 2006. No further emissions occur.

4.8.2.5.2 Methodological issues (2.G.2.d)

The emissions were calculated using equation 8.9 of the IPCC Guidelines (2006). Production emissions occurred only in foreign countries. Current emissions were not determined. In keeping with a commitment to maintain confidentiality, data relative to sport-shoe soles are reported under CRF 2.H.3.

Emission factors

Manufacturers have not reported production emissions.

It is assumed that no emissions occur during use.

In disposal, emissions may be equated with input quantities ($EF_{disposal} = 1$). In addition, in a procedure similar to the IPCC method for automobile tyres, a time lag of three years is assumed (IPCC (2006): Vol. 3, Equation 8.19).

Activity data

The filled quantities are based on manufacturers' European-wide sales figures. These figures are broken down, on the basis of Germany's population, to obtain figures for Germany. While such data have been available to the Federal Environment Agency since the 2001 report year, for reasons of confidentiality they are reported only in aggregate form, under CRF 2.H.3.

4.8.2.6 Other: Trace gas (2.G.2.e)

4.8.2.6.1 Category description (2.G.2.e)

SF_6, as a stable and readily detectable trace gas, even at extremely low concentrations, is used by research institutions to investigate a) ground-level and atmospheric airflows and gas dispersions and b) water currents. It is also used for the purpose of testing laboratory fume hoods.

As of report year 2007, use of SF_6 as a trace gas was reduced considerably with respect to earlier years.

4.8.2.6.2 Methodological issues (2.G.2.e)

The quantities used have been estimated by experts.

Emission factors

An "open use" is assumed, i.e. annual new inputs are completely emitted in the same year and are treated as consumption for production ($EF_{production}$ = 1). No recovery takes place.

Activity data

In 1996, total domestic use was estimated by experts of all relevant research institutions. Since then, use levels have been estimated by one expert at three-year intervals. These assessments indicate that the quantities used vary only slightly. The figures on use of SF_6 in the years 2007 through 2015 were upwardly corrected in 2017, to take account of first-time inclusion, in the inventory, of use of SF_6 for testing of laboratory fume hoods.

4.8.2.7 Other: Welding (2.G.2.e)

4.8.2.7.1 Category description (2.G.2.e)

According to gas suppliers, use of SF_6 in welding began in 2001. SF_6 is used as a protective gas in welding of metal. Since there is only one user in Germany, the pertinent data are subject to confidentiality protection.

4.8.2.7.2 Methodological issues (2.G.2.e)

Emissions occur only during use. Because they are confidential, data on consumption and emissions in connection with welding are reported under CRF 2.H.3.

Emission factors

No reliable data are available on SF_6 decomposition during use. Experts presume that the entire relevant input SF_6 quantities are emitted completely into the atmosphere during use. For this reason, consumption and emissions are considered equal for welding applications. The emission factor for welding is specified as EF_{use} = 1.

Activity data

The annual amounts consumed are determined via enquiry of the company that uses SF_6 for welding purposes.

4.8.2.8 Other: Optical glass fibre (2.G.2.e)

4.8.2.8.1 Category description (2.G.2.e)

Use of SF_6 in production of special optical glass fibre began in 2002. In such production, SF_6 is used for fluorine doping. Only a few production operations are in place in Germany.

4.8.2.8.2 Methodological issues (2.G.2.e)

Because the emission factor is based on confidential data, it, and the emissions related to production of optical glass fibres, are reported confidentially in CRF 2.H.3.

Emission factors

The 2006 IPCC-Guidelines (IPCC (2006): Vol. 3) contain no information on use of SF_6 in production of optical glass fibre. To date, experts have estimated the emission factor to be 70 % ($EF_{production}$ = 0.7). Measurements have yielded a considerably lower emission factor, however. For this reason, the emission factor has been reduced considerably. It is confidential, however. The time series for the emissions was recalculated retroactively, for all years.

Activity data

The annual consumption figures are obtained via surveys, carried out by the Federal Statistical Office (UStatG UStatG, 2005), of gas suppliers, with regard to their domestic sales. They have been increasing since 2001, with slight fluctuations.

4.8.2.9 Other: Medical and cosmetic applications (2.G.2.e)

4.8.2.9.1 Category description (2.G.2.e)

In Germany, fluorinated greenhouse gases, in addition to being used in medical metered dose inhalers (source category 2.F.4), are also used in various medical and cosmetic applications.

Since 2000, perfluorodecalin ($C_{10}F_{18}$, PFC-9-1-18) has been used, in pure form, in ophthamology and in research. In ophthamology, perfluorodecalin is used in retinal surgery within the eye, especially in treatment of retinal detachments, retinal tears, proliferative vitreoretinopathy, etc.. Perfluorodecalin is also used, in considerably smaller quantities, in research into organ preservation during transplants, as a contrast agent in diagnostic imaging techniques (magnetic resonance tomography, ultrasound) and as an oxygen carrier in cell cultivation.

Since 2012, perfluorodecalin has also been used as an ingredient in cosmetic products (skin care; nail care). In such products, it serves as a carrier or storage medium for oxygen. The perfluorodecalin concentrations used in such products, according to manufacturers, amount to 0.1 %.

In Germany, hydrofluoroethers (HFE) are the standard anaesthetic gases used for inhalative anaesthesia. They are used in some 9 million operations annually. Isoflurane, a halogenated ether (HCFE-235da2, CHF_2-O-CHCl-CF_3), has been used since 1985. Desflurane (HFE-236ea2, CHF_2-O-CHF-CF_3) and sevoflurane (HFE-347mmz1, CH_2F-O-CH$(CF_3)_2$, which have been used since 1995, currently have a combined market share of about 90 %. In relevant uses, the hydrofluoroethers are vaporized in special equipment. They are administered in concentrations of 1 % to 6 % in a carrier gas consisting of oxygen and nitrous oxide (N_2O). On average, 8.2 g of isoflurane, 32.6 g of desflurane or 11.4 g of sevoflurane are used per operation. The quantities of the various hydrofluoroethers that are used per operation vary, because the concentrations of narcotic gases – as provided through respirators, and along with carrier gases – needed to ensure proper anaesthetic effects differ widely.

As recommended by the 2006 IPCC Guidelines, medical and cosmetic applications of PFCs are placed in source category 2.G.2.

4.8.2.9.2 Methodological issues (2.G.2.e)

In ophthamological and research applications in which it is used in pure form, all of the perfluorodecalin used is emitted. The perfluorodecalin in cosmetic products is also emitted completely when the products are used (EF_{use} = 1).

Hydrofluoroethers used as inhalation anaesthetics are collected during operations and then vented into the atmosphere from central points. During operations, the various hydrofluoroethers that patients inhale are not exhaled in unchanged form; to some extent, and to varying degrees, they are metabolised in patients's bodies. In each case, the gas-specific emission factors amount to 100 % minus the applicable metabolisation rate.

No production emissions occur in the case of medical and cosmetic applications, since no relevant products are produced in Germany.

In the case of perfluorodecalin, the emissions from use are calculated, using Equation 2, via the quantities of perfluorodecalin sold in bulk and in cosmetic products. In a departure from the method proposed by the 2006 IPCC Guidelines for calculation of "prompt emissions" (equation 8.23), it is assumed that all of the quantities sold in a given year are emitted completely in the same year, i.e. the emissions are not calculated as the sum of half the purchases (sales) of the previous year and half the purchases (sales) of the current year. This approach is justified in that the time between sale and use tends to be very short.

Emissions from use of hydrofluoroethers used as anaesthetic gases are calculated with Equation 2, via the quantities used in Germany. The 2006 IPCC Guidelines provide no instructions for calculating such emissions.

Since the perfluorodecalin and the hydrofluoroethers are emitted completely when used, no disposal emissions have to be reported.

Because they are confidential, data on consumption and emissions in connection with perfluorodecalin are reported under CRF 2.H.3.

Emissions of hydrofluoroethers are not subject to reporting obligations. Germany voluntarily reports HFE emissions pursuant to the recommendations of the 2014 UNFCCC Reporting Guidelines (FCCC/CP/2013/10/Add.3, Decision 24/CP.19), under "additional greenhouse gases". The emissions are aggregated with other emissions that are not subject to reporting obligations, and they are listed in Chapter 4.9.3 under CRF 2.H.3.

Emission factors

The emission factors used have been obtained from opinions provided by experts; they are listed in Table 225.

The EF_{use} for all medical and cosmetic applications of perfluorodecalin is 100 %.

With regard to the hydrofluoroethers used as inhalation anaesthetics, the EF_{use} for isoflurane and desflurane is 99.8 %, and for sevoflurane it is 95 %.

In agreement with the IPCC specifications (2006 IPCC Guidelines, p. 8.32), a 100 % emissions level for use of perfluorodecalin (EF_{use} = 1) is assumed. In a departure from the Guidelines, Germany applies a product lifetime of only one year in this area.

The 2006 IPCC Guidelines do not provide any instructions relative to the use of hydrofluoroethers as inhalation anaesthetics.

Activity data

The annual imports of $C_{10}F_{18}$ to Germany, for use in ophthamology and research, were disclosed by the manufacturer F2 Chemicals, UK, on a confidential basis.

The quantities of cosmetic products containing $C_{10}F_{18}$ that are imported to Germany were disclosed, on a confidential basis, by the trading enterprise P2 cosmetics, which sells the products in Germany.

The quantities of hydrofluoroethers that are used as inhalation anaesthetics were determined via surveys of industry experts (hospitals, manufacturers of anaesthesia equipment), and with the help of literature references, in the framework of a research project (Barbara Gschrey, 2015).

4.8.2.10 Uncertainties and time-series consistency (2.G.2 all)

The uncertainties for this source category have been systematically quantified.

In the case of sound-proof glazing, since 2006 data from the top-down survey of annual new consumption, carried out on the basis of commercial sales data, have been compared with data from the Federal Statistical Office's pertinent annual surveys (UStatG, 2005). This procedure, which may be considered reliable and complete, has increased data reliability. Due to the wide range of influencing factors, the $EF_{production}$ cannot be measured reliably. Estimates resulting from a survey of ten industry experts, conducted in 1996 and 1999 (the experts represented window manufacturers, suppliers of filling devices and one scientific institute), indicate that the mean filling loss ranges between 30 % and 40 %. A 1 % rate is considered realistic for ongoing gas losses.

With regard to athletic shoes, the filled-quantities breakdown, by Member States, is subject to considerable uncertainties, in spite of the good quality of the data for the EU.

In the case of medical applications, the data on the quantities of perfluorodecalin used are considered to be of good quality, since they were obtained directly from the manufacturer (F2 Chemicals Ltd, UK), and that manufacturer is the sole exporter of perfluorodecalin to Germany. The uncertainties relative to cosmetic products are larger, since Germany's market for cosmetics is extremely dynamic, with the result that no reliable statistics for this purpose are available.

4.8.2.11 Category-specific quality assurance / control and verification (2.G.2 all)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The data for the current reporting year, like the data for most of the previous years, consist of data collected by an external expert working in the framework of a research project under commission to the Federal Environment Agency and of data collected in a survey of the Federal Statistical Office (UStatG, 2005).

For the most part, quality assurance was carried out by an external expert and by the Federal Statistical Office. In addition, the data are checked by the relevant Federal Environment Agency specialists upon receipt.

In 2011, the entire sector of F-gas emissions was subjected to voluntary trilateral review. Experts from England, Germany and Austria reviewed "each other's" F-gas inventories. The aims of the review were to exchange information regarding country-specific methods for preparing F-gas inventories; to learn about the institutional and legal regulations for F-gas inventories in each country; to identify obstacles for the preparation of complete, precise inventories; and to discuss differences and similarities between the various methods used to prepare F-gas inventories. The meeting helped all three countries to review their methods for relevant emission calculation. In addition, the transparency, completeness and precision of the various inventories were assessed. That review had a positive outcome, namely that Germany has a good F-gas inventory. As a result, no recommendations were issued for improvements of the German F-gas inventory.

No other data sources, apart from the data provided by the Federal Statistical Office, the data collected by the research contractor and the data reported by the pertinent companies, are available for review of the F-gas quantities determined for emissions reporting purposes, i.e. for review that would serve as a basis for verification. Comparisons with other countries have revealed no requirements for improvements. The emission factors either are in keeping with the default emission factors given by the 2006 IPCC Guidelines or are of the same order as the values used by other countries.

The methods and data relative to medical and cosmetic applications (sub-category 2.G.2.e) cannot be verified, since no countries other than Germany report emissions in this area.

4.8.2.12 Category-specific recalculations (2.G.2 all)

Recalculations were carried out in the area of optical glass fibres (2.G.2.e). For reasons of confidentiality, the recalculations cannot be described in any detail, however. In the area of medical and cosmetic products (sub-category 2.G.2.e), the quantities of hydrofluoroether used in 2016 as inhalation anaesthetics, and not subject to reporting requirements, were updated on the basis of newly published figures on operations. Since the pertinent substances are not subject to reporting requirements, they are not described quantitatively in the present context. The recalculated emissions are aggregated with other emissions that are not subject to reporting requirements and are reported in Chapter4.9.3 under CRF 2.H.3.

4.8.2.13 Planned improvements, category-specific (2.G.2 all)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.8.3 Use of N_2O (2.G.3)

4.8.3.1 Category description (2.G.3)

The German nitrous oxide market is dominated by Air Liquide, Linde AG and Westfalen AG, all of which are leading producers as well as importers. No nitrous oxide emissions occur in nitrous oxide production and in filling of the gas into gas bottles. Emissions occur solely in use of the gas. Medical applications represent the most important N_2O-emissions source. Other emissions sources include use of laughing gas as a propellant in whipped-cream aerosol cans and use in the semiconductor industry. N_2O is also released, in small amounts, in blasting. Nitrous oxide emissions in anaesthesia, a predominant emissions source since 1990, have been decreasing sharply, due to increasing use of intravenously administered anaesthetics instead of nitrous oxide. This trend is expected to continue.

Medicine – anaesthesia

In medicine, nitrous oxide, a gas with analgesic properties, is used for anaesthetic purposes. In such applications, nitrous oxide is mixed with pure oxygen, to produce an active gas mixture consisting of 70 % nitrous oxide and 30 % oxygen. In modern anaesthesia, the effects of nitrous oxide are enhanced through addition of other anaesthetics. While medical use of N_2O is not prohibited, there is strong resistence – especially in the German medical sector – against widespread, general use of the substance. Medical use of laughing gas has thus been decreasing continuously since 1990.

Food industry – whipped-cream aerosol cans

In the food industry, nitrous oxide is used as an additive known as "E 942". Foods sold in pressurised containers are extracted from such containers with the help of propellants. As it exits such a container, a food takes on either a foamy or a creamy consistency, depending on what type of food it is. The foods with added N_2O include whipped cream (in aerosol cans), quark (curd) and various desserts, such as ready-made puddings (Die Verbraucher Initiative e.V. (2005); Linde Gas (2017)).

Semiconductor manufacturing

A wide range of different chemicals and gases is used in semiconductor production. Argon, ultra-pure oxygen, hydrogen, ultra-pure helium and nitrogen account for the lion's share of the gases used. Special process gases, such as nitrous oxide (dinitrogen monoxide), ammonia and hexafluorethane, are used only in relatively small amounts, and the amounts involved have remained nearly constant over the past few years (AMD Saxony LLC&Co. KG, Dresden, Umweltbericht (environmental report) 2002/2003, (AMD, 2003). page 16).

Explosives

Explosives are used in both military and industrial contexts. Civil and commercial explosives are used in mining, in construction in rocky terrain, in demolition, in geology and in fireworks.

Nitrous oxide emissions occur primarily in detonation of explosives that contain ammonium nitrate, such as ANFO (ammonium nitrate / fuel oil) and emulsion explosives. In general, commercial / civil explosives consist to some 60 to 80 % of ammonium nitrate (AN). By contrast, Andex, an ANFO explosive, contains up to 94 % ammonium nitrate.

In Germany, two companies produce explosives for civil use: Orica Mining (formerly Dynamit Nobel) and Westpreng GmbH (Wasag Chemie).

While no nitrous oxide emissions occur in manufacturing of explosives, nitrous oxide can form in thermal decomposition of explosives. The reason for this is that ammonium nitrate (AN) forms nitrous oxide (laughing gas) and water as it decomposes thermally.

Under careful warming to a temperature above the melting temperature, the reaction is as follows:

$$NH_4NO_3 \longrightarrow N_2O + 2H_2O$$

But in a fast, detonative reaction of an AN-containing explosive, the reaction occurs as follows:

$$NH_4NO_3 \longrightarrow 2H_2O + N_2 + 0{,}5O_2$$

This means that under high pressure and temperature AN primarily forms nitrogen, oxygen and water as it reacts. Only a small concentration of primarily formed N_2O remains intact in the detonation process. For example, detonation clouds of amatols[80], which contain some 80 % AN, have only 0.1 mole N_2O per mole of ammonium nitrate. From this figure, a theoretical maximum of about 68 g (this figure was provided by an explosives expert; the stoichiometric value would be 44 g/mole amatol (80%-AN)) per kilogramme AN can be calculated ((Ornellas, 1982); {VOLK, F, 1997}: page 74). According to experts, this AN-content figure can be used as a basis for assumptions regarding N_2O emissions for other explosives.

[80] Amatol x/y : military explosives. pourable mixtures, generally consisting of x % TNT and y % ammonium nitrate

N_2O in automobile tuning

In automotive technology, nitrous oxide is used to improve combustion in gasoline / petrol engines, via so-called "laughing-gas injection". In the process, laughing gas is broken down into nitrogen and oxygen. The nitrogen cools the combustion process, and the oxygen increases the combustion power. This "tuning" tactic can quickly increase engine performance. To date, one company in Germany offers such tuning measures. Research has shown that the equipment used for such tuning is designed to consume the input laughing gas completely, without producing significant emissions.

4.8.3.2 Methodological issues (2.G.3)

Anaesthesia

The 1990 figure for N_2O emissions from medical applications is based on an extrapolation of a statistical plant survey conducted in 1990 in the territory of the former GDR. At the time, it was ascertained that one plant for the production of N_2O for anaesthetic purposes had existed in the former GDR. Also at the time in question, the plant had not yet been operational for long (it was constructed in 1988). The annual production capacity was approximately 1,200 t. Research indicated that there were no exports or imports of this substance, and thus it was assumed that all of the substance was used for domestic consumption. Via the per-capita emissions calculated from this for the former GDR, and assuming identical conditions, N_2 emissions of 6,200 t were estimated, as a rough approximation, for Germany in 1990. The N_2O figure for 2001 was obtained via a written memorandum, dating from 2002, of the Industriegaseverband e.V. (IGV) industrial-gas association. That figure was tied to a range of 3,000 ~ 3,500 t/a. The mean value from that range (3,250 t/a) was then used for generation of an N_2O-emissions time series.

Since 2005, the Industriegaseverband (IGV) industrial-gas association has carried out surveys of N_2O sales for all applications in Germany. In addition, the IGV has made the data from those surveys available to the Federal Environment Agency for reporting purposes. In 2010, the IGV entered into a voluntary agreement, with the Federal Ministry of Economics and Technology (BMWi), regarding annual provision of N_2O-sales data for purposes of emissions reporting.

The gaps in the data relative to uses in anaesthesia are closed via interpolation and extrapolation.

The pertinent emission factor is 100 %.

Whipped-cream aerosol cans

Use of N_2O in aerosol cans for whipped cream, in Germany, has to be carefully differentiated. In Germany, there is one maker of aerosol cans for whipped cream. That maker also fills the cans in Germany. In emissions calculations, it is assumed, on the basis of the above-described research, that that company accounts for a share of about 3 % of the laughing-gas sales of the IGV industrial-gas association. Most of the companies who deal with such aerosol cans have them filled abroad and then import them into Germany. The relevant sales of such companies are thus not included in the data of the IGV industrial-gas association. The MIV dairy-industry association has reported to the Federal Environment Agency the results of a one-time survey that showed that 50.2 million units of whipped-cream aerosol cans were sold in 2008. At the same time, the MIV association reported that the units involved vary in size, and that it is not possible to break the figures down by can sizes. Internet research showed that pressurized cartridges for this area are sold in Germany: cartridges with 8g of N_2O, for 0.5l (whipped-cream) cans, and cartridges with 16g of N_2O, for 1.0l cans. Comparison calculations have shown that 8g of N_2O is a safe approximation, for purposes of calculation, for the amount of laughing gas contained per sold unit (whipped-cream aerosol can). That, in turn, leads to an input figure of 401.6 t N_2O for whipped-cream aerosol cans in 2008 in Germany. Since no pertinent data are available for the years prior to 2008, that value is assumed to be constant.

The emission factor for whipped-cream aerosol cans is assumed to be 100 %.

Semiconductor manufacturing

On a one-time basis, the German Electrical and Electronic Manufacturers' Association (ZVEI) has provided information on quantities of laughing gas used (**activity data**) in the years 1990, 1995, 2000, 2001 and 2008. Values between those points are obtained via interpolation.

A wide range of different chemicals and gases is used in semiconductor production. Argon, ultra-pure oxygen, hydrogen, ultra-pure helium and nitrogen account for the lion's share of the gases used. Special process gases, such as nitrous oxide (dinitrogen monoxide) and ammonia, are used only in relatively small amounts, and the amounts involved have remained nearly constant over the past few years (AMD Saxony LLC&Co. KG, Dresden, Umweltbericht (environmental report) 2002/2003, (AMD, 2003): page 16).

The **emission factor** is confidential and is thus not described here in detail.

Explosives

In 2003, a total of 59 kt of explosives was produced in Germany. Of that figure, 13 kt were exported abroad, and 5.8 kt were imported into Germany[81]. Those figures, in turn, yield a figure of 51.8 kt for the amount of explosives used in Germany. Of that amount, ANFO accounts for a share of 60 %, emulsion explosives account for 25 % and dynamite explosives account for 15 %. ANFO explosives consist of 94 % ammonium nitrate and 6 % fuels. The corresponding relationship for emulsion explosives is 80 % to 20 %; for dynamite explosives, it is 50 % to 50 %.

At present, the quantities of nitrous oxide present in detonation clouds are not determined, while the pertinent quantities of NO and NO_2 are determined.

Normally, N_2O formation plays a significant role only in explosives that contain ammonium nitrate (AN). That said, no precise analyses of detonation clouds of ANFO explosives have been carried out. For this reason, it must be assumed that the N_2O concentrations formed upon detonation of ANFO are similar, with regard to AN content, to those formed upon detonation of amatols and ammonites[82], for which analyses have been carried out that support relevant estimates. The following result has been obtained: upon detonation, amatoles and ammonites form about 0.1 mole N_2O per mole of ammonium nitrate (AN).

According to the *Federal Office for Material Research and Testing* (BAM), levels of explosives use in Germany remained constant from 1990 to 2005.

The emission factor for use of explosives is 0.1036 kg N_2O/t explosives. That emission factor was determined, via measurement, by the BAM in February 2010. As a result, the emission factor has been corrected downward, considerably, with respect to the 2010 Submission.

For anaesthesia, whipped-cream aerosol cans and the semiconductor industry, the pertinent emissions are reported in aggregation with confidential emissions data from 1,12-dodecanedioic acid production (2.B.10).

[81] Personal communication: Federal Office for Material Research and Testing (BAM).

[82] Ammonite: Composition: 70-88 % ammonium nitrate, with 5-20 % nitroaromates, 1-6 % vegetable flour and, in some cases, 4 % nitroglycerine, aluminium powder and potassium perchlorate

4.8.3.3 Uncertainties and time-series consistency (2.G.3)

Since 2005, activity data for anaesthetic uses have been obtained from association information. For that reason, the uncertainty is estimated to be 20 %. The data on consumption for whipped-cream aerosol cans and explosives are subject to a very high level of uncertainty (75 %), since the relevant calculations are based on several assumptions and since a definite figure is available only for one year. The uncertainty of the activity data for the semiconductor industry is estimated at 10 %, since the data have been obtained from facility operators themselves. For the uncertainties applying to the explosives, the IPCC default value of +/- 75 % is used.

The uncertainty in the emission factors for anaesthesia and whipped-cream aerosol cans is set as 0 %, since at present it is assumed that N_2O undergoes no transformation in use, and that the gas thus escapes completely into the atmosphere following its use. The emission factor for use in semiconductor manufacturing is estimated to have an uncertainty of 15 %, since the data have been obtained from facility operators themselves. The emission factor for explosives is estimated to have an uncertainty of 5 %, since the emission factor has been determined via an official measurement.

With these results, the time series can be considered to show a normal type of distribution.

4.8.3.4 Category-specific quality assurance / control and verification (2.G.3)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

With regard to use in anaesthesia, a comparison with other countries shows that most other countries use an emission factor of 1.0, as Germany does. That figure is equivalent to the default value in the 2006 IPCC Guidelines (IPCC (2006): Vol. 3, p. 8.36).

With regard to nitrous oxide emissions from use of explosives, no comparisons with other comparison or data sources are possible, since Germany is the only country that reports such emissions.

The quantities of nitrous oxide used cannot be verified via other data sources, since no other data are available that would support such verification. A special survey was carried out in order to obtain the data for the present report.

4.8.3.5 Category-specific recalculations (2.G.3)

No recalculations are required.

4.8.3.6 Planned improvements, category-specific (2.G.3)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.8.4 Other – ORC systems (2.G.4 ORC systems)

4.8.4.1 Category description (2.G.4 ORC systems)

Fluorinated greenhouse gases have been used in ORC systems in Germany since 2003. They are reported in category 2.G.4.

The Organic Rankine Cycle (ORC) is used for generating electricity from heat sources with temperatures and pressures that are too low for steam-powered generation . ORC systems are used especially in geothermal power generation and in harnessing of waste heat from combined heat and power (CHP) stations and biogas plants.

The working media used in the ORC cycle are certain organic substances, such as HFCs, PFCs, hydrocarbons and silicone oils, that evaporate at lower temperatures than water does. In ORC systems, such working media evaporate and drive turbines, just as steam drives turbines in conventional power stations. The largest fill quantities, far and away – up to 75 tonnes of fluorinated working media in each case – are used in geothermal applications. Considerably smaller fill quantities (0.2 to 0.6 tonnes) are used in systems that harness waste heat from biogas plants and in compact combined heat-and-power (CHP) generating systems.

In Germany, C_5F_{12} was first used as a working medium – in an ORC pilot system – in 2003. That system was decommissioned in 2010. HFC-134a was used for the first time in an ORC system in 2008. In 2010, HFC-245fa was used for the first time as a working medium. Beginning 2011, several systems were commissioned that operate with HFC-245fa and with the working medium "Solkatherm", which consists of HFC-365mfc (65 %) and a perfluorinated polyether (PFPE) with the trade name "Galden" (35 %).

4.8.4.2 Methodological issues (2.G.4 ORC systems)

Emissions from ORC systems occur during filling, operation and disposal.

Production emissions are determined via new domestic consumption – the activity data – and calculated pursuant to Equation 1.

Emissions from use are determined on the basis of final quantities (i.e. in systems) of working media – the activity data – and via multiplication by the EF_{use}, in keeping with Equation 2.

Disposal emissions refer to new additions for the year that is x years (depends on product lifetime) prior to the current reporting year n. They are calculated pursuant to Equation 3.

Apart from one exception, disposal emissions have not begun playing any role yet, since most systems are new. Large ORC systems in geothermal applications are expected to have a useful lifetime of 30 years, while smaller systems are expected to have lifetimes of 20 years.

Emissions of the perfluorinated polyether "Galden" are not subject to reporting obligations. Germany voluntarily reports emissions of this substance pursuant to the recommendations of the 2014 UNFCCC Reporting Guidelines (FCCC/CP/2013/10/Add.3, Decision 24/CP.19), under "additional greenhouse gases." The emissions are aggregated with other emissions that are not subject to reporting obligations, and they are listed in Chapter 4.9.3 under CRF 2.H.3.

Emission factors

The emission factors used have been obtained from opinions provided by experts; they are listed in Table 225.

The filling loss is 2 %. It is country-specific, since ORC systems are not covered by the 2006 IPCC Guidelines and thus no default factors are yet available.

The emissions from use are estimated to be 4 %. In this area as well, the 2006 IPCC Guidelines provide no specifications.

Under the current technological state of the art, the emission factor for disposal is 20 %. That value is also country-specific.

Activity data

ORC systems are a new area of application for fluorinated greenhouse gases, an area for which little data and technical information has been gathered to date. Almost all of the data used, therefore, are based on information provided by producers and operators of ORC systems. The data were determined through expert-level discussions (Barbara Gschrey, 2015).

4.8.4.3 Uncertainties and time-series consistency (2.G.4 ORC systems)

The uncertainties for the "ORC systems" sub-category have been systematically quantified.

The data on the quantities used are considered to be of good quality overall. Germany has only a small number (fewer than 10 companies) of manufacturers and sellers of ORC systems with florinated working media, and the country's market is relatively small. The data on the quantities of HFC-245fa and Solkatherm (HFC-365mfc and PFPE) that are used annually are of good quality, since the data come directly from the manufacturers of these working media (Honeywell und Solvay Solexis), and these companies are the only sellers who export to Germany.

The emission factors are subject to considerable uncertainties. Since sales of ORC systems in Germany began only a few years go, no pertient, solid empirical studies have been carried out to date. The values are based on estimates provided by operators of such systems.

4.8.4.4 Category-specific quality assurance / control and verification (2.G.4 ORC systems)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The data for the 2003 report year, like the data for most of the previous years, were collected by an external expert working in the framework of a research project under commission to the Federal Environment Agency.

For the most part, quality assurance was carried out by an external expert. In addition, the data are checked by the relevant Federal Environment Agency specialists upon receipt.

No other data sources, apart from the data collected by the research contractor, are available for review of the F-gas quantities determined for emissions reporting purposes, i.e. for review that would serve as a basis for verification. No comparisons with other countries are possible, since no other countries report emissions from ORC systems. Neither can the emission factors be compared. The 2006 IPCC Guidelines provide no default emission factors, and thus no comparability is available in this area as well.

4.8.4.5 Category-specific recalculations (2.G.4 ORC systems)

No recalculations are required.

4.8.4.6 Planned improvements, category-specific (2.G.4 ORC systems)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.8.5 Other product manufacture and use: Other, charcoal use (2.G.4 Charcoal)

4.8.5.1 Category description (2.G.4 Charcoal)

In this category, CO_2, CH_4, N_2O and particulate emissions from use of charcoal for barbecuing are reported.

Only small quantities of charcoal are produced in Germany – by one major charcoal-factory operator and in a number of demonstration charcoal kilns. The pertinent quantities are determined by the Federal Statistical Office (STBA) and are subject to confidentiality requirements. Use of charcoal is reported under 1.B.1b.

Charcoal consumption increased continuously in the years 1990 through 2012, apart from a downturn in 2008 that was tied to an economic slowdown. The great majority of the charcoal used is imported.

4.8.5.2 Methodological issues (2.G.4 Charcoal)

The calculation model is based on the assumption that all calculation method is consumed within a year of its purchase and is burned completely.

The CO_2, CH_4 and N_2 emissions are calculated via a Tier 1 method.

Activity data

The production-quantity data, and the data on the imported and exported quantities of charcoal, for the years as of 1996, were obtained from the Federal Statistical Office ((Statistisches Bundesamt, FS 4, R 3.1), Produzierendes Gewerbe, Produktion im Produzierenden Gewerbe sowie der Außenhandelsstatistik ("manufacturing industry; production in the manufacturing industry and foreign-trade statistics").

The quantities consumed are calculated in keeping with the formula Production + Imports – Exports.

For the years 1990 through 1995, the quantities consumed are calculated from the per-capita consumption, which has been derived from the data for the years 1996 through 2013. In the process, it is assumed that consumption also grew linearly in those (earlier) years.

Emission factors

Since import and export data are published, no exact emission factors for CO_2, CH_4 and N_2O may be given, for reasons of confidentiality. It may be disclosed, however, that the relevant emission factors are comparable to the emission factors that can be derived from the 2006 IPCC Guidelines.

Each emission factor is applied to the entire time series.

4.8.5.3 Uncertainties and time-series consistency (2.G.4 Charcoal)

A Tier 1 method, with emission factors similar to those provided by the 2006 IPCC Guidelines, has been used, and thus that source's relevant uncertainties for the activity data and emission factors apply (IPCC (2006): Vol. 3, Ch. 5).

4.8.5.4 Category-specific quality assurance / control and verification (2.G.4 Charcoal)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

No other data, apart from the data provided by the Federal Statistical Office, are available for review of the relevant import, export and production quantities, for purposes of verification of the consumption-quantity data. The import and export figures were compared with the corresponding data of EUROSTAT. Its figures show good agreement with the figures the Federal Statistical Office has provided to EUROSTAT. It was not possible to compare production quantities, because EUROSTAT also lists them as confidential.

The emission factors were compared with the corresponding emission factors of other countries. For reasons of confidentiality, the result of that comparison can be documented only internally. The emission factors are comparable.

4.8.5.5 Category-specific recalculations (2.G.4 Charcoal)

The emissions had to be corrected for the year 2016, as a result of adjustments to foreign-trade statistics. The usage quantities – and, consequently, the emissions – increased by only 0.09% as a result, however. Because these changes are so slight, we have opted not to present them in a table.

4.8.5.6 Planned improvements, category-specific (2.G.4 Charcoal)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.8.6 Other product manufacture and use: Other, nitrous oxide from explosives (2.G.4 Explosives)

4.8.6.1 Category description (2.G.4 Explosives)

The nitrous oxide emissions from use of explosives are reported in the CRF tables of category 2.G.4. A description of that category, in the NIR, is provided in Chapter 4.8.3- Use of N2O (2.G.3).

4.9 Other production (2.H)

The category *Other production* is not a key category.

In the CSE, process-related emissions from production of particle board and from pulp production are reported under 2.H.1 Pulp and paper.

Process-related emissions from production of alcoholic beverages, and from production of bread and other foods, are listed under 2.H.2 Food and drink.

Confidential data on emissions of fluorinated greenhouse gases are reported under 2.H.3. Data on F gases subject to voluntary reporting are reported in that section as well, in aggregated form.

4.9.1 Other production: Pulp and paper (2.H.1)

4.9.1.1 Category description (2.H.1)

Gas	Method used	Source for the activity data	Emission factors used
NO_X, SO_2, NMVOC			CS

The category *Other production – pulp and paper* is not a source of greenhouse-gas emissions and is thus not a key category.

All emissions of climate-relevant gases from the pulp and paper industry, and from particle-board production, in Germany result from combustion of fuels; for this reason, they are reported in Chapter 3.2 as energy-related emissions. The pulp and paper industry does not produce any process-related emissions of climate-relevant gases within the meaning of the *2006 IPCC Guidelines*.

Two of the six pulp plants in Germany carry out sulphate-process **pulp production** via caustification. For these plants, fuel-related CO_2 emissions in lime ovens are already taken into account, as energy-related emissions, via the pertinent fuel statistics. The remaining four plants use the sulphite process.

No attempt was made to take account of country-specific CO emission factors in energy-related emissions from pulp production, since that would have required conversion of product-based emission factors into fuel-based emission factors. Such conversion is an extremely involved process. Compared to the relevant CO emissions from paper mills, the CO emissions from the six pulp plants are of insignificant quantities.

The sulphate and sulphite pulp-production processes can both be a source of SO_2 emissions. In sulphate pulp production, NO_X, CO and NMVOC emissions are also released from recovery boilers, lime ovens, bark boilers and auxiliary boilers.

Particle board is produced from wood chips, with added binders, in a process that applies heat and pressure. The main source of NMVOC emissions in such production are the wood chips used, which release NMVOC during drying via heating. NMVOC can also be emitted from wood and binders during the pressing process.

Particle board is produced in a total of 18 plants in Germany. Some 6,000 employees work in particle-board plants nation-wide. The particle-board industry tends to be dominated by larger companies.

4.9.1.2 Methodological issues (2.H.1)

The **pulp and paper industry** produces no process-related emissions of climate-relevant gases within the meaning of the *IPCC Good Practice Guidance* (Penman et al., 2000). Plant operators reported emission factors for the precursor substances nitrogen oxides, sulphur oxides and NMVOC.

Table 230: Emission factors for pulp production in German plants. (German contribution to revision of the BAT reference (BREF) document for the pulp and paper industry, 2007 (Spörl, 2009))

in kg/t	NO_X	NMVOC	SO_2
Sulphate pulp	1.75	3.7	0.03
Sulphite pulp	2		1

According to the most recent figures, the following quantities were produced, in a total of 157 plants:

Table 231: Pulp and paper production, produced quantities

Product	Quantities produced in 2017	
Production of paper, cardboard and carton (PCC):	22.92	million t
Raw-material production:		
Paper pulp	1,521,739	t
of this, sulphite pulp	*481,278*	*t*
of this, sulphate pulp	*1,040,461*	*t*
Wood pulp	795,997	t
Recycled paper	14,298,000	t
Quantity of recycled paper used for this purpose	(17,102,874	t)

Source: (VDP, 2018)

These figures, which the German Pulp and Paper Association (VDP) collects annually and publishes in a production report, are available back to the reference year, 1990.

Particle board

Emission factors

The emission factors, amounting to 0.9 kg/t for NMVOC and 0.3 kg/t for dust, were determined via expert judgements.

Activity data

The activity data were obtained from national statistics (Statistisches Bundesamt, FS 4, R 3.1).

Table 232: Updated activity data for the particle-board industry

Year	2013	2014	2015	2016	2017
Activity data for the particle-board industry [in t]	4,488,000	4,446,000	4,402,000	4,560,000	4,703,000

Source: Statistisches Bundesamt (Federal Statistical Office), Fachserie 4 Reihe 3.1, Melde-Nr. (reporting numbers): 1621 13 131; 1621 13 132; 1621 13 133; 1621 13 161; 1621 13 163; 1621 13 190; 1621 13 500, converted into tonnes

4.9.1.3 Uncertainties and time-series consistency (2.H.1)

Pulp and paper

Germany's country-specific emission factors reflect the considerable modernisations that have been carried out in German sulphate pulp plants and that have sharply reduced their emissions. In sulphite pulp plants, continual improvements led to considerable SO_2-emissions reductions with respect to corresponding emissions levels in 1990.

The uncertainties in the activity data are estimated to amount to 5 %. The uncertainties in the emission factors are estimated to amount to 20 %.

Particle board

The uncertainties in the activity data for the particle-board industry are ±5 % (expert assessment).

4.9.1.4 Category-specific quality assurance / control and verification (2.H.1)

Due to resources limitations, and to the area's minimal relevance, no QC/QA is carried out for reporting relative to precursors.

4.9.1.5 Category-specific recalculations (2.H.1)

No recalculations are required.

4.9.1.6 Planned improvements, category-specific (2.H.1)

Since plant operators have confirmed the emission factors from the international guidelines, no inventory improvements for this category are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.9.2 Other production: Food and drink (2.H.2)

4.9.2.1 Category description (2.H.2)

Gas	Method used	Source for the activity data	Emission factors used
CO_2	NA	NA	NA
NMVOC	CS	NS	CS/D

The category *Other production – food and drink* is not a source of greenhouse-gas emissions and is thus not a key category.

The food and beverage industry's emissions of direct climate gases in Germany result from fuel combustion; for this reason, they are reported under CRF 1.A.2. The food and beverage industry's important process-related emissions include non-methane volatile organic compounds (NMVOC) (IPCC 1996c: p. 2.41). Carbon dioxide emissions from food inputs that occur during certain production processes are not reported in CRF 2.H.2., since they result from use of biological carbon and do not contribute to net CO_2 emissions. The solvent emissions that occur in connection with extraction of oils & fats (soy, rapeseed, sunflower seeds, etc.) – i.e. from solvent use in connection with raw-material production – are reported in category 2.D.3. CO_2 used in sugar production, which is obtained from burning of limestone, is bound during the production process. For this reason, this process is not emissions-relevant (p. Lechtenböhmer et al. (2006b); Lechtenböhmer et al. (2006a).

Emissions of the food and drink industry are reported, in summary form, in the inventory in "Table2(I)s2" of the sectoral report for industrial processes. In the table "Background data of the sectoral report for industrial processes" ("Hintergrunddaten des sektoralen Reports für Industrielle Prozesse"), "Table2(I).A-G", the IEF is listed as NE, since the pertinent CO_2 emissions are reported under CRF 1.A.2.

Pursuant to the IPCC, emissions reporting for the food and drink category covers the following products:

Alcoholic beverages

- Wine
- Beer
- Spirits

Bread and other foods

- Meat, fish and poultry
- Sugar
- Margarine and solid and hardened fats
- Cake, cookies and breakfast cereals
- Bread
- Animal feedstuffs
- Coffee roasting

Default emission factors for NMVOC emissions relative to these products have been provided (IPCC et al. (1997): p. 2.41f).

4.9.2.2 Methodological issues (2.H.2)

For emissions calculations, national emission factors were used where available. Otherwise, the emission factors recommended by IPCC and CORINAIR were used. The basis for selection of emission factors consists of the research report "Emissions from the food industry" ("Emissionen aus der Nahrungsmittelindustrie") (Anderl et al., 2008; Theloke et al., 2008). The procedure is in keeping with that described in the NIR 2013.

Because the data exhibit very little variance, the data for reported year 2017 have been carried forward for the following years. A pertinent data update and recalculation will be carried out in the 2020 NIR (reported year 2018). For category 2.H.2, a total of 14.8 kt of NMVOC emissions result for 2017. Of those, 3.3 kt NMVOC are from sugar production and 3.5 kt NMVOC are from production of spirits.

4.9.2.3 Uncertainties and time-series consistency (2.H.2)

The uncertainties in the activity data are estimated to be 5-20 %. Further information about the relevant uncertainties is provided in the NIR 2013.

4.9.2.4 Source-specific quality assurance / control and verification (2.H.2)

Due to resources limitations, and to the area's minimal relevance, no QC/QA is carried out for reporting relative to precursors.

Other countries' reports contain very little information about 2.H.2, and thus no comparisons are possible at present. No comparison with ETS data is possible, since no emissions subject to emissions trading occur in 2.H.2.

4.9.2.5 Category-specific recalculations (2.H.2)

No recalculations are required.

4.9.2.6 Planned improvements, category-specific (2.H.2)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

4.9.3 Other sectors (2.H.3)

Gas	Method used	Source for the activity data	Emission factors used
HFC, PFC, SF6	Cf. Chapter 4.6.4: Table 222/ Table 225	Cf. Chapter 4.6.4 / 4.7.5 / 4.8.2	cf. Table 222/Table 225

SF_6 emissions from use in connection with *AWACS Maintenance* (2.G.2.a Military uses), with *Athletic shoes* (2.G.2.d. adiabatic properties – athletic shoes), with *Welding* (2.G.2.e Other – welding) and with production of *Optical glass fibres* (2.G.2.e Other – optical glass fibres) are reported, for reasons of confidentiality, in 2.H.3.

HFC emissions from use of the solvents HFC-43-10mee, HFC-245fa and HFC-365mfc; from use of HFC-23 and HFC-32 in the semiconductor industry; and from use in ORC systems – 2.G.4 (HFC-245fa and HFC 365mfc), are also reported in 2.H.3.

PFC emissions from use of the solvent C_6F_{14} (2.F.5), from use in athletic shoes (2.G.2.d Adiabatic properties – Athletic shoes); from use of perfluorodecalin in medical and cosmetic applications (2.G.2.e Other – Medical and cosmetic applications); and from use in the semiconductor industry (C_2F_6, C_3F_8, c-C_4F_8 and CF_4) are also reported in 2.H.3. Furthermore, NF_3 emissions from the semiconductor industry are also reported in 2.H.3.

In keeping with a recommendation of the Expert Review Team, it is noted that all information relative to the emissions reported under 2.H.3 – including category description, methodological issues, uncertainties & time-series consistency, category-specific recalculations & verification and planned improvements – is presented in the pertinent category chapters.

In addition to reporting on greenhouse gases subject to reporting obligations, Germany has decided to report on the greenhouses gases shown in Table 233, which are not subject to reporting obligations. This reporting covers the applications of relevance in Germany, which are also listed as such in the table. For reasons of confidentiality, Table 234 shows the emissions of these greenhouse gases, which are not subject to reporting obligations, in aggregated form.

Table 233: Overview of voluntarily reported fluorinated greenhouse gases, their global warming potentials (GWP) and their areas of application

Greenhouse gas	Formula	GWP	Area of application	QG
HFC-1234yf		4[1]	Commercial refrigeration Refrigerated transports Mobile air conditioning systems	2.F.1.a 2.F.1.d 2.F.1.e
HFC-1234ze		7[1]	Commercial refrigeration Stationary air conditioning systems XPS foams General-purpose aerosols	2.F.1.a 2.F.1.f 2.F.2.a 2.F.4.b

Greenhouse gas	Formula	GWP	Area of application	QG
HCFE-235da2 (isoflurane)	$CHF_2OCHClCF_3$	350	Inhaled anaesthetic	2.G.2.e
HFE-236ea2 (desflurane)	$CHF_2OCHFCF_3$	989	Inhaled anaesthetic	2.G.2.e
HFE-347mmz1 (sevoflurane)	$CH_2FOCH(CF_3)_2$	216[2]	Inhaled anaesthetic	2.G.2.e
PFPE/PFPMIE	$CF_3(OCF(CF_3)CF_2)_n(OCF_2)_mOCF_3$	10,300	ORC systems	2.G.4

Unless indicated otherwise, the GWP figures come from the 4th IPCC Assessment Report (IPCC 2007).

[1] GWP values pursuant to Regulation (EU) No 517/2014 (F-GasV, 2014)

Table 234: Aggregated greenhouse emissions of the additional greenhouse gases – which are not subject to reporting requirements – HFC-1234yf, HFC-1234ze, HCFE-235da2, HFE-236ea2, HFE-347mmz1 and PFPE/PFPMIE

Year	Emissions, in t CO_2 equivalents
1990	3,038
1991	3,795
1992	4,619
1993	5,512
1994	6,474
1995	7,504
1996	13,874
1997	20,026
1998	26,671
1999	33,809
2000	41,439
2001	47,758
2002	54,433
2003	61,463
2004	68,849
2005	76,591
2006	88,534
2007	95,727
2008	101,095
2009	108,838
2010	116,013
2011	122,420
2012	129,802
2013	129,984
2014	120,964
2015	122,488
2016	125,274
2017	126,469

5 Agriculture (CRF Sector 3)

5.1 Overview (CRF Sector 3)

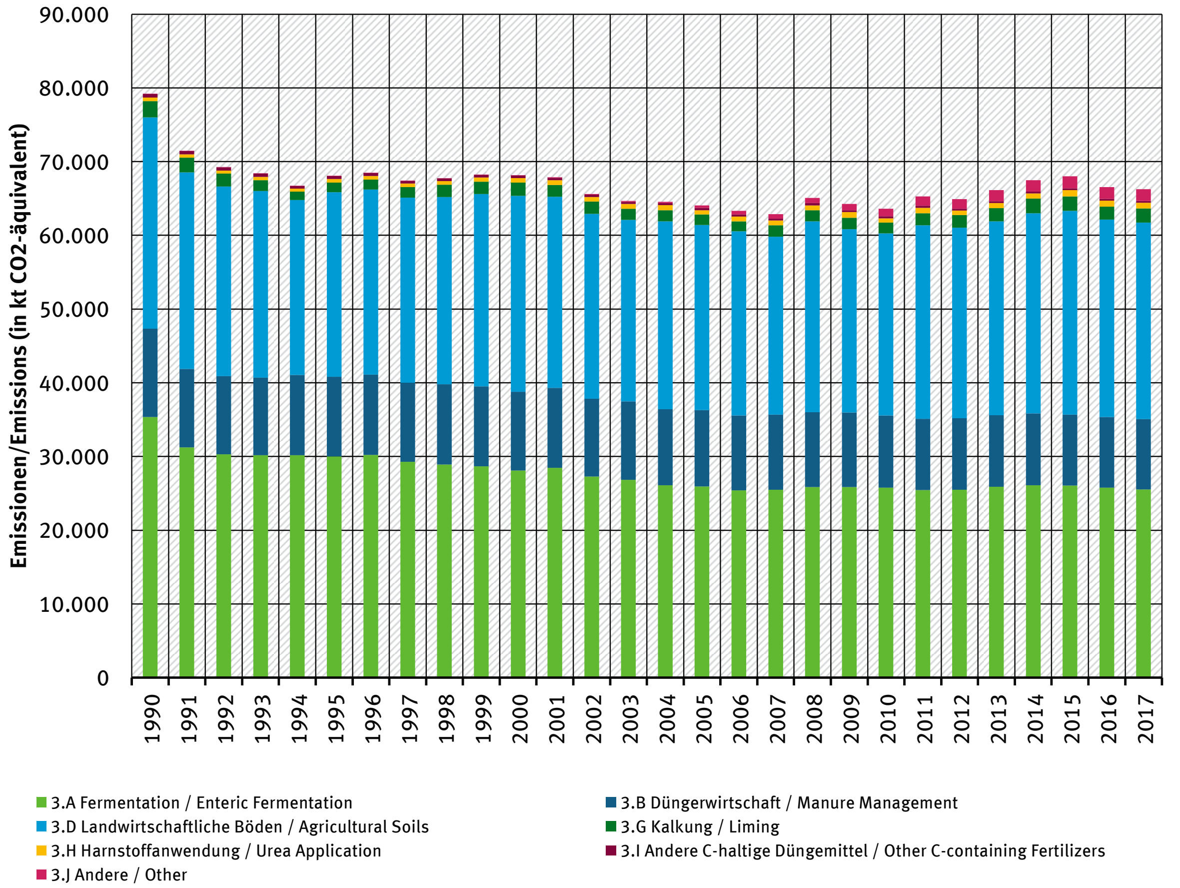
5.1.1 Categories and total emissions, 1990 - 2017

In category 3, "Agriculture", Germany reports on emissions from enteric fermentation (3.A), from manure management (including manure digestion and storage of digestates of manure) (3.B), from use of agricultural soils (3.D), from liming (3.G), from use of urea (3.H) and from use of other carbon-containing fertilisers (3.I). The NIR also reports on emissions occurring in connection with digestion of energy crops (3.J: Emissions from digestion of energy crops and from storage of digestates; 3.D: Emissions from application of digestates). Emissions from digestion of other substances, such as food waste and green waste, are reported, along with the emissions from spreading of the resulting digestates, in waste sector 5.B.2 (cf. Chapter 7.3.2).

Emissions from rice cultivation (3.C) do not occur in Germany, while clearance of land by prescribed burning (3.E) is not practiced in Germany (NO). Field burning of agricultural residues (3.F) is prohibited in Germany by law (Federal Law Gazette (BGBl), 2004, and preceding federal and Länder provisions; cf. Rösemann et al. (2019b), Chapter 11.8) (NO).

For the present 2019 NIR, Figure 47 provides an overview of the development of greenhouse-gas emissions, since 1990, in the areas 3.A, 3.B, 3.D, 3.G, 3.H and 3.J. The pertinent data have been calculated with the GAS-EM inventory model (cf. Chapter 5.1.2).

Figure 47: Overview of greenhouse-gas emissions in CRF Sector 3



5.1.2 The GAS-EM emissions-inventory model

5.1.2.1 Guidelines applied, and detailed report

The GAS-EM emissions-inventory model is based primarily on the relevant sets of guidelines (greenhouse gases: IPCC (2006): Vol. 1 & 4; air pollutants, especially NH_3: (EMEP (2016)). The aforementioned guidelines present no methods for calculation of emissions from digestion of energy crops.

Over the past few years, many of the methods described in the guidelines have been refined for purposes of the GAS-EM model. And a national method has been developed for calculation of emissions from digestion of energy crops. A comprehensive description of the GAS-EM inventory model, including listings of relevant additional sources, is presented in the pertinent detailed report (Rösemann et al., 2019b). The following remarks summarize that detailed report.

5.1.2.2 Basic structure of the GAS-EM emissions-inventory model

Feed intake serves as the basis for emissions calculations in the animal husbandry sector. It is calculated as a function of basic and yield-related energy requirements, as Figure 48 shows with the example of dairy cows. That approach provides the CH_4 emissions from enteric fermentation (3.A), as well as the carbon and nitrogen excretions data needed to calculate emissions from management of manure and digested slurry (3.B). The latter, in turn, enter into calculations of nitrogen discharges into agricultural soils (3.D).

Figure 48: Logical structure behind national methods for calculating emissions from animal husbandry, illustrated with the example of dairy cows. ("Performance indicator" stands for the sum of basic and performance-related requirements.)

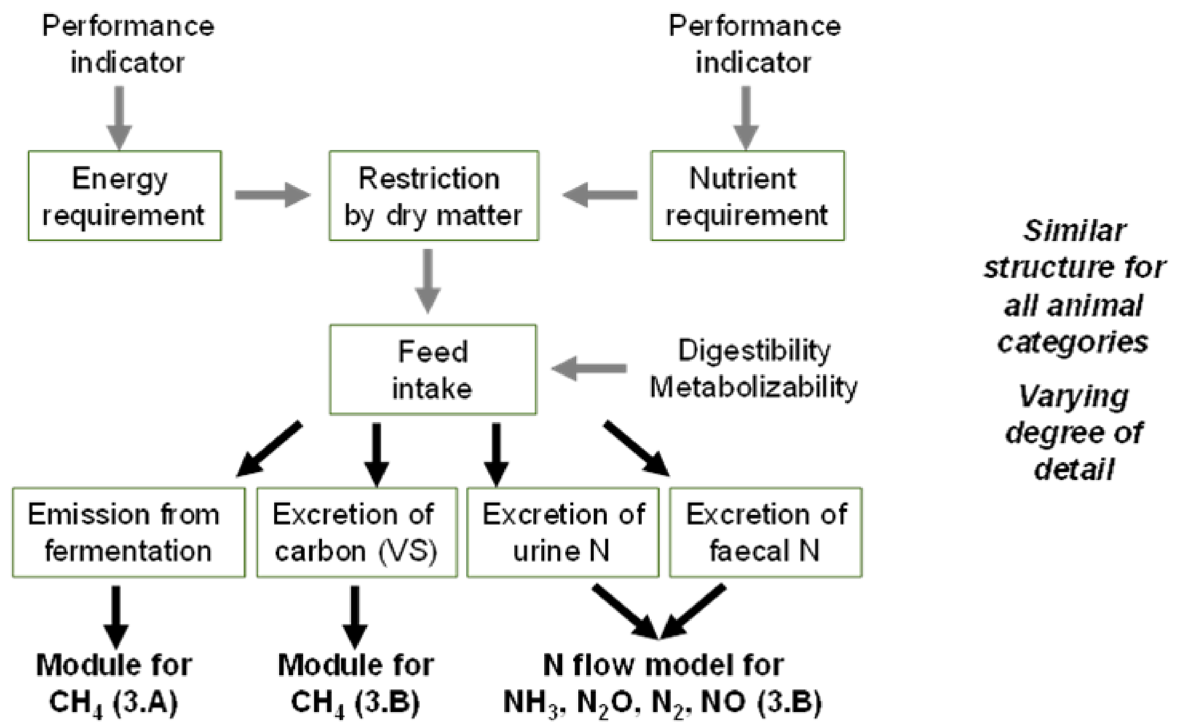
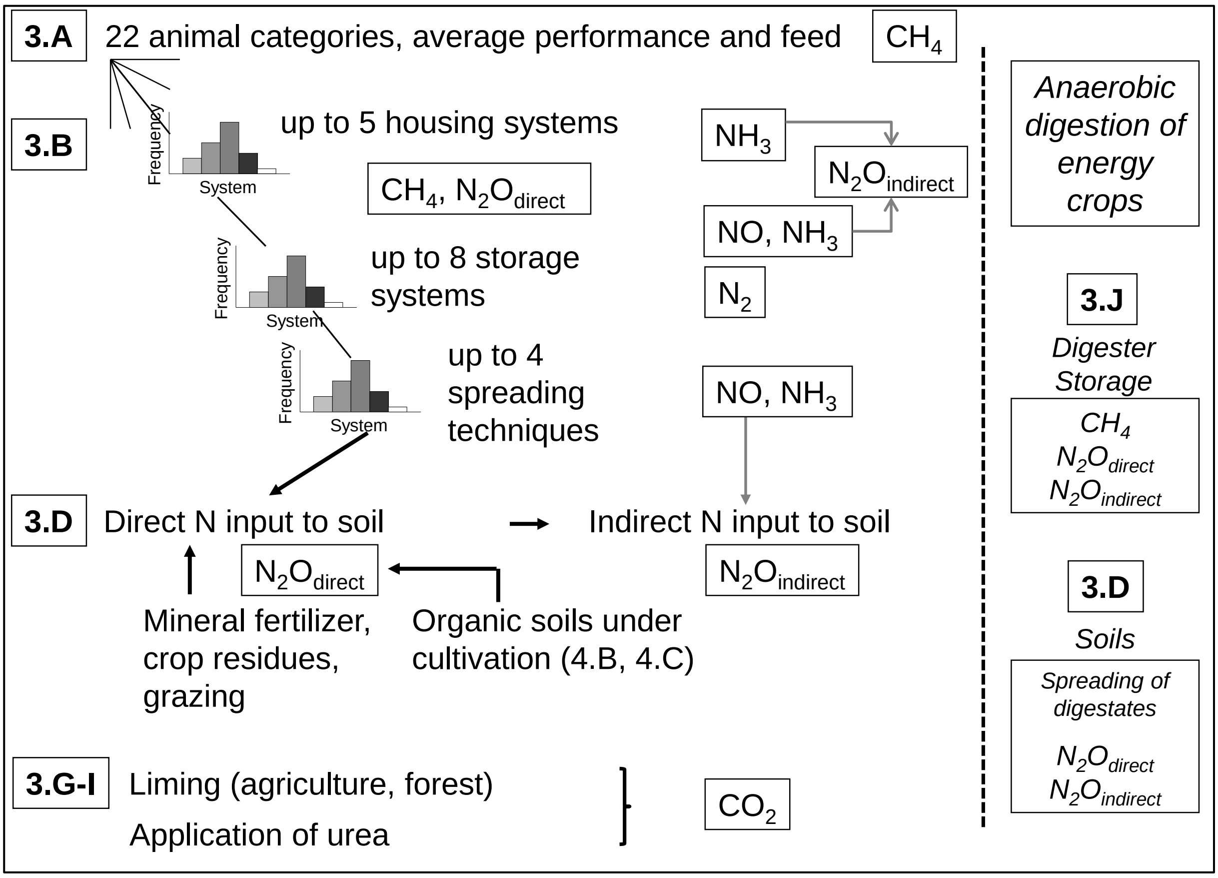


Figure 49 shows how the GAS-EM model, for purposes of calculations in categories 3.A and 3.B, first differentiates between animal categories and sub-categories and then further subdivides those categories into housing systems, storage systems (with digestion as a separate storage system) and procedures for application of manure and digestates. CH_4 emissions are calculated separately for each animal sub-category in 3.A and 3.B. For categories 3.B and 3.D, N_2O emissions are calculated on the basis of an N-flow concept (cf. Chapter 5.1.2.4). In categories 3.G-I, CO_2 emissions are calculated for liming and urea application. In line with the IPCC's guidelines, these calculations also include the area of liming of forests. Emissions from digestion of energy crops are calculated in two separate sections: Emissions from digesters and storage of digestates, in 3.J; and emissions from soils, as a result of application of digestates, in 3.D.

Figure 49: Concept and thematic content behind the GAS-EM model



5.1.2.3 Treatment of CH_4 within the emissions inventory

The GAS-EM inventory model is used to calculate CH_4 emissions from enteric fermentation and VS excretions of agricultural livestock (cf. Chapters 5.2 and 5.3.2), taking account of slurry-based and straw-based systems and their typical forms of storage. Anaerobic digestion of manure and energy crops, in biogas plants, is included in the calculations (cf. Chapters 5.1.3.6.5 and 5.1.4).

5.1.2.4 The nitrogen-flow concept (3.B, 3.D)

With the GAS-EM model, N-species emissions are calculated on the basis of the N-flow concept (Dämmgen & Hutchings, 2005); cf. in this connection Chapter 3.3.4.3.1 in Rösemann et al. (2019b)

To make it possible to apply the concept, the relevant animal N excretions have to be determined (cf. Chapter 5.1.3.4). For dairy cows, heifers, male beef cattle, swine, laying hens, pullets, broilers, ducks and turkeys, males and hens, N excretions are calculated as the difference between the amount of N taken in with feed and basic and yield-based N requirements (animal weight, weight gain, annual milk production or egg production (i.e. numbers of eggs) and, if relevant, numbers of young). The N intake with feed is determined on the basis of animal energy requirements and the energy and N content of the feed. For other animals, N-excretion data are taken from the pertinent German technical literature.

In the case of N excretions, a distinction is made between the two fractions "organic N" and "TAN readily converted into NH_3" (TAN – "total ammoniacal nitrogen"). TAN is present in the urine of mammals; in the GAS-EM model, in each case TAN is considered to be equivalent to the N content of urine. Poultry excrete "UAN" (uric acid nitrogen); in the inventory, UAN is treated as equivalent to TAN. As a result of the manner in which the relevant emission factors are defined, NH_3 emissions are calculated primarily in proportion to the available TAN quantity, while N_2O emissions, NO emissions and N_2 emissions are calculated in proportion to the available N quantity. For this reason, the calculations take account of two parallel N pools. These are (1) the entire N quantity available at the relevant stage being considered, i.e. the sum of organic N and TAN, and (2) TAN by itself.

The N excretions determined for a given animal category are divided into stable emissions and pasture emissions. This division is made in accordance with the percentages of time the relevant animals spend in the stable and in pasture.

In the case of solid-manure systems, N inputs from bedding material are also taken into account, along with N excretions.

For each animal category, the amounts of N occurring in housing systems are divided in accordance with the relative shares of the animal-housing systems commonly used in Germany. N losses via NH_3 emissions are subtracted from the TAN pool and from the total N pool. The remaining N and TAN amounts for all stables are combined separately, for slurry-based systems and then for straw-based systems, and are transferred into the correspondent storage systems.

The inventory takes account of air-scrubbing systems in swine husbandry; cf. Chapters 3.3.4.3.3 and 3.4.5.2 in Rösemann et al. (2019b). The N removed via air-scrubbing systems is treated as TAN, as if it were directly applied with manure (see below).

The total N and TAN amounts (for solid-manure systems, including the N inputs from straw bedding) accruing to the storage systems are divided, separately for the categories solid manure and slurry, among the different storage systems commonly used in Germany, in keeping with the applicable percentage shares. Anaerobic digestion of manure in biogas plants is included in the calculations (cf. Chapter 5.1.3.6.5). From storage, NH_3 emissions from the TAN pool and the total N pool occur. The N losses occurring via emissions of N_2O, NO and N_2 are calculated as a total, for housing systems and for storage systems, and then subtracted from the total N pool. At the same time, these N losses are subtracted from the TAN pool, in a manner in keeping with the ratio of the TAN quantity to the total-N quantity. The remaining N / TAN quantities are spread, with the N removed via air-scrubbing systems being added to the TAN pool.

The amount of N applied is divided among the different application techniques commonly used in Germany, taking account of the different durations of manure incorporation commonly observed. This is carried out in accordance with the different application techniques' relative proportions of the total amount of manure applied, differentiated by animal category and by the categories of solid manure and liquid manure. The N_2O emissions released from agricultural soils as a result of application of manure, and of digestates of manure, are calculated in proportion to the N quantity applied.

The total N quantity excreted during grazing yields the N quantity available in the soil that is used for calculation of N_2O emissions from grazing.

The N flows that occur in connection with digestion of energy crops, and with storage and application of the resulting digestates, are treated separately from the N flows for animal husbandry. The former are calculated on the basis of the N quantity in the digested energy crops (cf. Chapter 5.1.4.2), via a procedure analogous to that described above for animal N excretions.

In a procedure analogous to that used for manure application, the N_2O emissions from agricultural soils, resulting from application of mineral fertiliser, are calculated in proportion to the N quantity applied.

5.1.3 Characterization of animal husbandry in agriculture

5.1.3.1 Animal categories (3.A, 3.B)

For calculation of emissions from animal husbandry in German agriculture, animal stocks are divided into sub-categories, to permit description of sub-stocks that are homogeneous with regard to yield and to housing systems. Table 235 compares the animal categories to be reported on in the in CRF tables with the animal categories used in the German inventory.

The CRF categories "mules and asses" and "buffalo" are reported as "IE", since the numbers of animals in those categories are included in the figures for "horses" and "other cattle" (cf. Chapter 5.1.3.2.2).

The categories deer, rabbits, ostriches and fur-bearing animals are not reported in the CRF tables pursuant to IPCC (IPCC (2006): Vol., 4) are not reported, because their contribution to the total emissions is less than 0.05 % of the overall inventory and less than 500 kt CO_2 equivalents (pursuant to FCCC/CP/2013/10/Add.3), and since it cannot be assured that annual inventories of such emissions (pursuant to FCCC/CP/2013/10/Add.3, para 37) will be carried out. The emissions contributions from those categories are estimated in Chapter 19.3.1. All those sources for which no emissions are reported ("NE" is entered) are listed in Chapter 21.

Table 235: CRF animal categories, and the subdivisions used for purposes of German emissions reporting (3.A, 3.B)

CRF animal categories		Animal categories in the German inventory
	Dairy cows	"Dairy cows" [a]
1	Other cattle	"Calves" (to 4 months old) [a] Young female cattle as of 4 months old ("heifers") [a] Young male cattle as of 4 months old ("male beef cattle") [a] "Suckler cows" [a] "Male cattle older than 2 years" [a]
2	Sheep	"Mature sheep" "Lambs"
3	Swine	"Sows" (incl. suckling piglets to 8 kg) "Weaners" "Fattening pigs" "Boars"

	CRF animal categories	Animal categories in the German inventory
4	Buffalo	--- [a]
	Camels	--- [b]
	Deer	--- [c]
	Goats	"Goats"
	Horses	"Heavy horses" [d] "Light horses and ponies" [d]
	Mules and asses	--- [d]
	Poultry	"Laying hens" "Broilers" "Pullets" "Geese" "Ducks" "Turkeys, males" "Turkeys, females"
	Rabbits	--- [c]
	Reindeer	--- [b]
	Ostriches	--- [c]
	Fur-bearing animals	--- [c]

[a] In the years through 2012, the German inventory included buffalo with suckler cows; as of 2013, the official animal-population figures for the categories "other cattle" and "dairy cows" include buffalo. The buffalo data cannot be separated out from those figures.

[b] These animals do not occur in Germany.

[c] These animals are not reported on, since their emissions contribution is insignificant; cf. Chapter19.3.1.

[d] In the years through 2009, the German inventory included mules and asses with light horses and ponies; as of 2010, the official animal-population figures for horses include mules and asses. The data for those animals cannot be separated out from the horse figures.

5.1.3.2 Animal place data (3.A, 3.B)

The GAS-EM inventory model calculates in chronological increments of one year. It cannot model interannual fluctuations, including fluctuations of animal populations. The German inventory thus is based on the assumption that the numbers of occupied and unoccupied animal places, as shown by official statistics as of a specified reference date (cf. Chapter 5.1.3.2.1), remain constant throughout the course of the relevant year. It can be shown that, in the case of categories of animals with lifetimes of less than one year, this concept correctly takes account of the vacancies occurring between any two production cycles; cf. Chapter 3.1.2.2 in Rösemann et al. (2019b).

For purposes of inventory calculations, the numbers of occupied animal places found as of the reference date are interpreted as the applicable numbers of animals. This approach is in keeping with the definition of AAP ("average annual population") given in IPCC (2006): Vol. 4), Section 10.2.2., a definition that has also been adopted by EMEP (cf. EMEP (2016)-3B-14).

5.1.3.2.1 Surveys of the Federal and Länder statistical offices

The Federal Statistical Office and the statistical offices of the Länder (federal states) carry out agricultural-structure surveys[83] that, in addition to collecting other data, carry out censuses of cattle, swine, sheep, horses (as of 2010: equids) and poultry. In the periods 1990 – 1996 and 1999 – 2007, such agricultural structural surveys were carried out every other year. In 2010, they were carried out in the framework of the 2010 agricultural census (Landwirtschaftszählung 2010

[83] https://www.destatis.de/DE/Meta/AbisZ/Agrarstrukturerhebung.html

– LZ 2010)[84], a more extensive census. Thereafter, they were carried out again in 2013 and 2016. The 1990, 1992, 1994 and 1996 surveys were each carried out on 3 December, while the reference date for the surveys carried out in 1999 – 2007 was 3 May and that for the surveys carried out in 2010, 2013 and 2016 was 1 March.

In addition to the agricultural-structure surveys, annual livestock censuses are carried out (Statistisches Bundesamt, FS 3, R 4.1). Through 1998, such surveys were carried out semiannually for cattle and sheep (June, December), every four months for swine (April, August, December), and every two years, in even-numbered years (in December), for all animal species, i.e. also for horses and poultry. In each case, the reference date was the third calendar day of the pertinent month. Since 1999, the livestock census for cattle and swine has been carried out twice annually, as of the reference dates 3 May and 3 November. For the sheep census, the reference date was 3 May in the period 1999 through 2009. In 2010, it was 1 March. As of 2011, it has been 3 November.

Census data from official surveys are thus available for cattle, swine and sheep for all years since 1990. In the inventories through 1998, the December data were used (for sheep, the June data). Thereafter, through 2010, the May data were used (for sheep, in 2010: 1 March, since neither May nor November data were available). By agreement with the Federal Statistical Office, the November reference date is to be used as of 2011 (EU Regulation No 1165/2008, Article 4 European Parliament - Council of the European Union (2008)). These figures are in keeping with the figures the Federal Statistical Office has provided to EUROSTAT. The change in the reference date, to 3 November, does not significantly affect the population figures in the case of cattle and swine. Among the figures for sheep, livestock-population figures had to be corrected; cf. Chapter 5.1.3.2.2.

The numbers of goats in Germany were not surveyed between the years 1977 and 2010. Until 2004, the Federal Ministry of Food and Agriculture (BMEL) estimated goat populations at the national level. As of 2005, the pertinent time series was continued via estimation by the Federal Statistical Office. In 2010, the total number of goats (reference date: 1 March) was officially determined for the first time, in the framework of the 2010 agricultural census (LZ 2010). The resulting figure is considerably lower than the estimates used in for earlier years. By agreement with the Federal Statistical Office, those estimates, which are also reported to EUROSTAT, continue to be used in the inventory. Official goat-population figures obtained by the Federal Statistical Office are available for 2013 and 2016 (reference date: 1 March).

For horses / equids, and for poultry, population figures are available only at intervals of two to three years, from agricultural-structure surveys (reference dates: through 1998, 3 December; for 1999 – 2007, 3 May; in 2010, 2013 and 2016, 1 March). By agreement with the Federal Statistical Office, the population figures have not been adjusted to take account for the variations in reference dates.

The 2013 poultry counts carried out by the Federal Statistical Office and the statistical offices of the Länder were tied to a revision of the relevant reporting groups. The revision was carried out because previous surveys (most recently, in 2010) had failed to take account of a number of large poultry flocks, due to the then-applicable rules for selection of the farms to be surveyed. The poultry counts obtained in 2013 are thus considerably higher than the surveys from prior years would have led one to expect. The Federal Statistical Office has not corrected the official poultry counts for earlier years until 2010. As a result, the counts used in the inventory for the period

84 https://www.destatis.de/DE/ZahlenFakten/Wirtschaftsbereiche/LandForstwirtschaft/Landwirtschaftszaehlung2010/Ergebnisse.html

2010 through 2013 show a marked increase. Due to the basic differences between the 2010 and 2013 livestock censuses, this trend does not reflect any real development in poultry counts. The rise in poultry counts that occurred from 2013 to 2016 is considerably flatter.

For purposes of inventory calculations, and in the interest of conformance with emissions-reporting requirements, a number of data gaps had to be closed, and some of the animal-place figures had to be adjusted. These changes, and the manner in which buffalo, mules and asses are taken into account, are discussed in Chapter 5.1.3.2.2.

5.1.3.2.2 Special aspects of animal-place figures in the inventory

Since 2008, cattle-population figures have been taken from the HIT database[85] of the Bavarian State Ministry for Food, Agriculture and Forestry (Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten – StMELF), in which all cattle are individually registered. Via the new survey method, systematically higher population figures result for years as of 2008 than result for earlier years in which not all animals were counted, due to the survey thresholds applied. A comparison carried out by the Federal Statistical Office for 2007 reveals that the population figures for cattle shown in HIT are 2.9 % higher than those resulting via the conventional survey method (for dairy cows alone, the population figures are 2.8 % higher). The Federal Statistical Office reports that the cattle time series for the period prior to 2008 will not be adjusted in this regard. As a result, emissions from keeping of cattle are slightly underestimated for the years 1990 to 2007. In the interest of obtaining maximally homogeneous animal categories, some of the cattle categories used in official surveys have been modified for purposes of the inventory; cf. Chapters 4.4.1.1, 4.5.1.1, 4.6.1.1 and 4.7.1.1 in Rösemann et al. (2019b).

As of the time-series year 2013, the cattle population data provided by the Federal Statistical Office also include bison and buffalo. The buffalo numbers cannot be extracted from cattle data. As a result, as of the time-series year 2013 the buffalo emissions are included in the cattle emissions. Consequently, as of the 2015 submission buffalo are no longer treated as a separate category in the inventory (included elsewhere, IE). The emissions produced by buffalo in the time-series years 1990 through 2012 are taken into account in the inventory by adding the buffalo populations to the numbers of suckler cows. On the other hand, the Federal Statistical Office has not published any buffalo counts. For this reason, figures of the Deutscher Büffelverband (German buffalo association) have been used for the period as of 2000. In keeping with a recommendation in the final report for the "Initial Review under the Kyoto Protocol and Annual 2006 Review under the Convention", for the years prior to 2000 the time series for the buffalo population at the national level was completed via linear extrapolation. For the years 1990 through 1995, mathematically negative population figures result; they have been replaced with zeros.

For swine as well, several of the categories used in official surveys have been modified with a view to obtaining maximally homogeneous animal categories. The official numbers of animals for piglets weighing up to 20 kg animal^{-1}, and for young pigs and fattening pigs weighing at least 20 kg animal^{-1}, have been converted, using the procedure described in Haenel et al. (2011), into numbers of animals for the inventory categories "weaners" and "fattening pigs". This conversion has no impact on the total number of swine, however. For purposes of emission calculation, the number of piglets weighing up to 8 kg is deducted from that total number, however. This is done in keeping with an inventory concept whereby piglets weighing up to 8 kg are considered suckling piglets that, with regard to their emissions, are implicitly included in calculations for sows.

The official population numbers for sheep have been corrected for all years as of 2010; cf. Chapter 6.1.1.1 in Rösemann et al. (2019b). This has been done to take account of the change in the relevant

[85] Herkunftssicherungs- und Informationssystem für Tiere ("origin-tracing and information system for animals"), http://www.hi-tier.de

survey date from spring (until 2009, May / June) to 1 March (2010) and to 3 November (since 2011). The correction compensates for the apparent reduction in the number of lambs that this change entails (as well as the corresponding reduction in the total number of sheep).

Official goat-population figures are available for 2010, 2013 and 2016. Those figures were used as a basis for calculating, via linear interpolation, (otherwise unavailable) goat-population figures for 2011, 2012, 2014 and 2015. The animal number for 2017 has been estimated via extrapolation of the trend prevailing between 2013 and 2016.

In the inventory, population figures for horses are subdivided into the two categories "heavy horses" and "light horses and ponies", to take account of the differences in emissions behaviour between the two categories. In the 2010 agricultural census, and in the 2013 and 2016 censuses, "numbers of equids", rather than numbers of horses, were counted. The equid figures include the counts for mules and asses. The numbers for mules and asses cannot be separated out of the equid data (included elsewhere, IE). As of the 2015 submission, therefore, the inventory no longer includes "mules and asses" as a separate category. Until the year 2009, the counts for mules and asses were added to the counts for light horses and ponies. In keeping with data of the Interessengemeinschaft für Esel und Maultiere IGEM (2009), the applicable number for mules and asses has been estimated at 8,500 mules and asses per year. Gaps within the time series for horses have been filled in via linear interpolation. The relevant animal number for 2017 has been estimated via extrapolation of the trend prevailing between 2013 and 2016.

Until 2007, in contrast to actual housing practice (placement in stalling systems, as laying hens, as soon as they complete their 18th week of life – this is also the practice taken into account in the inventory) pullets were officially counted until they reached the age of 6 months. In the inventory, therefore, a fraction of the pullets was shifted into the laying-hen category, while the sum total for pullets and laying hens was not changed; cf. Chapters 8.3.1 and 8.5.1 in Rösemann et al. (2019b). The next poultry count, after 2007, took place in 2010. As of that count, shifting of figures between the pullet and laying-hen categories is no longer required, since the relevant populations have been counted in keeping with actual housing practice.

For all poultry categories, gaps in the animal-number time series have been closed via linear interpolation. For 2017, the values for 2016 have been retained, since extrapolation of the relevant trends between 2013 and 2016 would have led, in some cases, to implausibly high or low (in some cases, negative) animal-population data for 2017.

In the inventory, the official census data for turkeys were broken down by the categories "turkeys, males" and "turkeys, females", for all years since 1990, to take account of the pertinent differences in growth.

5.1.3.2.3 Animal place data used in the inventory (3.A, 3.B)

Table 236 presents a compilation of the animal-place figures on which German reporting is based. The animal-population data for dairy cows and other cattle have been updated for all years at the district level. In some cases, this has led to slight changes in the animal-population data at the national level. With the data presentation chosen for Table 236, these changes are not apparent in any comparison with the corresponding table in the NIR 2018

In 2016, shifting occurred between the figures for weaners and those for fattening pigs. The total number of swine, as shown in Table 236, remained unchanged with respect to the corresponding figure in the NIR 2018, however. The shifting is due to updating of the weights for fattening pigs in 2016 (cf. Chapter 5.1.3.3); that updating influenced the calculation of the population figures for weaners and fattening pigs (cf. in this regard Chapters 5.4.1.1 and 5.5.1.1 in Rösemann et al. (2019b).

With regard to the uncertainties for the numbers of animals, cf. Table 280 in Chapter 5.1.6.

Table 236: Animal-place figures used in German reporting (3.A, 3.B), in thousands

[in thousands]	Dairy cows	Other cattle	Swine	Sheep	Goats	Horses	Poultry
1990	6,355	13,133	26,502	3,266	90	499	113,879
1995	5,229	10,661	20,387	2,991	100	634	111,228
2000	4,570	9,969	21,768	2,743	140	500	120,180
2005	4,236	8,800	22,743	2,643	170	508	120,560
2008	4,218	8,754	22,678	2,437	190	521	128,608
2009	4,205	8,742	23,022	2,350	220	491	128,754
2010	4,183	8,629	22,244	2,245	150	462	128,900
2011	4,190	8,340	22,788	1,980	143	462	145,044
2012	4,190	8,319	23,648	1,966	137	461	161,189
2013	4,268	8,418	23,391	1,877	130	461	177,333
2014	4,296	8,447	23,667	1,892	133	455	176,080
2015	4,285	8,351	22,979	1,867	136	448	174,827
2016	4,218	8,249	22,761	1,851	139	442	173,574
2017	4,199	8,082	22,921	1,863	142	436	173,574

5.1.3.2.4 Comparison with livestock-population figures of the FAO (3.A, 3.B)

The United Nations Food and Agriculture Organization (FAO) publishes global livestock-census data in its FAOSTAT Internet database[86]. In general, the German figures in FAOSTAT come from the German Federal Statistical Office, which is also the data source for the German inventory. Nonetheless, numerous discrepancies result, for cattle, swine, sheep, goats, horses and poultry, when the data of FAOSTAT (as of 10 July 2018: time series through 2016) are compared with the data used in the 2019 Submission: For the period between 1990 and 2016, only about 14 % of the FAOSTAT figures agree with the corresponding German data (even when the figures rounded to whole 100s are taken into account).

The main reasons for the differences – large, in part – between the FAOSTAT data and the German data are that FAOSTAT has assigned a number of entries to the wrong years, and that it is inconsistent in its choice of methods for closing data gaps.

In the following section, the most important results of the data comparison are listed.

Cattle (including buffalo): The FAOSTAT livestock-population figures agree with the official German data only for the years 2014 – 2016. Prior to the year 2000, the FAOSTAT figures are shifted by a year with respect to the German figures. For example, the cattle-population figure that Germany listed for 1998 is listed by FAOSTAT for 1999. In the years 2011 – 2013, FAOSTAT uses the data from the May census, while the German inventory – in keeping with an EU provision (cf. Chapter 5.1.3.2.1) – uses the data from the November census.

Swine: In general, the swine-census figures listed by FAOSTAT cannot be compared with the corresponding inventory figures, since the inventory, for methodological reasons, deducts the numbers of piglets that weigh less than 8 kg (cf. Chapter 5.1.3.2.2). A comparison of a) the FAOSTAT swine-population figures and b) the swine-population figures of the Federal Statistical Office without deduction of suckling piglets shows that the FAOSTAT figures, like the FAOSTAT cattle-census figures for the period prior to 2000, are shifted – erroneously – by one year. With the exception of the years 2011 – 2013, in which the FAOSTAT figures agree with those of the May census, while the German inventory, in keeping with an EU provision (cf. Chapter 5.1.3.2.1), calculates using the data of the November census, the animal-number time series are largely similar. The figures actually agree (taking account of the rounding to whole 100s of animal places) only for the years 2001 – 2003 and 2007 – 2009, however.

[86] FAOSTAT http://www.fao.org/faostat/en/#data/QA

Sheep: In the periods 1993 – 2000 and 2005 – 2009, the FAOSTAT figures are very similar to the data of the Federal Statistical Office. They actually agree (taking account of rounding to 100s of animal places) only for the years 2007 – 2009, however. In the periods 1990 – 1992 and 2001 – 2004, there are discrepancies – some of them large – that cannot be explained with the available information. As of 2010, comparisons of the two time series are irrelevant, since the official sheep-population figures have been corrected in the inventory (cf. Chapter 5.1.3.2.2).

Goats: For the years prior to 2003, the FAOSTAT goat counts are shifted by one year with respect to the corresponding German figures. For example, FAOSTAT's goat count for 1991 is the same as the German goat count for 1990. For the years 2003, 2003, 2005, 2007, 2008, 2013 and 2016, the FAOSTAT figures agree with the corresponding German figures. For the years in between those years, years in which Germany neither collected nor estimated data in this category, FAOSTAT lists data that must be the result of estimations, although FAOSTAT states that those data are official data. The pertinent estimates are implausible especially for the period as of 2011, since they contradict the trends obtained via linear interpolation between the supporting years.

Horses (including mules and asses): The FAOSTAT figures for the period prior to 2010 list horse-only counts, i.e. do not include mules and asses. When the added mules and asses are deducted from the inventory figures (cf. Chapter 5.1.3.2.2), for purposes of comparison, the FAOSTAT figures show a one-year lag behind the German figures until the year 2004. In this context, it should be noted that the livestock-population figures given by FAOSTAT often differ from those listed in official German statistics. As of 2005, the FAOSTAT data and the German data agree only for the years 2013 and 2016. In those years between 2005 and 2016 in which Germany collected no data in this category, the FAOSTAT estimates – like those for goats – show an implausible chronological progression.

Poultry: The poultry counts largely agree for nearly all years with animal censuses (1994, 1999, 2003, 2005, 2007, 2010 and 2013). This does not hold for 2016, however. In FAOSTAT, the results of the censuses of the years 1990, 1996 and 2001 have been erroneously entered in the following year in each case. In addition, FAOSTAT's closures of data gaps for the period as of 2010 are implausible, to a degree similar to the implausibility of its closures of data gaps for goats and horses. These implausibilities make the time series for the period as of 2010 seem erratic.

5.1.3.3 Yield, energy and feed data (3.A, 3.B)

To calculate emissions in accordance with a Tier 2 method, one requires data on animal yield (animal weight, weight gain, milk yield, milk protein content, milk fat content, numbers of births, grazing data (if applicable), numbers of eggs and weights of eggs) and on the relevant feed (phase feeding, feed components, protein and energy content, energy metabolizability and digestibility of organic matter). To divide the total numbers of turkeys, as reported by the Federal Statistical Office, into cocks and hens, one must know the applicable sex ratio. For the most part, such data are not available from official statistics. In the present case, such data were obtained from the open literature, from association publications, from regulations for agricultural consulting in Germany and via surveys of experts.

The following changes have been made with respect to the 2018 Submission; cf. Chapter 3.5.2 in Rösemann et al. (2019b):

- **Dairy cows:** The characteristics of dairy standard concentrates have been updated (lower values for the gross energy (GE) content of the feed and its digestible energy (DE) content). The data for milk production are now broken down to the district level, rather than to the Länder level. The weight data for the years 2003, 2014 and 2016 have been updated.

- **Heifers:** An underestimation of metabolizable energy (ME) requirements – and thus, of feed intake – that occurred through the 2018 Submission has been corrected; cf. Chapter 3.5.2 in Rösemann et al. (2019b)). The characteristics of concentrates have been updated (somewhat higher metabolizable energy (ME) content, lower raw protein content, higher digestibility of organic matter, and higher ash content). The weight data have been updated (slight changes) for nearly all years of the time series.
- **Male beef cattle:** For concentrates, the metabolizable energy (ME) content, the digestibility of organic matter and the ash content have all been increased. The weight data have been updated (this involved slight changes) for nearly all years of the time series.
- **Fattening pigs and weaners:** The starting weight of fattening pigs, which is equivalent to the final weight of weaners, has been updated for Bavaria – and, thus, in the average figure for the national level.
- **Sheep and horses:** The VS excretions have been adjusted; cf. Chapter 5.1.3.5.
- **Broilers:** The data item "total gross meat quantity obtained at slaughter" has been updated for 2016.

Table 237 shows the mean animal weights for dairy cows, other cattle, swine and poultry. The mean animal weight for dairy cows is obtained from the pertinent starting and final weights (averaged over the German Länder (states), and weighted with the animal numbers at the Länder level); cf. Chapter 4.3.1.3 in Rösemann et al. (2019b). With regard to calculation of the mean animal weights for other cattle, swine and poultry, cf. Chapter 4.9.2.1, 5.7.2 and 8.9.1.2 in Rösemann et al. (2019b). For dairy cows, other cattle and swine, slight discrepancies have resulted with respect to the 2018 NIR, as a result of the aforementioned changes. For the most part, these changes are not apparent in the figures presented in Table 237, however.

Table 237: Average animal weights (3.A, 3.B)

[kg animal^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Dairy cows	607.9	621.8	644.3	646.7	645.3	641.9	646.7	647.8	646.1	645.9	645.3	649.7	648.4	650.9
Other cattle	338.7	351.1	367.7	365.4	365.7	366.0	367.7	365.6	365.2	367.2	367.1	369.6	370.7	371.2
Swine	66.7	69.0	67.3	67.0	66.6	66.7	65.3	64.1	63.7	63.6	63.7	63.3	63.3	63.2
Poultry	1.63	1.60	1.69	1.78	1.76	1.79	1.78	1.74	1.72	1.69	1.69	1.69	1.68	1.68

The animal weights for sheep, goats and horses do not enter into the emissions calculations, but they have been estimated for CRF-3.B: Sheep, 50 kg animal^{-1}; goats, 40 kg animal^{-1}; and horses, 490 kg animal^{-1}; cf. Chapters 6.5.1, 6.6.1 and 7.5.1 in Rösemann et al. (2019b).

Table 238 shows daily milk yield from dairy cows, expressed as an average for Germany as a whole; it is obtained by dividing the annual milk yield by 365 days. Discrepancies with respect to the 2018 NIR result from the use of input data for milk production that are more finely differentiated at the spatial level (as mentioned above).

Table 238: Mean daily milk yield for dairy cows (3.A)

[kg d-1]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Milk yield	12.88	14.78	16.60	18.40	18.61	19.02	19.41	19.84	20.06	20.12	20.66	20.90	21.22	21.31

For dairy cows, heifers, male beef cattle, sows, weaners and fattening pigs, the gross energy (GE) intake is calculated as a function of yield. Cf. in this regard the following chapters in Rösemann et al. (2019b): dairy cows, 4.3.2 through 4.3.4; heifers, 4.5.3; male beef cattle, 4.6.3; sows, 5.3.3; weaners, 5.4.3; fattening pigs, 5.5.3. Such calculations are tied to the condition that feeding exactly meets animal net-energy-for-lactation (NEL) and metabolizable energy (ME) requirements[87]. The

[87] The energy requirements for dairy cows are given in terms of the "net energy for lactation (NEL)" (cf. Kirchgessner et al. (2008)), while the term "metabolizable energy (ME)" is used for other animals for which the German inventory includes energy-requirements calculations (for example, cf. GfE – Gesellschaft für Ernährungsphysiologie (2006)).

NEL and ME requirements figures comprise all relevant sub-requirements categories (maintenance, growth, production of young and products, grazing) that are relevant for the applicable animal category in each case. The quantity of feed, of a given composition, required to meet NEL and ME energy requirements is calculated on the basis of the energy requirements and the mean NEL and ME energy content of the feed . The GE intake for a given animal is calculated on the basis of the feed quantity ingested and the mean GE content of the feed. The GE intake figures for calves, suckler cows, male cattle older than 2 years and boars are standard values. Cf. in this regard the following chapters in Rösemann et al. (2019b): calves, 4.4.2; suckler cows, 4.7.2; male cattle older than 2 years, 4.8.2; boars, 5.6.3. No GE intake figures are determined for the remaining animal categories (sheep, goats, horses, poultry).

Table 239 shows the daily GE intake for dairy cows, other cattle and swine. The discrepancies with respect to the 2018 Submission (somewhat lower values for dairy cows, considerably higher values for other cattle) are the result of changes – as mentioned above – with respect to last year's report.

Table 239: Mean daily GE intake (3.A)

[MJ place^{-1} d^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Dairy cows	259.4	278.2	295.0	308.8	309.8	312.9	317.0	319.7	321.3	321.2	324.6	327.2	330.1	330.8
Other cattle	108.3	111.7	116.6	116.4	116.7	116.6	117.3	117.0	117.1	117.6	117.6	118.4	118.6	118.7
Swine	30.2	31.8	32.6	33.0	33.3	33.8	33.8	34.0	34.3	34.5	34.8	35.0	35.2	35.5

Table 241 through Table 243 show, for dairy cows, other cattle and swine, the input data for the VS calculation on which the calculation of CH_4 emissions from manure management is based (cf. Chapter 5.3.2.2.1). The data include dry-matter (DM) intake, digestibility of organic matter and ash content of feed. For details on DM intake, we refer to the animal-specific chapters in Rösemann et al. (2019b); cf. Table 240. No DM intake figures are determined for sheep, goats, horses and geese, because no pertinent data on feeding are available. Neither are any standard values available. For this reason, the VS-excretion figures are obtained by other methods; cf. Chapter 5.1.3.5.

Table 240: Description of DM intake in Rösemann et al. (2019b)

Animal category	Chapter	Animal category	Chapter
Dairy cows	4.3.3, 4.3.4	Mature sheep	---
Calves	4.4.2	Lambs	---
Heifers	4.5.3	Goats	---
Male beef cattle (for fattening)	4.6.3	Heavy horses	---
Suckler cows	4.7.2	Light horses / ponies	---
Male cattle > 2 years	4.8.2	Laying hens	8.3.4
Sows	5.3.3	Broilers	8.4.3
Weaners	5.4.3	Pullets	8.5.4
Fattening pigs	5.5.3	Geese	---
Boars	5.6.3	Ducks	8.7.4
		Turkeys	8.8.2.3

Table 241: Daily DM intake

[kg^{-1} place^{-1} d^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Dairy cows	14.15	15.10	15.97	16.68	16.73	16.89	17.10	17.24	17.32	17.32	17.50	17.64	17.79	17.83
Other cattle	5.81	5.99	6.26	6.24	6.26	6.26	6.30	6.28	6.28	6.31	6.31	6.35	6.37	6.37
Swine	1.83	1.93	1.98	2.00	2.02	2.05	2.05	2.06	2.08	2.10	2.11	2.12	2.14	2.15

The digestibility of organic matter, and the ash content of feed, are given as key index values for feed (Beyer et al. (2004); information from producers); where the data are not available, suitable substitute values are used. Discrepancies with respect to the 2018 Submission result from aforementioned changes with respect to the last report.

Table 242: Digestibility of organic matter in feed (3.A)

[%]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Dairy cows	72.9	73.5	73.9	74.4	74.4	74.5	74.6	74.6	74.7	74.6	74.8	74.9	75.0	75.0
Other cattle	73.4	73.3	73.1	73.3	73.4	73.4	73.4	73.4	73.5	73.5	73.5	73.5	73.5	73.5
Swine	84.7	84.7	84.7	84.8	84.8	84.8	84.8	84.8	84.9	84.9	84.9	84.9	84.9	84.9

Table 243: Ash content of feed

[kg kg^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Dairy cows	0.096	0.093	0.091	0.089	0.089	0.088	0.088	0.087	0.087	0.087	0.087	0.087	0.087	0.087
Other cattle	0.093	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095
Swine	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056	0.056

The following chapters present further information related to animal husbandry – for example, excretion data (N, VS).

None of the animal models used call for mean percentages of pregnant animals as input figures. For cattle, they are reported in CRF Table 3.A, however, in the interest of completeness.

5.1.3.4 N excretions (3.B)

The manner in which N excretions are determined is described in the animal-specific chapters in Rösemann et al. (2019b); cf. Table 244.

Table 244: Descriptions of N excretions in Rösemann et al. (2019)

Animal category	Chapter	Animal category	Chapter
Dairy cows	4.3.8	Mature sheep	6.3.5
Calves	4.4.6.1	Lambs	6.4.5
Heifers	4.5.7.1	Goats	6.6.5
Male beef cattle (for fattening)	4.6.7.1	Heavy horses	7.3.5
Suckler cows	4.7.6.1	Light horses / ponies	7.4.5
Male cattle > 2 years	4.8.6.1	Laying hens	8.3.8.1
Sows	5.3.7.1	Broilers	8.4.7.1
Weaners	5.4.7.1	Pullets	8.5.8.1
Fattening pigs	5.5.7.1	Geese	8.6.6
Boars	5.6.7.1	Ducks	8.7.8.1
		Turkeys	8.8.6.1

For dairy cows, heifers, male beef cattle, swine, laying hens, pullets, broilers, ducks and turkey cocks and turkey hens, N excretions are calculated as a function of yield. For other animals, the N-excretion values are taken from the relevant German technical literature.

Calculation of N excretions as a function of yield is based on the assumption that feeding precisely meets energy requirements (cf. Chapter 5.1.3.3). The N quantity ingested by an animal is obtained from the ingested quantity of feed and the mean N quantity of the feed ration that conforms to relevant national feeding recommendations. Growth-related N retention, N output via products (milk/eggs) and N losses via pregnancy/offspring are all deducted from the ingested N quantity. The remaining N quantity is the N-excretion figure.

The following parameters enter into calculation of N excretions:

- Dairy cows: milk production, milk-protein content, milk-fat content, animal weight, weight gain, numbers of births per year, feed characteristics
- Heifers and male beef cattle: weight gain, final weight and feed characteristics;
- Swine: animal weight; for sows, also number of piglets per year; for weaners and fattening pigs, also weight gain and feed characteristics;
- Laying hens, pullets, ducks, turkeys: weight gain, final weight, and feed characteristics; for laying hens, also egg production and egg weights;
- Broilers: Gross meat quantities at slaughter, feed characteristics.

For animal categories with grazing, calculated N excretions per animal place and year are broken down into in-pasture and in-stable excretions, since only in-stable excretions can enter into calculation of N_2O emissions in 3.B. Calculation of N_2O emissions in 3.D takes account of N excretions in pasture. N excretions are divided into in-stall and in-pasture categories in keeping with the relative time proportions for time in stall and time in pasture (cf. Chapter 19.3.2, Table 548).

Table 245 shows the time series for N excretions. For goats, the N excretions are constant over time (11.0 kg place^{-1} a^{-1}). Discrepancies with respect to the 2018 Submission arise only for cattle. They result from changes in methods and input data (cf. Chapter 5.1.3.3).

Table 245: N excretions per animal place and year (3.B(b))

[kg place^{-1} a^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Dairy cows	97.5	103.3	110.0	114.8	114.3	115.1	116.3	117.3	117.6	117.3	118.7	120.3	121.8	121.9
Other cattle	43.3	45.6	48.0	48.1	48.1	48.1	48.4	48.3	48.3	48.5	48.5	48.9	49.1	49.0
Swine	12.1	12.6	12.7	12.8	12.8	12.9	12.9	12.9	12.9	13.0	13.0	13.0	13.1	13.2
Sheep	7.7	7.7	7.8	7.8	7.7	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8
Horses	48.2	48.1	49.0	48.8	48.8	48.8	48.8	48.8	48.8	48.8	48.8	48.8	48.8	48.8
Poultry	0.70	0.67	0.69	0.74	0.74	0.75	0.77	0.75	0.73	0.70	0.71	0.72	0.73	0.73

Table 246 shows the annual N excretions for the four manure management systems "slurry-based (without digestion)," "straw-based (without deep bedding and without digestion)," "deep bedding (without digestion)" and "digestion"; as well as for "grazing".

Table 246: Annual N excretions, broken down by manure management systems (3.B(b)) and grazing systems (3.D)

[kt a^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total	1639.2	1412.0	1388.8	1337.3	1336.1	1342.8	1331.4	1336.1	1356.2	1373.7	1391.8	1388.2	1381.5	1374.8
Slurry-based [a]	913.7	864.9	848.0	787.2	729.0	713.0	678.4	657.0	658.3	645.3	649.7	642.3	642.2	639.2
Straw-based [b]	455.5	317.7	308.6	296.4	302.5	302.3	302.0	304.7	310.5	315.6	319.2	319.6	317.8	315.2
Deep bedding [a]	52.0	53.1	57.1	70.7	74.2	75.2	74.6	71.7	71.5	72.1	72.2	70.7	69.9	68.5
Digestion	0.04	0.56	4.8	32.3	83.6	106.4	132.3	161.6	175.2	198.2	206.5	210.1	207.2	208.9
Grazing	218.0	175.7	170.3	150.7	146.7	145.9	144.0	141.0	140.6	142.5	144.3	145.6	144.4	143.0

[a] Without digestion

[b] Without deep bedding and without digestion

5.1.3.5 VS excretions (3.B)

The VS excretions for dairy cows, other cattle, swine and poultry (exception: geese) are calculated with the national procedure of Dämmgen et al. (2011); cf. Chapter 3.3.3.1 in Rösemann et al. (2019b).

Equation 5: Calculation of VS excretions

$$VS_{\mathrm{i}} = m_{\mathrm{feed,\,DM,\,i}} \cdot (1 - X_{\mathrm{DOM,\,i}}) \cdot (1 - x_{\mathrm{ash,\,feed}})$$

Where

VS_{i}	VS excretions for animal category i (in kg place^{-1} d^{-1})
$m_{\mathrm{feed,\,DM,\,i}}$	Dry-matter intake, animal category i (in kg place^{-1} d^{-1})
$X_{\mathrm{DOM,\,i}}$	Digestibility of organic matter, animal category i (in kg kg^{-1})
$X_{\mathrm{ash,\,i}}$	Ash content of feed, animal category i (in kg kg^{-1})

The VS excretions for geese are estimated on the basis of the VS excretions for ducks; cf. Chapter 8.6.4 in Rösemann et al. (2019b): 0.023 kg pl^{-1} d^{-1}.

The input data for the VS calculation include: dry-matter intake, digestibility of organic matter and ash content of feed; for a pertinent overview for dairy cows, other cattle and swine, cf. Chapter 5.1.3.3.

The VS excretions, calculated with national input data, for dairy cows, other cattle, swine and poultry are shown in Table 247. Discrepancies with respect to the 2018 Submission arise only for dairy cows and other cattle. They result from changes in methods and input data (cf. Chapter 5.1.3.3). In the number format used in Table 247, the differences for dairy cows are mostly invisible.

Table 247: Daily VS excretions, for dairy cows, other cattle, swine and poultry (without geese) (3.B(a))

[kg place^{-1} d^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Dairy cows	3.47	3.64	3.78	3.89	3.91	3.93	3.97	3.99	4.01	4.01	4.03	4.05	4.07	4.08
Other cattle	1.40	1.45	1.52	1.51	1.51	1.51	1.52	1.51	1.51	1.51	1.51	1.53	1.53	1.53
Swine	0.26	0.28	0.28	0.29	0.29	0.29	0.29	0.30	0.30	0.30	0.30	0.30	0.30	0.31
Poultry	0.023	0.022	0.023	0.026	0.026	0.026	0.027	0.026	0.025	0.024	0.025	0.025	0.025	0.025

Table 248 shows the daily VS excretions for sheep, goats and horses. In keeping with Rösemann et al. (2019b), the values for sheep and horses have been increased with respect to the 2018 Submission. Because the applicable population fractions for small and large animals vary from year to year, the mean VS excretions for sheep and horses do not remain constant over time. The annual variations are very small, however.

Table 248: Daily VS excretions for sheep, goats and horses (3.B(a))

[kg place^{-1} d^{-1}]	*VS*	Mean value, 2017
Mature sheep	0.53	0.41
Lambs	0.21	
Goats	0.30	0.30
Heavy horses	2.59	2.39
Light horses and ponies	1.73	

5.1.3.6 Housing systems, storage systems and application procedures (CRF 3.B, 3.D)

5.1.3.6.1 Frequency distributions (3.B, 3.D)

The German inventory uses annual frequency distributions, broken down by animal sub-categories, for the various husbandry systems (proportions for pasture grazing / stable housing; proportions for different housing systems), manure-storage systems and manure-application techniques, and time allotted to pasture grazing. The data for manure digestion and storage of digestates are discussed in Chapter 5.1.3.6.5 . Data collection and processing for the inventory, at the level of the German Länder (states), is described in detail in Chapter 3.4.3 in Rösemann et al. (2019b). With regard to description of the frequency distributions at the level of Germany as a whole, we refer to Chapter 19.3.2 in the present 2019 NIR.

The following tables show, for the important animal categories "dairy cows," "other cattle," "swine," and "poultry," how the pertinent animal populations break down with respect to the various categories of manure management systems.

Table 249: Slurry-based systems without digestion, in % of excreted VS (3.B(a))

[%]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Dairy cows	54.4	70.9	72.1	70.4	65.1	62.8	60.3	57.3	56.2	54.2	53.6	53.5	53.9	53.5
Other cattle	58.2	56.0	52.8	46.8	41.5	39.5	37.4	36.0	35.7	34.9	34.5	34.5	34.6	34.3
Swine	80.6	87.2	89.0	88.4	85.8	84.7	82.8	81.3	80.8	79.1	78.8	77.9	78.1	78.3

Table 250: Straw-based systems without digestion, in % of excreted VS (3.B(a))

[%]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Dairy cows	27.9	15.6	14.8	15.4	15.5	15.5	15.6	15.4	15.3	15.3	15.3	15.2	15.1	15.1
Other cattle	20.4	19.3	19.6	19.8	21.0	21.3	21.9	21.8	21.6	21.6	21.7	21.8	21.8	21.8
Swine	17.3	10.9	9.1	7.8	7.0	6.6	6.4	6.2	5.9	5.9	5.8	5.8	5.7	5.7
Poultry	100.0	99.9	99.6	96.8	93.8	92.2	90.2	89.1	88.7	87.3	87.0	86.5	86.6	86.5

Table 251: Deep bedding systems without digestion, in % of excreted VS (3.B(a))

[%]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Dairy cows	0.1	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other cattle	6.5	8.3	9.4	13.6	14.9	15.4	15.5	15.4	15.4	15.3	15.2	15.0	15.0	15.0
Swine	2.2	1.9	1.6	1.4	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.2	1.3	1.3

Table 252: Digestion systems, in % of excreted VS (3.B(a))

[%]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Dairy cows	0.003	0.050	0.47	3.1	8.9	11.3	14.0	17.1	18.2	20.1	20.8	20.8	20.5	20.9
Other cattle	0.003	0.032	0.26	1.9	4.4	5.5	6.9	8.5	9.2	10.1	10.3	10.3	10.3	10.6
Swine	0.003	0.042	0.33	2.4	5.9	7.4	9.5	11.2	12.0	13.7	14.1	15.1	14.9	14.8
Poultry	0.004	0.056	0.43	3.2	6.2	7.8	9.8	10.9	11.3	12.7	13.0	13.5	13.4	13.5

Table 253: Grazing, in % of excreted VS (3.B(a))

[%]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Dairy cows	17.7	13.2	12.5	11.1	10.5	10.3	10.1	10.2	10.3	10.4	10.4	10.5	10.5	10.5
Other cattle	14.8	16.4	18.0	17.9	18.2	18.2	18.3	18.3	18.1	18.1	18.2	18.4	18.3	18.4

5.1.3.6.2 Bedding material in solid-manure systems

In solid-manure systems, additional nitrogen enters the system via the bedding material. In the inventory, this nitrogen is taken into account in calculation of N_2O and NO emissions from manure management. Table 548 in Chapter 19.3.2 lists the applicable bedding-material quantities, as fresh matter, for the various different animal-housing procedures. With a dry-matter content of 86 %, and an N quantity of 0.58 % in dry matter (cf. Chapter 3.3.4.3.2 in Rösemann et al. (2019b)), the bedding-material N quantities listed in Table 254, for the various animal categories, result. In some years, the values for dairy cows and other cattle differ from the values reported in the 2018 NIR. A primary reason for this is that the updating of animal-population data mentioned in Chapter 5.1.3.2.3 leads to some shifting of applicable fractions for animal-housing systems – and, thus, for solid-manure systems – with respect to aggregation (weighted averaging) at the national level. For dairy cows, this effect is apparent, as a result of the number format chosen for Table 254, only in the year 1990. For other cattle, it is completely masked by a decrease, with respect to the 2018 NIR, in the applicable quantities of straw bedding for male beef cattle older than two years (cf. Chapter 3.5.2 in Rösemann et al. (2019b), in the section "Chapter 4.8").

Table 254: Annual totals for N inputs via bedding material, in straw-based systems

[kt a^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total	**52.2**	**40.2**	**38.1**	**37.0**	**37.9**	**37.8**	**37.3**	**36.7**	**36.7**	**37.1**	**37.1**	**36.7**	**36.1**	**35.6**
Dairy cows	17.2	7.6	7.1	6.7	6.7	6.7	6.7	6.7	6.7	6.8	6.9	6.9	6.7	6.7
Other cattle	23.6	20.8	21.0	20.1	20.9	21.1	21.1	20.5	20.4	20.6	20.7	20.5	20.2	19.8
Swine	3.18	1.78	1.58	1.41	1.28	1.26	1.18	1.18	1.19	1.17	1.18	1.13	1.12	1.13
Sheep	0.83	0.75	0.70	0.68	0.62	0.60	0.58	0.51	0.50	0.48	0.48	0.47	0.47	0.47
Goats	0.04	0.05	0.07	0.08	0.09	0.11	0.07	0.07	0.07	0.06	0.06	0.07	0.07	0.07
Horses	6.54	8.30	6.65	6.75	6.91	6.51	6.12	6.12	6.12	6.12	6.03	5.95	5.86	5.78
Poultry	0.80	0.91	1.10	1.27	1.39	1.46	1.52	1.62	1.72	1.83	1.79	1.74	1.70	1.70

5.1.3.6.3 Maximum methane-producing capacity B_o (3.B(b))

For calculation of emissions (cf. Chapter 5.3.2.2.1), the methane formation related to manure storage is characterized via the animal-specific maximum methane-producing capacity B_o and the storage-specific methane conversion factor *MCF*. With regard to the *MCF,* cf. Chapter 5.1.3.6.4.

Table 255 *shows the* B_o values used and the origins of the relevant data. For cattle and swine, the data are national data. For other animals (apart from pullets and geese), IPCC default values have been used. No IPCC default values are available for pullets and geese. For pullets, in a conservative approach, the default value (IPCC (2006): Vol. 4) for laying hens was used. For the B_o for geese, a value of 0.36 m^3 kg^{-1} has been adopted, in keeping with Chapter 8.6.4 in Rösemann et al. (2019b). Owing to variations in the population fractions for the various poultry categories, *the mean* B_o for poultry is not a constant, as Table 256 illustrates.

Table 255: Maximum methane-producing capacity B_o (3.B(b))

[m^3 kg^{-1}]	B_o	Source
Cattle	0.23	(Dämmgen et al., 2012b)
Swine	0.30	(Dämmgen et al., 2012b)
Sheep	0.19	(IPCC, 2006): Vol. 4, 10.82
Goats	0.18	(IPCC, 2006): Vol. 4, 10.82
Horses	0.30	(IPCC, 2006): Vol. 4, 10.82
Laying hens	0.39	(IPCC, 2006): Vol. 4, 10.82
Broilers	0.36	(IPCC, 2006): Vol. 4, 10.82
Ducks	0.36	(IPCC, 2006): Vol. 4, 10.82
Turkeys	0.36	(IPCC, 2006): Vol. 4, 10.82
Pullets	0.39	Assumption (see text)
Geese	0.36	Chapter 8.6.4 in Rösemann et al. (2019b)

Table 256: Maximum methane-producing capacity B_o for poultry (3.B(b))

[m^3 kg^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Poultry	0.380	0.377	0.375	0.372	0.371	0.371	0.370	0.370	0.371	0.371	0.371	0.371	0.372	0.372

5.1.3.6.4 Methane conversion factors MCF (3.B)

In CRF 3.B(a), the MCF values for the various national manure management categories are to be reported under "Additional Information." In Germany, the pertinent categories are "slurry-based without digestion", "straw-based without digestion" (heap), "deep bedding without digestion", "digestion" and "pasture". The values are weighted average values, over all animal categories, based on the MCF values described below. The category "slurry-based without digestion" includes all animals housed in slurry-based systems with no digestion of the animals' manure. The categories "straw-based without digestion (solid-manure-storage systems)" and "deep bedding without digestion" should be understood in the same way. The "digestion" category includes all animals whose manure is digested.

Table 257 shows the MCF values for cattle, broken down by the storage systems commonly used in Germany. The national values proposed by Dämmgen et al. (2012b) are in boldface type. In a conservative approach, chosen due to a lack of IPCC default values or national values, the MCF applying to "liquid manure without natural crust" was used for "liquid manure with solid cover" (including tent structures), "liquid manure with floating chopped-straw cover" and "liquid manure with floating cover foil." The values for deep bedding and pasture were taken from (IPCC (2006): Vol. 4, 10.44ff).

Table 257: Methane conversion factors *MCF* (in percent of B_o) for cattle (3.B(a))

		MCF [%]
Liquid manure	Open tank, without natural crust	**17**
	Solid cover	17
	Natural crust	**10**
	Floating cover (chopped straw)	17
	Floating cover (cover foil)	17
	Below slatted floor > 1 month	**17**
Solid manure	Deep bedding	17
	Heap	**2**
Pasture		1

Table 258 lists the methane conversion factors MCF for manure storage in swine husbandry. As for cattle, the value are national values ((Dämmgen et al. (2012b), boldface type), default values from (IPCC (2006): Vol.4, 10.44ff) and conservative assumptions in cases in which no MCF is known. For cattle, the MCF for "deep bedding" is the same as that for liquid manure without natural crust, and thus the same relationship has been assumed to hold for swine. Free-range management of swine ("pasture") plays a very insignificant role in Germany and is thus not taken into account in the inventory (not occurring, NO).

Table 258: *Methane-conversion factors* MCF *(in percent of* B_o) for swine (3.B(a))

		MCF [%]
Liquid manure	Open tank, without natural crust	**25**
	Solid cover	25
	Natural crust	**15**
	Floating cover (chopped straw)	25
	Floating cover (cover foil)	25
	Below slatted floor > 1 month	**25**
Solid manure	Deep bedding	25
	Heap	**3**

The average methane conversion factors for slurry-based systems without digestion, for dairy cows, other cattle and swine, depend on the frequency of the various applicable housing procedures and thus are not constant, as Table 259 shows.

Table 259: Average methane conversion factors MCF *(*in percent of B_o) for slurry-based systems without digestion (3.B(a))

[%]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Dairy cows	14.3	14.0	14.0	14.4	14.8	14.9	15.1	15.2	15.2	15.3	15.3	15.3	15.3	15.3
Other cattle	14.5	14.3	14.6	14.9	15.1	15.2	15.3	15.3	15.3	15.4	15.4	15.4	15.4	15.4
Swine	24.7	23.7	23.6	22.8	22.4	22.2	22.1	22.1	22.1	22.1	22.1	22.2	22.2	22.2

For storage of manure from other animals (goats, sheep, horses and poultry), the default values from (IPCC (2006): Vol. 4, 10.44ff) have been used (cf. Table 260).

Table 260: Methane conversion factors MCF (in percent of B_o) for goats, sheep, horses and poultry (3.B(a))

MCF [%] [a]	
Heap	2
Poultry manure	1.5
Pasture	1

For systems in which manure is digested, a variable MCF results, when the various contributions from pre-storage systems, digesters and systems for storage of digestates are taken into account (cf. Chapter 5.1.3.6.5).

5.1.3.6.5 Manure digestion and storage of digestates (3.B)

Pursuant to IPCC (2006): Vol. 4, Tab. 10.17, anaerobic digestion of manure, and storage of the resulting digestates, is a separate storage-system type. In keeping with the German situation, that storage type is taken into account for cattle, swine and poultry Haenel and Wulf (2016); Chapters 3.3.4.4 and 3.4.4 in Rösemann et al. (2019b)). The time series for the activity data have been provided by the Association for Technology and Structures in Agriculture (KTBL). They are based primarily on data of the Deutsches Biomasseforschungszentrum (DBFZ), but they also take account of the animal N excretions calculated for the inventory. Those excretions have changed – considerably, in part – with respect to the 2018 Submission, as a result of updating of yield-determining data (cf. Chapter 5.1.3.3). KTBL has updated the input data for manure digestion for all years of the time series; cf. KTBL (2018).

Equation 6, using the example of slurry, describes the concept used by KTBL (2018) to determine the relevant relative fractions of manure that undergo digestion. Equation 6 is used in a similar manner for solid manure (including the N from the bedding material). The aggregation into "manure, total" is carried out on the basis of numbers of animals and of animal-specific manure production.

Equation 6: Concept for calculation of the percentage shares of digested manure with respect to total manure production

$$pct_{\mathrm{SL,\,dig,i}}(y) = 100 \cdot \frac{SL_{\mathrm{dig,i}}(y)}{SL_{\mathrm{total,i}}(y)} = 100 \cdot \frac{W_{\mathrm{el,\,dig}}(y) \cdot s_{\mathrm{i}}}{SL_{\mathrm{total,i}}(y)}$$

Where

$pct_{\mathrm{SL,\,dig,\,i}}$	Quantity of digestates, as a fraction of the total slurry production of animal category I (in %)
i	Index of the pertinent animal category
y	Year (1990, 1991, ...)
$SL_{\mathrm{dig,\,i}}$	Quantity of nitrogen in digestates of animal category i (in kg a^{-1})
$SL_{\mathrm{total,\,i}}$	Total slurry production (nitrogen quantity) of animal category i (in kg a^{-1})
$W_{\mathrm{el,\,dig}}$	Annual electrical work of German biogas plants (in GWh_{el} a^{-1})
s_{i}	Work-specific substrate input (nitrogen quantity) of animal category i (in kg GWh_{el}^{-1})

KTBL (2018) derived the applicable annual electrical work $W_{\mathrm{el,\,dig}}$, differentiated by German Länder (states) and plant-performance classes, from data of the registry of biogas plants (Biogasanlagenregister) (as of 31 Dec. 2016, 9396 plants). In the process, consideration of the factor "equivalent electrical work" makes it possible to take account also of those biogas plants that solely feed biomethane into the gas network, i.e. without producing any electricity. The work-specific substrate input s_{i} was calculated separately for cattle slurry, cattle manure, swine slurry and poultry manure, using data from 1,664 biogas plants. The nitrogen quantities $SL_{\mathrm{total,\,i}}$ were derived from the numbers of animals and from the animal-specific slurry and solid-manure production (including bedding material). The time series have been updated with respect to the 2018 Submission.

Table 261 shows the resulting updated fractions for digestion of cattle slurry, cattle solid manure, swine slurry and poultry manure, as well as the resulting updated digested fractions of the total manure quantity from animal husbandry, expressed as percentages of the N quantities entering into storage systems. For solid swine manure, no digestion is taken into account, since the relevant data are of uncertain reliability, due to the small quantities of solid manure involved.

Table 261: Relative shares of manure undergoing digestion (in % of the N quantities entering storage), for the various animal categories with manure undergoing digestion, along with pertinent weighted averages for all animal husbandry overall

[%]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total	**0.003**	**0.045**	**0.40**	**2.7**	**7.0**	**8.9**	**11.1**	**13.5**	**14.4**	**16.1**	**16.6**	**16.9**	**16.7**	**17.0**
Cattle slurry	0.005	0.060	0.55	3.7	10.5	13.4	16.7	20.6	22.2	24.5	25.4	25.9	25.7	26.2
Cattle solid manure	0.001	0.013	0.11	0.8	1.8	2.3	2.8	3.5	3.8	4.1	4.2	4.4	4.4	4.6
Swine slurry	0.003	0.048	0.38	2.7	6.4	8.0	10.3	12.2	13.0	14.8	15.2	16.2	16.1	15.9
Poultry manure	0.004	0.055	0.43	3.2	6.2	7.8	9.7	10.8	11.2	12.7	12.9	13.4	13.3	13.4

The data in Table 261 are also used to calculate the share of stored VS quantities that undergo digestion.

The total MCF for digestion of manure and slurry in biogas plants, including pre-storage systems and systems for storage of digestates, is calculated in accordance with a national method; cf. Equation 7. For derivation of this equation, cf. Chapter 3.3.4.4.1 in Rösemann et al. (2019b).

Equation 7: Calculation of total MCF for digestion of manure and slurry in biogas plants, including pre-storage of substrate and storage of digestates

$$MCF\% = MCF\%_{ps} + (100\,\% - MCF\%_{ps}) \cdot \left((1-\mu_{rg}) \cdot L_{dig} \; + \; \mu_{rg} \cdot \frac{MCF\%_{residues}}{100\,\%} \right)$$

Where

$MCF\%$	Total MCF for the system "pre-storage system + digester + system for storage of digestates" (in %)
$MCF\%_{ps}$	MCF for the pre-storage system (in %)
μ_{rg}	Potential for residual gas production, with respect to B_o (with $0 \le \mu_{rg} \le 1$ m^3 m^{-3})
L_{dig}	Relative leakage rate of the digester, with respect to the quantity of CH_4 produced in the digester (with $0 \le L_{dig} \le 1$ m^3 m^{-3})
$MCF\%_{residues}$	MCF for the system for storage of digestates (in %)

Table 262 shows the methane conversion factors $MCF\%_{ps}$ for pre-storage systems. For derivation of this equation, cf. Chapter 3.4.4.2.2 in Rösemann et al. (2019b).

Table 262: Methane conversion factors for pre-storage systems (in percent of B_o)

$MCF\%_{ps}$ [%]	
Cattle slurry	1.7
Cattle solid manure	0.2
Swine slurry	2.5
Poultry manure	0.15

On the basis of KTBL (2018), the potential CH_4 off-gas quantity μ_{rg} with respect to B_o is considered to be 4.6 % (or 0.046 m^3 m^{-3}); cf. Chapter 3.4.4.2.2 in Rösemann et al. (2019b).

In keeping with the figures given in Bachmaier and Gronauer (2007), Börjesson and Berglund (2007), GÄRTNER (2008) and Roth et al. (2011), The leakage rate of digester L_{dig} is set at 1 %, or 0.01 m^3 m^{-3} (KTBL, 2018). In a 2016 study, UBA also applied a leakage rate of 1 % UBA (2016b).

A leakage rate is assumed even for a gas-tight system for storage of residues from manure digestion; that leakage rate is assumed to be the same as that of the digester. Taking account of the relative share of gas-tight storage systems, with respect to all storage of digestates, one obtains Equation 8.

Equation 8: Calculation of *MCF* for systems for storage of digestates

$$MCF\%_{\text{residues}} = x_{\text{gts}} \cdot (100 \cdot L_{\text{sto, gt}}) + (1 - x_{\text{gts}}) \cdot MCF\%_{\text{ngts}}$$

Where

$MCF\%_{residues}$	MCF for the system for storage of digestates (in %)
x_{gts}	Relative share of gas-tight storage of digestates (in kg kg^{-1})
$L_{sto, gt}$	Relative leakage rate for gas-tight storage of digestates ($L_{sto, gt} = L_{dig}$)
$MCF\%_{ngts}$	MCF for non-gas-tight systems for storage of digestates (in %)

In general, digestates are in a liquid state. For non-gas-tight storage of digestates, it is assumed that a natural floating crust forms, as a result of co-digestion of energy crops, which increases the dry-matter content in the digestates. This type of storage is thus similar to open storage of undigested cattle slurry with a natural floating crust. For this reason, the relevant MCF for undigested cattle slurry is used for $MCF\%_{ngts}$: 10 % (cf. Chapter 5.1.3.6.4).

Table 263 shows the fraction of gas-tight storage of manure digestates, as a percentage share of all storage of manure digestates, and in percent of N inputs. The data were derived by KTBL (2018) from the pertinent input quantities of digestion substrates, broken down by German Länder and by plant-performance classes, as well as by the percentage shares of biogas plants with gas-tight, covered storage of digestates, with respect to the performance classes prevailing in Germany. The sharp increase, from 2011 to 2012, in the use of gas-tight storage of digestates is attributed to the 2012 German act on electricity feed-in (Energieeinspeisegesetz, EEG), which mandates gas-tight covers for all digestate-storage systems that went into operation on or after 1 January 2012. The percentage values for gas-tight covers were updated with respect to the 2018 Submission. This led to slight discrepancies in the years 2015 and 2016. Since no data on use of such covers were available for 2017, the relevant figures for 2016 were retained for that year.

Table 263: Percentage shares for storage of digestates in gas-tight and non-gas-tight storage systems (in percent of the N inputs in biogas plants)

[%]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
gas-tight	0.0	4.5	9.1	15.2	30.4	35.5	40.6	45.6	57.0	59.0	60.9	61.6	61.9	61.9
non- gas-tight	100.0	95.5	90.9	84.8	69.6	64.5	59.4	54.4	43.0	41.0	39.1	38.4	38.1	38.1

The total MCF values resulting from Equation 7, for the systems "pre-storage systems + digester + system for storage of digestates", for dairy cows, other cattle, swine and poultry, are listed in the following table.

Table 264: Average methane conversion factors *MCF* (in percent of B_o) for manure management systems with digestion (3.B(a))

[%]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Dairy cows	3.00	3.02	3.00	2.97	2.92	2.90	2.88	2.85	2.81	2.80	2.79	2.79	2.79	2.79
Other cattle	2.98	2.90	2.87	2.81	2.75	2.72	2.69	2.67	2.62	2.62	2.61	2.60	2.60	2.60
Swine	3.88	3.86	3.84	3.82	3.75	3.73	3.71	3.69	3.65	3.64	3.63	3.63	3.63	3.63
Poultry	1.56	1.54	1.53	1.50	1.44	1.42	1.40	1.38	1.33	1.33	1.32	1.31	1.31	1.31

The reduction of CH_4 emissions from manure management that is related to digestion depends on the fraction of manure that is digested, as well as on the relative frequency of gas-tight systems for storage of digestates. The pertinent reductions resulting in Germany are given in Chapter 5.3.2.2.3.

Table 265 lists the N_2O emissions that the inventory takes account of for the various relevant sub-systems and manure types. For details, cf. Chapter 3.3.4.4.2 in Rösemann et al. (2019b). N_2O and NO emissions from agricultural soils, resulting from application of digestates, are described in Chapter 5.5.

Table 265: Calculation of N_2O emissions from anaerobic digestion

		Slurry	Solid manure / poultry manure
Pre-storage systems		0	Equation9
Digester		0	0
System for storage of digestates	gas-tight	0	0
	non- gas-tight	Equation10	Equation10

Equation9: Calculation of N_2O emissions from systems for pre-storage of solid manure and poultry manure

$$E_{\text{N2O-N, dig,ps}} = (N_{\text{excr, dig}} + N_{\text{straw, dig}}) \cdot EF_{\text{N2O-N, dig,ps}}$$

Where

$E_{\text{N2O-N, dig, ps}}$	N losses via N_2O emissions from pre-storage of solid manure or poultry manure (in kg a^{-1})
$N_{\text{excr, dig}}$	Fraction of annual in-stable N excretions that goes to digestion (in kg a^{-1})
$N_{\text{straw, dig}}$	Fraction of annual N inputs from bedding material that goes to digestion (in kg a^{-1})
$EF_{\text{N2O-N, dig, ps}}$	N_2O-N emission factor for pre-storage of solid manure or poultry manure (in kg N_2O-N per kg N)

Equation10: Calculation of N_2O emissions from non-gas-tight storage of digestates

$$E_{\text{N2O-N, dig,ngts}} = (1 - x_{\text{gts}}) \cdot N_{\text{tot,dig,ferm}} \cdot EF_{\text{N2O-N, dig,ngts}}$$

Where

$E_{\text{N2O-N, dig, ngts}}$	N losses via N_2O emissions from non-gas-tight storage of digestates (in kg a^{-1})
x_{gts}	Relative share of gas-tight storage of digestates (in kg kg^{-1})
$N_{\text{tot, dig, ferm}}$	Total N quantity from digestates that leaves the digester (in kg a^{-1})
$EF_{\text{N2O-N, dig, ngts}}$	N_2O-N emission factor for non-gas-tight storage of digestates (in kg N_2O-N per kg N)

The N_2O emission factors used in the inventory are listed in Table 266. For the derivation of these factors, we refer to Chapter 3.4.4.2.3 in Rösemann et al. (2019b).

Table 266: N_2O-N emission factors for manure pre-storage and for storage of digestates

	[kg kg^{-1}]	Solid manure	Poultry manure
Pre-storage systems	$EF_{\text{N2O-N, dig, ps}}$	0.001	0.0001
Systems for storage of digestates, non-gas-tight	$EF_{\text{N2O-N, dig, ngts}}$	0.005	0.005

The N quantity in digestates at the beginning of storage ($N_{\text{tot, dig, ferm}}$) is calculated with inclusion of the N losses from pre-storage. It is assumed that no N losses from digesters occur.

The procedure for calculating NO emissions occurring in connection with manure digestion is similar to that for calculating N_2O emissions. As is customary in the German inventory's sections on manure management (cf. Chapter 3.3.4.3.5 in Rösemann et al. (2019b), equation (3.57)), the NO-N emission factor is assumed to be one-tenth of the N_2O-N emission factor.

To calculate the N_2O emissions that result indirectly from agricultural soils, as a result of deposition of reactive nitrogen (cf. Chapter 5.5.2.1.2), one must also calculate the NH_3 emissions that occur in connection with digestion of manure. NH_3 emissions are calculated for pre-storage of solid manure and poultry manure, for non-gas-tight storage of digestates and for application of digestates. On the other hand, for pre-storage of slurry, for digesters and for gas-tight storage of digestates, it is assumed that NH_3 emissions either do not occur or are negligible. For details on the extensive subject of NH_3-calculation methods, see Chapters 3.3.4.4.3 and 3.4.4.2.4 in Rösemann et al. (2019b).

5.1.4 Digestion of energy crops: Concept and activity data

5.1.4.1 The concept, and its consideration in the CRF tables

The inventory covers the six energy-crop categories that are the most important in Germany in terms of quantities: maize silage, grass silage, whole-plant silage, wheat grain, rye grain and Corn Cob Mix (CCM). They differ only slightly in terms of their key characteristics (N and VS content in dry matter, maximum methane formation potential B_o; cf. KTBL (2018). This makes it possible to treat the total dry matter for all included energy crops as a single energy-crop category. The procedure for calculating the pertinent emissions is similar to that for calculating emissions from digestion of solid manure (cf. Chapter 5.1.3.6.5), with the exception that no pre-storage is included.

In practice, manure and energy crops are normally digested together. Nonetheless, the emissions occurring in connection with digestion of these two substrate categories are calculated separately, with a view to highlighting the contribution that energy-crop digestion makes to the greenhouse-gas balance.

For further details on emission calculation in connection with digestion of energy crops, see Chapters 3.3.5, 3.4.4.1 and, especially, Chapter 10 in Rösemann et al. (2019b).

The following emissions are calculated that result, directly or indirectly, from digestion of energy crops, as well as from storage and application of digestates:

Digester

- CH_4 (via leakage)

Storage

- CH_4 (via leakage)
- Direct N_2O
- N_2O resulting indirectly from deposition of NH_3 and NO from storage
- NO

Application

- Direct N_2O
- N_2O resulting indirectly from deposition of NH_3 and NO via application
- N_2O resulting indirectly from leaching / surface runoff of the nitrogen applied via spreading of digestates
- NO

The emissions from digesters and systems for storage of digestates (CH_4, N_2O, indirect N_2O from deposition of NH_3 and NO from storage) are described in Chapter 5.9 and reported under 3.J in CRF Table 3s2. The direct and indirect N_2O emissions occurring as a result of spreading of digestates are described in Chapter 5.5 and reported under 3.D (CRF 3.D: a.2.c, b.1 and b.2). The NO emissions from storage of digestates and from application of digestates are reported separately, as NO_x emissions, under 3.J in CRF Table 3s2.

5.1.4.2 Activity data and parameters

The activity data used in calculation of the pertinent emissions consist of the total quantities of energy-crop dry matter that are input into digestion; cf. Table 267. The underlying substrate quantities were derived and provided in connection with work related to manure digestion (KTBL (2018); cf. Chapter 5.1.3.6.5). The dry-matter value for 2016 has been updated (lowered) with respect to the 2018 NIR.

Table 267: Total dry matter in the energy crops input into biogas plants

[kt a^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
	3.4	43.2	374.2	3,175	7,105	9,115	11,461	14,295	15,657	18,953	19,795	20,603	20,486	20,750

A weighted average B_o value of 0.36 m^3 kg^{-1} was derived from the B_o values for the six energy-crop categories (cf. Chapter 5.1.4.1), using the IPCC default value for the density of methane (0.67 kg m^{-3}). The following weighted averages for the VS and N content resulted (with respect to dry matter): VS content, 0.947 kg kg^{-1}; N content, 0.0148 kg kg^{-1}.

The VS quantity required for calculation of the CH_4 emissions is obtained by multiplying the dry matter by the average VS content; cf. Table 268.

Table 268: Total VS quantity in the energy crops input into biogas plants

[kt a^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
	3.2	40.9	354.3	3,007	6,729	8,632	10,854	13,538	14,827	17,949	18,745	19,511	19,400	19,650

The N quantities required for calculation of the N emissions are obtained with the help of the relevant N content; cf. Table 269.

Table 269: Total N quantity in the energy crops input into biogas plants

[kt a^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
	0.05	0.64	5.5	47.0	105.2	134.9	169.6	211.6	231.7	280.5	293.0	304.9	303.2	307.1

In keeping with KTBL (2018), the leakage rates for digesters and gas-tight systems for storage of digestates are considered to be the same as those used in connection with manure digestion (cf. Chapter 5.1.3.6.5).

Table 270 shows the fractions of gas-tight storage of residues of energy-crop digestion, as percentages of the pertinent input fresh matter (KTBL, 2018). The data for the years 2015 and 2016 have been updated with respect to the 2018 Submission (2015, slight reduction; 2016, slight increase; in both cases, by 0.1 percentage points). Since no data on use of such covers were available for 2017, the relevant figures for 2016 were retained for that year. The sharp increase, from 2011 to 2012, in the use of gas-tight storage of digestates is attributed to the 2012 German act on electricity feed-in (Energieeinspeisegesetz, EEG), which mandates gas-tight covers for all digestate-storage systems that went into operation on or after 1 January 2012. The data differ somewhat from those for storage of manure digestates (cf. Table 263). This is due to the fact (KTBL, 2018) that the total fraction of energy crops, with respect to the manure / energy-crop substrate mix, increases with plant (i.e. facility) size (a relationship that also holds for the covered-system fraction of systems for storage of digestates).

Table 270: Percentage shares for systems for gas-tight and non-gas-tight storage of digestates of energy crops (in percent of the fresh matter inputs in biogas plants)

[%]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
gas-tight	0.0	4.7	9.4	15.8	31.7	37.0	42.2	47.5	59.4	61.8	63.7	64.5	64.7	64.7
non- gas-tight	100.0	95.3	90.6	84.2	68.3	63.0	57.8	52.5	40.6	38.2	36.3	35.5	35.3	35.3

A range of different application methods, and different incorporation periods for cropland and grassland, are used. The relevant available relative-frequency figures were obtained from surveys of the Federal Statistical Office in 2011 (for the year 2010) and 2016 (for the year 2015); cf. Chapter 19.3.2, Table 550.

5.1.5 Activity data for emissions from agricultural soils and crops

5.1.5.1 N_2O emissions from agricultural soils (3.D)

5.1.5.1.1 The N quantities behind direct N_2O emissions (3.D)

Table 272 shows those N quantities, from various sources, that are used as a basis for calculation of direct N_2O emissions pursuant to (IPCC (2006): Vol. 4, 11.7) (cf. Chapter 5.5.2.1.1).

Since no data on mineral-fertiliser application are collected, the inventory considers the N quantities from mineral-fertiliser application to be the same as the N quantities given by official statistics, at the German Länder (states) level, on sales of mineral fertilisers. The delay in the relevant surveys amounts to half a year. For purposes of the inventory, it is assumed that all of the mineral fertiliser sold in the second half of year j-1, and all of the mineral fertiliser sold in the first half of year j, is applied (spread) in year j.

The N quantity in the total quantity of applied manure is calculated with the help of the N-flow concept (cf. Chapter 3.3.4.3.1 in Rösemann et al. (2019b)): As Table 271 shows, the N quantity applied with manure and digestates from manure digestion is equivalent to the sum of a) the N quantity excreted in housing systems and b) the N quantity introduced to solid-manure systems via bedding material, minus the losses via N emissions from housing and storage (manure: Chapter 5.1.2.4; digestates from manure digestion: Chapter 5.1.3.6.5). Changes with respect to the 2018 NIR are the result of updating of input data; cf. Chapters 5.1.3.2.3, 5.1.3.3 and 5.1.3.6.5.

Table 271: Calculation of the N quantities in the total sum of manure applied (including digestates of manure) (3.D)

[kt a^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
N excretions [a]	1421.2	1236.3	1218.5	1186.6	1189.4	1196.9	1187.3	1195.0	1215.6	1231.1	1247.6	1242.6	1237.1	1231.8
+ bedding material N [b]	52.2	40.2	38.1	37.0	37.9	37.8	37.3	36.7	36.7	37.1	37.1	36.7	36.1	35.6
- (NH_3-N + NO-N) [c]	-268.4	-226.5	-227.1	-227.5	-227.8	-228.2	-223.2	-223.5	-227.0	-228.4	-230.3	-227.5	-225.7	-224.6
- N_2O-N [d]	-5.7	-5.1	-5.0	-5.0	-5.0	-5.0	-4.9	-4.9	-4.8	-4.8	-4.8	-4.8	-4.7	-4.7
- N_2 [e]	-17.0	-15.2	-14.9	-14.9	-15.0	-15.0	-14.8	-14.6	-14.4	-14.3	-14.4	-14.3	-14.2	-14.1
Result	**1182.4**	**1029.7**	**1009.7**	**976.2**	**979.5**	**986.4**	**981.7**	**988.8**	**1006.1**	**1020.7**	**1035.2**	**1032.8**	**1028.5**	**1024.1**

[a] Total N excretions after deduction of excretions during grazing; cf. Table 246 in the present NIR (corresponds to the sum of line 38 in CRF Table 3.B(b))

[b] cf. Table 254 in the present NIR

[c] cf. cell O37 in CRF Table 3.B(b)

[d] cf. Table 312 in the present NIR (corresponds to cell T40 in CRF Table 3.B(b), multiplied by the molar ratio 28/44)

[e] N_2 emissions from manure management are calculated as three times the N_2O-N emissions (cf. Rösemann et al. (2019b), Chapter 3.3.4.3.5, equation (3.58))

The N quantity that is applied with digestates from digestion of energy crops is obtained as the N quantity in the energy crops input into digestion, minus the N losses via emissions from the system for storage of digestates.

For each Land (state) in Germany, N quantities from sewage-sludge application are taken from data of the Federal Environment Agency (Section III 3.3) and (since 2009) of the Federal Statistical Office (Section G 202).

The direct N_2O emissions from N excretions during grazing are calculated in proportion to the N quantity excreted on pasture (cf. Chapter 5.1.3.4).

The quantities of N remaining in the soil in crop residues are obtained from the relevant areas under cultivation, yields and crop-specific N content data. Data on areas under cultivation and fresh-matter yields are reported in (Statistisches Bundesamt, FS 3, R 3). The data are converted into dry-matter yields with the help of dry-matter-content data given by the Fertiliser Ordinance (DüV - Düngeverordnung, 2017). The relative N quantities contained in crop residues are taken from the Fertiliser Ordinance (DüV - Düngeverordnung, 2017) and from a list prepared by the Institute of Vegetable and Ornamental Crops (IGZ, 2011). The N quantities removed from relevant areas, for bedding material in animal husbandry, are deducted. For the pertinent input data and calculation methods, cf. Chapter 11.7 in Rösemann et al. (2019b).

Changes with respect to the 2018 Submission result for the following N quantities on which calculation of direct N_2O emissions is based:

- **Manure, including digestates from manure digestion:** The N quantities are higher, for all years, than the quantities reported in the 2018 NIR. There are two main reasons for this: The N_2O emission factor for solid manure that has been used until now has been downwardly corrected (cf. Chapter 5.3.4.2.2). This leaves more N for application, within the storage system. In addition, higher N excretions have resulted for heifers, as a result of the error correction mentioned in Chapter 5.1.3.3. All other instances of updating that are referred to in Chapters 5.1.3.2.3, 5.1.3.3, 5.1.3.6.1, 5.1.3.6.2, 5.1.3.6.5 and 5.3.4.2.3 also have impacts on the N quantity. Those impacts are masked by the impacts tied to the two reasons mentioned immediately above, however.
- **Digestates of energy crops:** The N contributions from this source agree with the values reported in the 2018 NIR, for all years except 2015 and 2016. The differences in the years 2015 and 2016 result from the activity data updates described in Chapter 5.1.4.2. In the year 2015, the pertinent difference is so small that it is not apparent in a comparison of Table 272 with the corresponding table in the 2018 NIR.
- **Sewage sludge:** The quantity of applied sewage sludge has been updated for the year 2016 (slightly reduced).
- **Grazing:** As a result of updating of animal-population data and yield data (cf. Chapters 5.1.3.2.3 and 5.1.3.3), and especially as a result of the corrections in heifer N excretions made with respect to the 2018 NIR (cf. Chapter 5.1.3.3), the N excretions on pasture are noticeably higher with respect to the corresponding figures in the 2018 NIR.
- **Crop residues:** The above-ground crop residues have been updated for some agricultural crops and for grassland. For numerous vegetable crops, the N content in the crop itself, and the applicable ratios of crop residues to harvest quantities, have been updated. These changes have led to higher N quantities in crop residues, for all years.

The time series for N quantities from crop residues shows the following two interesting features: a) a sharp increase from 2013 to 2014, and b) in 2015, a decrease to the level seen in 2013. These features result directly from the excellent harvest obtained in 2014.

Table 272: N quantities on which calculation of direct N_2O emissions from agricultural soils are based (3.D)

[kt a⁻¹]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Mineral fertiliser	2163.7	1787.4	2014.4	1778.4	1807.2	1550.6	1569.0	1786.5	1640.4	1648.8	1675.3	1822.8	1710.6	1658.8
Manure, including digestates from manure digestion	1182.4	1029.7	1009.7	976.2	979.5	986.4	981.7	988.8	1006.1	1020.7	1035.2	1032.8	1028.5	1024.1
Digestates of energy crops	0.0	0.6	5.3	45.2	101.9	131.0	165.1	206.5	227.4	275.6	288.1	300.0	298.3	302.1
Sewage sludge	27.4	35.3	33.0	27.4	25.6	25.5	26.0	25.1	25.0	21.5	21.3	18.7	18.7	18.7
Grazing	218.0	175.7	170.3	150.7	146.7	145.9	144.0	141.0	140.6	142.5	144.3	145.6	144.4	143.0
Crop residues	485.7	498.5	560.5	587.6	615.8	645.1	572.6	560.7	605.6	605.6	689.4	606.3	589.7	621.9

5.1.5.1.2 Area of organic soils under cultivation (3.D)

Table 273 shows the applicable areas of organic soils under cultivation, broken down by cropland and grassland. The data have been provided by the LULUCF sector. They represent the relevant areas of drained grassland. They thus differ from the grassland areas on which the LULUCF sector reports, in Chapter 6.1.2.2.1, since LULUCF also includes areas of undrained wet grassland.

Table 273: Areas of organic soils under cultivation (3.D)

[thousands of ha]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total	**1307.6**	**1303.1**	**1298.6**	**1279.3**	**1267.0**	**1264.3**	**1261.6**	**1258.9**	**1256.2**	**1252.0**	**1247.7**	**1243.5**	1235.1	1235.1
Cropland	301.5	306.1	310.7	315.5	348.4	355.5	362.5	369.6	376.6	378.0	379.3	380.7	383.3	383.3
Grassland (drained)	1006.1	997.0	987.9	963.8	918.6	908.8	899.1	889.3	879.6	874.0	868.4	862.9	851.7	851.7

5.1.5.1.3 Deposition of reactive nitrogen (3.B, 3.D, 3.J)

Deposition of reactive nitrogen is derived from the NH_3 and NO emissions from the German agricultural sector, as calculated in the inventory. This is carried out for the NH_3 and NO sources "housing and storage" (3.B), "storage of digestates of energy crops" (3.J) and "application and grazing" (3.D). In addition to spreading of manure and digestates from manure digestion, "application" also includes spreading of mineral fertiliser and digestates of energy crops.

Table 274 shows, for categories 3.B and 3.J, the quantities of reactive nitrogen on which the calculations of indirect N_2O from N deposition are based. Similar data for the sector 3.D are provided in Table 275. The differences in the two tables, with respect to the 2018 Submission, result from the updating of input data described above, in connection with Table 272.

Table 274: Sectors 3.B and 3.J: Quantities of reactive nitrogen from deposition of NH_3 and NO

[kt a⁻¹]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
3.B, Manure, including digestates from manure digestion	268.4	226.5	227.1	227.5	227.8	228.2	223.2	223.5	227.0	228.4	230.3	227.5	225.7	224.6
3.J, Digestates of energy crops	0.0	0.0	0.1	1.0	1.8	2.2	2.5	2.9	2.4	2.8	2.7	2.8	2.7	2.8

Table 275: Sector 3.D: Quantities of reactive nitrogen from deposition of NH_3 and NO

[kt a⁻¹]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
3.D, Total	**371.9**	**311.2**	**314.4**	**297.9**	**308.5**	**316.7**	**307.1**	**334.3**	**321.2**	**335.0**	**336.5**	**350.1**	**343.8**	**337.8**
3.D, Manure, digestates from manure digestion, mineral fertiliser, grazing	371.9	311.1	313.4	289.1	288.7	291.1	274.7	293.6	278.5	285.3	286.0	298.9	292.9	286.2
3.D, Digestates of energy crops	0.0	0.1	1.0	8.8	19.8	25.6	32.4	40.6	42.6	49.8	50.5	51.1	50.9	51.6

5.1.5.1.4 Leaching and surface runoff (3.D)

For calculation of N_2O emissions from leaching and surface runoff, and in accordance with IPCC (2006): Vol. 4, the activity data used consists of the sum of the nitrogen in applied quantities of mineral fertiliser, manure, digestates (including digestates of energy crops) and sewage sludge, plus the N quantities in crop residues. For details, cf. Chapter 12.2 in Rösemann et al. (2019b).

Only part of the available N quantity is leached. The ratio of that quantity to the available N quantity is given by $Frac_{LEACH}$ (cf. IPCC (2006): Vol. 4, 11.21). For $Frac_{LEACH}$, Germany uses the IPCC default value 0.30 kg kg^{-1} (IPCC (2006)). Vol. 4, 11.24, Table 11.3). The criterion for use of that default value is that the soil's water-retention capacity is exceeded; cf. (IPCC (2006): Vol. 4, 11.24, Table 11.3). This criterion must be assumed to be fulfilled, on a yearly average, throughout all Germany, since new groundwater formation takes place everywhere in Germany (Neumann & Wycisk, 2002). The calculated quantities of leached nitrogen are shown in Table 276. The differences, with respect to the 2018 Submission, result from the updating of input data described in Chapter 5.1.5.1.1, in connection with Table 272.

Table 276: Leached N quantity (including surface runoff) (3.D)

[kt a^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
	1223.2	1058.2	1137.9	1069.6	1103.0	1045.4	1037.6	1112.6	1093.5	1114.4	1156.0	1177.9	1137.1	1130.6

5.1.5.2 CO_2 emissions from liming and urea application (3.G-I)

The reports differentiate between dolomite and the other lime fertilisers, in order to take account of how the two groups differ in carbonate carbon content, as well as in their CO_2 emission factors. With regard to the other lime fertilisers, application of calcium ammonium nitrate is considered as a separate case. The CO_2 emissions from such application are reported under CRF 3.I ("Other carbon-containing fertilisers"). CO_2 emissions from application of other lime fertilisers and dolomite are reported under CRF 3.G. The reported CO_2 emissions comprise, in keeping with the requirement in (IPCC (2006): Vol. 4, Chapter 11.3) and CRF Table 3.G-I, both emissions from agriculture and emissions from liming in the forestry sector.

No data on applied quantities of lime fertiliser are available. For this reason, the applied quantities are considered to be equal to the product quantities sold, and statistically recorded (Statistisches Bundesamt, FS 4, R 8.2), within the country. The delay in the relevant surveys amounts to half a year. For purposes of the inventory, it is assumed that all of the lime fertiliser sold in the second half of year j-1, and all of the lime fertiliser sold in the first half of year j, is applied (spread) in year j. Calcium carbonate, compound lime, carbolic lime ("Carbokalk"), residual lime and calcium ammonium nitrate are all taken into account. For purposes of emissions calculations, product quantities reported in units of CaO or N are converted into units of $CaCO_3$, for limestone, and of $CaMg(CO_3)_2$, for dolomite.

Dolomite's share of the total quantity of fertiliser lime is not recorded statistically. For purposes of the inventory, that share has been calculated on the basis of the expert judgement (personal communication of R. Müller of the Düngekalk-Hauptgemeinschaft group (a department within the BV Kalk lime industry association)), Cologne, 25 August 2016), according to which the lime fertiliser used in the forestry sector consists of one-third $MgCO_3$, and the use of dolomite in the agricultural sector is negligible.

Table 277 shows the lime-fertiliser quantities, for the agriculture and forestry sectors taken together, on which the emissions calculations are based; cf. Chapter 11.9 in Rösemann et al. (2019b).

Table 277: Lime-fertiliser quantities (3.G & 3.I)

[kt a⁻¹]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Limestone [in $CaCO_3$]	4175.2	2580.2	3791.2	3008.2	3319.2	3342.5	3164.0	3468.6	3661.4	3803.8	4369.4	4304.6	3795.3	4278.7
Dolomite [in $CaMg(CO_3)_2$]	763.0	425.0	339.8	195.7	151.8	190.5	166.7	184.0	174.8	198.0	186.1	164.6	133.7	118.7
Calcium ammonium nitrate [in $CaCO_3$]	1143.7	925.0	897.3	705.6	686.2	531.5	604.6	617.8	578.3	535.2	524.9	550.6	497.3	491.1

The CO_2 emissions from urea application are calculated in proportion to the quantities of applied urea listed in Table 278 (including applied urea ammonium nitrate solution). These quantities were derived stoichiometrically (via multiplication by the molar ratio 60/28) from the urea-N quantities reported in official statistics.

Table 278: Applied quantities of urea, including urea ammonium nitrate solution (3.H)

[kt a⁻¹]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
	654.0	650.8	788.9	815.4	883.5	1084.1	801.0	1022.6	852.0	947.8	951.6	1167.6	1118.7	1048.3

5.1.5.3 NMVOC emissions from agricultural crops

Table 279 shows the input data for agricultural crops for which NMVOC emissions are calculated pursuant to EMEP (2016)-3D-15 ff (cf. Chapter 5.5.2.1.5). The beginning and end years of the time series are listed, by way of example, for the relevant areas under cultivation and the fresh-matter yields. Data on areas under cultivation and fresh-matter yields are reported in (Statistisches Bundesamt, FS 3, R 3). The data are converted into dry-matter yields on the basis of DM-content data given by the Fertiliser Ordinance (DüV - Düngeverordnung, 2017). The relative emission duration for wheat, rye, rape and grass have been taken from EMEP (2016)-3D-16, Table 3-3, and applied, analogously, to the other crops involved.

Table 279: Input data for calculation of NMVOC emissions from agricultural crops (overview)

Crop	Area under cultivation [ha]		Fresh matter yield [Mg ha⁻¹]		DM content [kg kg⁻¹]	Relative emission duration [a a⁻¹]
	1990	2017	1990	2017		
Wheat	2419.9	3172.8	6.3	7.7	0.86	0.3
Rye	1067.1	537.3	3.8	5.1	0.86	0.3
Barley	2612.5	1566.2	5.4	6.9	0.86	0.3
Oats	533.5	139.7	4.5	4.5	0.86	0.3
Triticale	77.4	389	5.1	6.0	0.86	0.3
Grain maize	228.4	432.2	6.8	10.5	0.86	0.3
Silage maize	1365.4	2096.1	40.4	47.5	0.28	0.3
Rape	557.5	1304.7	3.0	3.3	0.91	0.3
Root crops	1249.6	656.9	40.6	69.7	0.22	0.3
Grass clover ley, alfalfa, forage grass	856.6	549.9	34.0	39.9	0.20	0.5
Legumes	121.2	197.0	3.4	3.7	0.86	0.3
Pastures and meadows	5417.2	4507.3	31.6	34.0	0.20	0.5

5.1.6 Total uncertainty of all GHG emissions in sector 3

Along with calculation of emissions, the total uncertainty for all GHG emissions in Sector 3 was calculated. This was done in accordance with the "Approach 1" procedure described in IPCC (2006), Chapter 3, a procedure based on Gaussian error propagation calculation. By way of convention, it is ignored that such error propagation calculations assume a normal distribution, a distribution requirement that some of the activity data and emission factors that enter into the calculation do not meet or cannot be verified to meet. The standard version of the "Approach 1" described in IPCC (2006): Vol. 1, Chapter 3 is used as a basis for the present greenhouse-gas inventory for the agricultural sector: The emission factors for the various time-series years are correlated, while the activity data are uncorrelated. For asymmetric distributions, the larger of the two intervals [2.5 percentile; average] and [average; 97.5 percentile] was used, as required by

IPCC (2006): Vol. 1, Chapter 3, for "Approach 1." (For the Federal Environment Agency's uncertainties calculation, using the "Approach 2" procedure, for the greenhouse-gas report as a whole, the upper and lower bound of the 95 % confidence interval, and the type of distribution involved, were provided in the CSE for all uncertainties of agricultural figures.) Further details on uncertainties calculation for the German inventory are presented in Chapter 14 in Rösemann et al. (2019b).

Table 280 shows, for the time-series year 2017, the total uncertainty, as calculated with the "Approach 1" procedure, for all emissions of the "agriculture" sector (Sector 3), including emissions from digestion of energy crops and from storage and application of digestates of energy crops. Table 280 also shows the uncertainty for the overall trend since 1990. All emissions values are given in CO_2 equivalents; pursuant to IPCC (2006): Vol. 4, these conversions were obtained using the greenhouse warming potential (GWP) conversion factors 25 kg kg^{-1} for CH_4 and 298 kg kg^{-1} for N_2O.

In the interest of clarity, the presentation in Table 280 uses the collective animal categories "other cattle," "swine," "horses" and "poultry." The uncertainties given here for activity data and emission factors apply for each individual sub-category. The uncertainties calculations for emissions level and trend, as given in Table 280, were carried out using all of the individual sub-categories and their specific uncertainties, however.

With regard to the uncertainty values used, cf. Chapters 5.2.3, 5.3.2.3, 5.3.4.3, 5.3.5.3, 5.5.4, 5.8.4 and 5.9.7. The uncertainties for the emission factors clearly tend to be considerably higher than those for the activity data, and thus they predominate in the combined uncertainty in the column "Combined uncertainty as % of total national emissions".

The total uncertainty for the emissions in sector 3 (animal husbandry, use of agrictural soils, digestion of energy crops) is 36.5 % (valid for the year 2017). It is caused, to a large extent, by the uncertainties for the N_2O emissions from agricultural soils, as the column "Combined uncertainty as % of total national emissions" indicates. The uncertainty for the trend for the period 1990 – 2017 is 12.9 %.

Table 280: Total-uncertainties calculation for emissions from Sector 3 (animal husbandry, agricultural soils), including digestion of energy crops

Source category EntFer = Enteric Fermentation MM = Manure Management DEC = Digestion of Energy Crops	Gas	Base year emissions, in CO_2 equivalents (GWP$_{CH4}$ = 25, GWP$_{N2O}$ = 298)	Year 2017 emissions, in CO_2 equivalents	Activity data uncertainty (half the 95 % confidence interval)	Emission factor uncertainty (half the 95 % confidence interval)	Combined uncertainty (half the 95 % confidence interval)	Auxiliary calculations [A]	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Square of "Uncertainty introduced into the trend in total national emissions" [B]
		kt a^{-1}	kt a^{-1}	%	%	%		%	%	%	%	
EntFer, dairy cows	CH_4	19,074.7	14,337.5	4	20	20.4	19.5	0.02	0.18	0.41	1.02	1.22
EntFer, other cattle	CH_4	14,866.4	10,042.4	4	20	20.4	9.6	0.03	0.13	0.60	0.72	0.88
EntFer, swine	CH_4	677.7	661.1	4	20	20.4	0.0	0.00	0.01	0.02	0.05	0.00
EntFer, sheep	CH_4	518.2	296.4	10	30	31.6	0.0	0.00	0.00	0.05	0.05	0.01
EntFer, goats	CH_4	11.3	17.7	20	30	36.1	0.0	0.00	0.00	0.00	0.01	0.00
EntFer, horses	CH_4	204.6	180.5	10	30	31.6	0.0	0.00	0.00	0.00	0.03	0.00
MM, dairy cows	CH_4	2,640.6	2,210.0	4	20	20.4	0.5	0.00	0.03	0.00	0.16	0.02
MM, other cattle	CH_4	2,623.8	1,514.4	4	20	20.4	0.2	0.01	0.02	0.17	0.11	0.04
MM, swine	CH_4	2,684.7	2,370.3	4	20	20.4	0.5	0.00	0.03	0.03	0.17	0.03
MM, sheep	CH_4	22.5	12.9	10	30	31.6	0.0	0.00	0.00	0.00	0.00	0.00
MM, goats	CH_4	0.5	0.8	20	30	36.1	0.0	0.00	0.00	0.00	0.00	0.00
MM, horses	CH_4	38.8	34.2	10	30	31.6	0.0	0.00	0.00	0.00	0.01	0.00
MM, poultry	CH_4	89.4	148.2	10	20	22.4	0.0	0.00	0.00	0.02	0.03	0.00
MM, direct N_2O, dairy cows	N_2O	1,028.5	746.1	4	100	100.1	1.3	0.00	0.01	0.14	0.05	0.02
MM, direct N_2O, other cattle	N_2O	1,113.8	818.5	4	100	100.1	1.5	0.00	0.01	0.14	0.06	0.02
MM, direct N_2O, pigs	N_2O	376.4	494.3	4	100	100.1	0.6	0.00	0.01	0.23	0.04	0.05
MM, direct N_2O, sheep	N_2O	28.5	16.2	10	100	100.5	0.0	0.00	0.00	0.01	0.00	0.00
MM, direct N_2O, goats	N_2O	1.6	2.6	20	100	102.0	0.0	0.00	0.00	0.00	0.00	0.00
MM, direct N_2O, horses	N_2O	60.1	53.1	10	100	100.5	0.0	0.00	0.00	0.00	0.01	0.00
MM, direct N_2O, poultry	N_2O	37.5	67.1	10	100	100.5	0.0	0.00	0.00	0.05	0.01	0.00
MM, indirect N_2O, all animals	N_2O	1,256.9	1,051.7	40	400	402.0	40.7	0.00	0.01	0.00	0.75	0.56
Soils, mineral fertilisers	N_2O	10,132.1	7,768.1	1	200	200.0	549.6	0.01	0.10	1.79	0.14	3.23
Soils, spreading of manure	N_2O	5,537.1	4,795.5	20	200	201.0	211.5	0.00	0.06	0.41	1.71	3.10
Soils, sewage sludge	N_2O	128.4	87.5	20	200	201.0	0.1	0.00	0.00	0.05	0.03	0.00
Soils, crop residues	N_2O	2,274.4	2,912.3	50	200	206.2	82.1	0.01	0.04	2.55	2.60	13.25
Soils, organic soils	N_2O	2,594.2	2,838.2	1	200	200.0	73.4	0.01	0.04	1.68	0.05	2.84
Soils, grazing	N_2O	1,951.3	1,279.1	20	200	201.0	15.0	0.00	0.02	0.89	0.46	1.01
Soils, indirect N_2O (deposition)	N_2O	1,741.3	1,340.1	50	400	403.1	66.4	0.00	0.02	0.59	1.20	1.78
Soils, indirect N_2O (leaching, runoff)	N_2O	4,295.8	3,652.5	170	230	286.0	248.5	0.00	0.05	0.17	11.09	122.97

Source category EntFer = Enteric Fermentation MM = Manure Management DEC = Digestion of Energy Crops	Gas	Base year emissions, in CO_2 equivalents	Year 2017 emissions, in CO_2 equivalents	Activity data uncertainty (half the 95 % confidence interval)	Emission factor uncertainty (half the 95 % confidence interval)	Combined uncertainty (half the 95 % confidence interval)	Auxiliary calculations [A]	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Square of "Uncertainty introduced into the trend in total national emissions" [B]
		(GWP_{CH4} = 25, GWP_{N2O} = 298)										
		$kt\ a^{-1}$	$kt\ a^{-1}$	%	%	%		%	%	%	%	
DEC, digester and storage	CH_4	0.3	1,357.9	10	20	22.4	0.2	0.02	0.02	0.34	0.24	0.18
DEC, storage, direct N_2O	N_2O	0.1	253.6	10	100	100.5	0.1	0.00	0.00	0.32	0.05	0.10
DEC, storage, indirect N_2O (deposition)	N_2O	0.0	13.0	10	400	400.1	0.0	0.00	0.00	0.07	0.00	0.00
DEC, soils, direct N_2O	N_2O	0.2	1,414.9	10	200	200.2	18.3	0.02	0.02	3.57	0.25	12.83
DEC, soils, indirect N_2O (deposition)	N_2O	0.0	241.8	10	400	400.1	2.1	0.00	0.00	1.22	0.04	1.49
DEC, soils, indirect N_2O (leaching, runoff)	N_2O	0.0	318.4	10	230	230.2	1.2	0.00	0.00	0.92	0.06	0.86
Liming, without dolomite	CO_2	1,837.1	1,882.6	3	3	4.2	0.0	0.00	0.02	0.01	0.10	0.01
Liming, dolomite	CO_2	363.7	56.6	100	3	100.0	0.0	0.00	0.00	0.01	0.10	0.01
Liming, calcium ammonium nitrate	CO_2	503.2	216.1	3	3	4.2	0.0	0.00	0.00	0.01	0.01	0.00
Application of urea	CO_2	479.6	768.7	1	1	1.4	0.0	0.00	0.01	0.00	0.01	0.00
Total		79,195.5	66,272.9									
					Percentage uncertainty in total inventory:		36.5			Trend uncertainty (percentage):		12.9

[A] The data in this column describe auxiliary data needed to derive the percentage uncertainty in total inventory in the bottommost cell of this column. In order to calculate the data the calculation procedure provided by IPCC (2006b) 3.31, Table 3.2, column H, has been used. Note, however, that the head of column as prescribed by IPCC (2006)-3.31, Table 3.2, column H ("Contribution to Variance by Category") does not correctly describe the data in column H. Hence the head of column has been modified.

[B] The head of this column, as prescribed by IPCC (2006b)-3.31, Table 3.2, column M („Uncertainty introduced into the trend in total national emissions“), has been modified in order to match the formula provided by IPCC (2006b) and applied in the table above to calculate the data in this column.

5.1.7 Quality assurance and control

General quality control (QC) and, additionally for 3.D & 3.J, category-specific quality control, and quality assurance (QA), have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity (SNE).

5.1.7.1 The Thünen Institute's quality management for emissions inventories

The Thünen Institute's quality management for emissions-inventory preparation has been developed in conformance with the IPCC guidelines and the QSE (Chapter 1.6.1). The framework for the quality management, and the process for carrying it out, are described in detail in the relevant concept (BMELV, 2016) and in the provisions for implementation of the concept (TI (Johann Heinrich von Thünen-Institut), 2016). Documents of importance for quality control are added to the inventory description that is archived by the Single National Entity. The requirements and procedures set forth by the provisions for implementation of the concept were fully complied with. The following sections discuss important aspects of the quality control for the present submission.

5.1.7.2 Input data, calculation procedures and emissions results

Checking of the emissions calculations and of the NIR has included checking for the following:

- The equations used in the calculation procedures agree formally with those used for the 2018 emissions report.
- For purposes of quality assurance, the following areas were checked in advance of the 2018 emissions report:
    - Calculation procedures for cattle (checked by KTBL);
    - VS and N excretions of sheep and horses (checked by Thünen Institute);
    - Characteristics of concentrates for dairy cows, heifers and male beef cattle (checked by Thünen Institute);
    - National N_2O emission factor for solid manure (checked by KTBL).
- The following changes have been made on the basis of the results of such checking (cf. Chapter 3.5.2 in (Rösemann et al., 2019b)):
    - For heifers, the coefficients for calculation of cumulative energy requirements have been corrected. This has led to a considerable increase in VS and N excretions and in the related emissions. For male beef cattle older than two years, the applicable quantity of bedding material was reduced. This led to a slight decrease of the potential for N emissions.
    - For sheep and horses, the VS excretions were upwardly corrected. This resulted in higher CH_4 emissions from manure management. (The N excretions did not require updating.)
    - For dairy cows, heifers and male beef cattle, the characteristics of concentrates have been partly updated. The relevant impacts are slight.
    - National N_2O emission factor for solid manure: The emission factor, which was based on a very limited database, and which was not in agreement with the IPCC (2006) emission factor for deep bedding, has been replaced with the relevant value from IPCC (2006). This has led to a decrease in N_2O emissions from manure management for solid-manure systems, and to an increase in N_2O emissions from agricultural soils.
- The activity data have been checked for plausibility and consistency and updated, as necessary, on the basis of newer data.

- It has been ensured that the areas of the organic soils used for cropland or as managed grassland are consistent across the LULUC (Chapter 4.B, 4.C) and Agriculture (3.D) sections.
- Every single time series of the emissions results for the 2019 Submission was checked for consistency with the corresponding time series in the 2018 Submission. All discrepancies can be explained as the result of updating of input data.
- The fluctuations and trends in the time series can be explained, and the most important of these are described in the NIR.
- The activity data and emissions results were compared with corresponding data of central European countries that are either direct neighbors of Germany or that have comparable agricultural practices. In most cases, the German data fall within the middle range, or are at the level found in one or more of the countries being compared, or are at the level of an IPCC (2006) standard value. Any important departures from these criteria discrepancies can be justified, in each individual case.
- The input data and calculation results for all relevant emission sources in agricultural-sector emissions reporting are provided, as background for the results presented in the NIR 2019 and the CRF tables, in an EXCEL file that is available as a supplement to Rösemann et al. (2019b) (cf. Chapter 2.4 in (Rösemann et al., 2019b)).
- The data in the NIR text have been checked for consistency, via comparison with the calculation results.
- To ensure that the activity data and emission factors (IEF) were correctly entered into the Central System of Emissions (CSE) database, on which the CRF tables are based, the emissions as calculated with the CSE were compared with the emissions as calculated with the GAS-EM inventory model.

5.1.7.3 Verification

The national emissions results calculated with the GAS-EM inventory model cannot be compared with other pertinent data from Germany, since no such data are available. Consequently, as described in Chapter 5.1.7.2, the input data and emissions results were compared with corresponding data of other countries and with IPCC (2006) default values. That process is discussed in the present NIR, in the relevant sub-chapters.

In the framework of a verification project for the 2014 NIR, an external expert (Zsolt Lengyel, Verico SCE) reviewed the German emissions calculations. That review found that the input data are consistent, and that the calculations are consistent and have been carried out in keeping with the methodological requirements set forth in the IPCC Guidelines.

Furthermore, the GAS-EM model is continuously validated and verified in the framework of the European Agricultural Gaseous Emission inventory Research network (EAGER) group and, via review of modules, by KTBL (cf. Chapter 5.1.7.2).

5.1.7.4 Reviews and reports

The ERT recommendations from the reviews through the 2015 Submission have been implemented.

The recommendations made by the Expert Review Team in the 2016 In Country Review have been implemented in full. This applies especially to the aspects on which the 2016 Resubmission was based:

- An increase of the Tier 1 emission factor for CH_4 from enteric fermentation of lambs, from 3.2 kg place^{-1} a^{-1} to 3.6 kg place^{-1} a^{-1};
- Adjustment of the method for calculation of indirect N_2O emissions from leaching and surface runoff, to bring the calculation into line with the IPCC (2006) methods;

- Calculation of CO_2 emissions from liming carried out separately for dolomite and limestone.

The Individual Review of the 2017 German reporting for 2015, which was planned for September 2017, did not take place. The 2017 report was reviewed in spring 2017, however, in the framework of an EU review pursuant to Article 19(2) of EU Regulation 525/2013. In Step 1 of that review, all five of the questions raised by the Technical Expert Team with regard to the agricultural sector were satisfactorily answered (EEA, 2017). No changes in the inventory methods or input data were called for. As a result of this positive result in Step 1, Step 2, which the EU regulations would normally call for, was waived.

The review of the 2018 report took place in September 2018. At the time the present 2019 NIR was being prepared, the final review report was not yet available (cf. Chapter 1.6.1.3).

A national quality audit carried out by the firm of Verico SCE (auditor for the agricultural sector: Markus Helm), in April 2016, confirmed that the reporting system's Quality System for Emission Inventories (QSE) – and thus its emissions reporting for the agricultural sector – are in conformance with the requirements of the IPCC (2006) Guidelines (Betzenbichler et al., 2016).

5.2 Enteric fermentation (3.A)

5.2.1 Category description (3.A)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
L/-	**3.A.1 Enteric fermentation**	**Dairy cows**	**CH_4**	**19,074.71**	**1.56%**	**14,337.51**	**1.61%**	**-24.8%**
L/T	**3.A.1. Enteric fermentation**	**Other cattle**	**CH_4**	**14,866.45**	**1.22%**	**10,042.41**	**1.13%**	**-32.4%**
-/-	3.A.2.-4. Enteric fermentation	Other animals (sheep, goats, horses, swine)	CH_4	1,411.78	0.12%	1,155.73	0.13%	-18.1%

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier1/Tier2/Tier3	M/Q/AS/RS/NS	CS/D

The category *Dairy cows* is the most important emissions source within the source category *Enteric fermentation*. It is a key category for methane in terms of emissions level. This is due to the large numbers of animals and the high yields involved. The category *Other cattle* is also a key category – in terms of both emissions level and trend.

CH_4 from enteric fermentation occurs via microbial conversions in animals' digestive tracts. The quantities released per animal and unit of time depend on the animal species in question, individual-animal yield and feed composition.

Germany reports CH_4 emissions from enteric fermentation of dairy cows, other cattle (calves, heifers, bulls, suckler cows, male cattle older than 2 years), swine (sows, including suckling piglets weighing up to 8 kg per animal, weaner piglets, fattening pigs and boars), sheep, goats and horses.

The CH_4-emissions trend is shaped by decreasing animal populations – for cattle especially, throughout the entire period, and for all animal categories in the early 1990s – and by improved feed digestibility, which is partly offset by increasing GE intake levels in connection with increases in milk production and animal weights.

Table 281 shows the changes of CH_4 emissions from enteric fermentation, for the entire livestock population since 1990, as well as the percentage shares of these emissions with respect to the total emissions from the German agricultural sector, broken down by CH_4 and greenhouse gases (GHG, in CO_2 equivalents). The percentage shares of the total emissions differ, since the GHG also include the N_2O emissions.

Table 281: CH_4 emissions from enteric fermentation, in the entire animal husbandry sector (3.A): Changes since 1990, and shares of total emissions from the German agricultural sector (broken down by CH_4 and GHG (CO_2)) (3.A)

[%]	Change since 1990	Share of total agricultural emissions (CH_4 and GHG)	
		1990	2017
CH_4	-27.8	81.4	77.0
GHG (CO_{2eq})		44.6	38.5

5.2.2 Methodological issues (3.A)

5.2.2.1 Methods (3.A)

The CH_4 emissions from enteric fermentation of dairy cows are calculated with a national method (Tier 3); see below. For other cattle and swine, the calculation is a Tier 2 method (IPCC (2006): Vol. 4, 10.24 ff); see below. Figures for sheep, goats and horses are calculated using a Tier 1 method that employs default emission factors (cf. Chapter 5.2.2.2).

In the national method for calculation of CH_4 emissions from enteric fermentation of dairy cows (Dämmgen et al., 2012c), the emission factor is calculated, pursuant to Kirchgessner et al. (1994), as a function of intake of raw fibre, N-free extracts, raw protein and fat:

Equation 11: Calculation of the CH_4 emission factor for dairy cows (national method)

$$EF_{\mathrm{CH4,ent}} = a \cdot M_{\mathrm{XFi}} + b \cdot M_{\mathrm{NFE}} + c \cdot M_{\mathrm{XP}} + d \cdot M_{\mathrm{XF}} + e$$

Where

$EF_{\mathrm{CH4,\ ent}}$	Emission factor for CH_4 from enteric fermentation (in kg place^{-1} a^{-1} CH_4)
a	Coefficient (a = 0.079 kg kg^{-1})
M_{XFi}	Raw-fibre intake (in kg place^{-1} a^{-1})
b	Coefficient (b = 0.010 kg kg-1)
M_{NFE}	Intake of N-free extracts (in kg place^{-1} a^{-1})
c	Coefficient (c = 0.026 kg kg^{-1})
M_{XP}	Intake of raw protein (in kg place^{-1} a^{-1})
d	Coefficient (d = - 0.212 kg kg^{-1})
M_{XF}	Intake of fat (in kg place^{-1} a^{-1})
e	Constant (e = 365 · 0.063 kg place^{-1} a^{-1})

The intake of raw fibre, N-free extracts, raw protein and fat is determined from the basic feed-composition data and from the pertinent quantities of ingested feed (cf. Chapter 5.1.3.3).

The methane conversion factor is calculated from those figures, with the help of the GE intake (cf. Chapter 5.1.3.3):

Equation 12:

$$x_{\mathrm{CH4,GE}} = \frac{\eta_{\mathrm{CH4}} \cdot EF_{\mathrm{CH4,ent}}}{GE}$$

Where

$x_{\mathrm{CH4,\ GE}}$	Methane-conversion factor for dairy cows (in MJ MJ^{-1})
η_{CH4}	Energy content of methane (η_{CH4} = 55.65 MJ (kg CH_4)$^{-1}$)
$EF_{\mathrm{CH4,\ ent}}$	Emission factor for CH_4 from enteric fermentation (in kg place^{-1} a^{-1} CH_4)
GE	Gross energy intake (in MJ place^{-1} a^{-1} GE)

As a result of increasing milk yields, the feed intake and, thus, the GE intake, for dairy cows increase over the years, with the relative fraction of more easily digestible concentrated feed, i.e. as a share of the total ration, growing and thereby supplanting basic feed; cf. Chapter 4.3.3.3 in Rösemann et al. (2019b). As a result of this shifting within feed rations, the increase in the CH_4 emissions from enteric fermentation, as calculated with Equation 7, is smaller than the increase in the GE intake. This results, in turn, in a decreasing trend over the years, tied to the trend in milk yield, in the methane conversion factor; cf. Table 282 and Chapter 5.2.2.3.

Table 282: Dairy cows: Milk yield, GE intake, enteric-fermentation related CH_4 emissions and methane conversion factor (3.A)

	1990	2017
Average daily milk yield [kg animal place^{-1} d^{-1}]	12.9	21.3
Annual GE intake [GJ animal place^{-1} a^{-1}]	94.7	120.7
Annual CH_4 emissions from enteric fermentation [kg animal place^{-1} a^{-1}]	120.1	136.6
Methane conversion factor [MJ MJ^{-1}]	0.071	0.063

The Tier 2 method that is used for other cattle and swine calculates the emission factor from the GE intake (cf. Chapter 5.1.3.3) and the methane conversion factor, in accordance with the following formula:

Equation13: Calculation of the CH_4 emission factor (Tier 2 method, IPCC (2006)): Vol. 4, p. 10.31)

$$EF_{CH4,ent} = GE \cdot \frac{x_{CH4,GE}}{\eta_{CH4}}$$

Where

$EF_{CH4,ent}$	Emission factor for CH_4 from enteric fermentation (in kg place^{-1} a^{-1} CH_4)
GE	Gross energy intake (in MJ place^{-1} a^{-1} GE)
$x_{CH4,GE}$	Methane-conversion factor (in MJ MJ^{-1})
η_{CH4}	Energy content of methane (η_{CH4} = 55.65 MJ (kg CH_4)$^{-1}$)

The category-specific methane conversion factors for the various sub-categories of the other cattle are given in Table 283. Due to changes in the composition of the overall population, the weighted average value for all other cattle varies slightly over the years. Table 283 shows the average value for all other cattle for the first and last year of the time series.

Table 283: Methane conversion factors for other cattle (3.A)

	MJ MJ^{-1}	Source
Heifers, male beef cattle, suckler cows, mature males > 2 years	0.065	(IPCC, 2006): Vol. 4, Tab. 10.12
Calves	0.041	(DÄMMGEN ET AL., 2013)
Average value for all other cattle, 1990	0.0638	Calculation
Average value for all other cattle, 2017	0.0638	Calculation

Table 284 shows the national category-specific methane conversion factors for the various swine categories (Dämmgen et al., 2012c), along with the weighted average values for all swine in the first and last year of the time series. The average values differ as a result of the changes in the composition of the overall swine population.

Table 284: Methane conversion factors for swine (Dämmgen et al., 2012c) (3.A)

	MJ MJ^{-1}
Sows	0.0071
Weaners	0.0044
Fattening pigs	0.0046
Boars	0.0071
Average values for all swine, 1990	0.0052
Average values for all swine, 2017	0.0050

With regard to the emission factors calculated with Equation13, cf. Chapter 5.2.2.2.

A general description of calculation of CH_4 emissions from enteric fermentation is provided in Chapter 3.3.2 in Rösemann et al. (2019b). Animal-specific details are also provided in Rösemann et al. (2019b), in the chapters referred to in Table 285.

Table 285: Descriptions of calculation of CH_4 emissions from enteric fermentation, in Rösemann et al. (2019)

Animal category	Chapter	Animal category	Chapter
Dairy cows	4.3.5	Mature sheep	6.3.2
Calves	4.4.3	Lambs	6.4.2
Heifers	4.5.4	Goats	6.6.2
Male beef cattle (for fattening)	4.6.4	Heavy horses	7.3.2
Suckler cows	4.7.3	Light horses / ponies	7.4.2
Male cattle > 2 years	4.8.3	Laying hens	---
Sows	5.3.4	Broilers	---
Weaners	5.4.4	Pullets	---
Fattening pigs	5.5.4	Geese	---
Boars	5.6.4	Ducks	---
		Turkeys	---

5.2.2.2 Emission factors (3.A)

Table 286 shows the CH_4 emission factors calculated per animal place for enteric fermentation of dairy cows, other cattle and swine.

Table 286: Animal-place-based CH_4 emission factors, enteric fermentation (3.A)

[kg $^{-1}$ place^{-1} a^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Dairy cows	120.1	124.6	128.5	131.5	131.9	132.6	133.6	134.3	134.7	134.7	135.4	135.9	136.4	136.6
Other cattle	45.3	46.7	48.8	48.7	48.8	48.8	49.1	49.0	49.0	49.2	49.2	49.6	49.7	49.7
Swine	1.02	1.07	1.09	1.10	1.10	1.11	1.12	1.12	1.12	1.13	1.14	1.14	1.15	1.15

The changes with respect to the 2018 Submission result from the changes, as mentioned in Chapter 5.1.3.3, in animal-yield data.

Table 287 shows the inventory's Tier 1 emission factors for sheep, goats and horses. The values shown have been used for the entire time series. The emission factor for goats has been taken from IPCC (2006): Vol. 4, Tab. 10.10. The emission factors given in IPCC (2006): Vol. 4, Tab. 10.10 for sheep and horses have been used for adult sheep and heavy horses; cf. Chapters 6.3.2 and 7.3.2 in Rösemann et al. (2019b). The emission factors for lambs and light horses / ponies have been derived from the Tier 1 emission factors for adult sheep and heavy horses, respectively; cf. Chapters 6.4.2 and 7.4.2 in Rösemann et al. (2019b). Because the compositions of the small-animal / large-animal populations do not remain constant, the emission factors reported in the CRF tables vary slightly, from year to year, for sheep overall and for horses overall. Table 287 shows the average value for 2017.

Table 287: Tier 1 emission factors for CH_4 from enteric fermentation of sheep, goats and horses (3.A)

[kg place^{-1} a^{-1}]	EF	Average value for 2017
Mature sheep	8.0	6.4
Lambs	3.6	
Goats	5.0	5.0
Heavy horses	18.0	16.6
Light horses / ponies	12.0	

5.2.2.3 Emissions (3.A)

The calculated CH_4 emissions from enteric fermentation, for all German animal husbandry, are listed in Table 288.

Table 288: CH_4 emissions from enteric fermentation (3.A)

[kt a⁻¹]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total	**1414.1**	**1201.1**	**1124.0**	**1037.1**	**1033.9**	**1034.4**	**1030.2**	**1017.7**	**1019.3**	**1036.1**	**1044.1**	**1042.4**	**1030.9**	**1021.4**
in % of 1990	**100.0**	**84.9**	**79.5**	**73.3**	**73.1**	**73.1**	**72.8**	**72.0**	**72.1**	**73.3**	**73.8**	**73.7**	**72.9**	**72.2**
Dairy cows	763.0	651.5	587.3	557.3	556.4	557.7	559.0	562.7	564.3	575.0	581.5	582.3	575.3	573.5
Other cattle	594.7	497.9	486.4	428.6	427.4	426.8	423.6	408.5	407.6	414.4	415.5	413.9	409.6	401.7
Swine	27.1	21.9	23.8	25.0	25.1	25.7	24.8	25.5	26.5	26.4	26.9	26.2	26.1	26.4
Sheep	20.7	18.9	17.6	16.9	15.4	15.0	14.3	12.6	12.5	11.9	12.0	11.9	11.8	11.9
goats and horses	8.6	10.9	9.0	9.3	9.6	9.2	8.4	8.4	8.3	8.3	8.2	8.1	8.0	7.9

The emissions trend since 1990 has been shaped primarily by

- the trend in numbers of animals (cf. Chapter 5.1.3.2.3), especially with regard to cattle, which make an especially significant contribution to emissions from enteric fermentation (the dairy-cow population in 2017 was about 34 % lower than it was in 1990; the corresponding figure for other cattle is about 38 % lower than the figure in 1990);
- continual increases in yields (milk production, animal weights, weight gains); cf. Chapter 5.1.3.3;
- considerable decrease, over the years, of the methane conversion factor for dairy cows (cf. Chapter 5.2.2.1).

5.2.3 Uncertainties and time-series consistency (3.A)

Table 280 in Chapter 5.1.6 shows the uncertainties in activity data and emission factors that have been used in estimating the total uncertainty of the German GHG inventory.

The uncertainty for CH_4 emission factors for enteric fermentation is a default value from IPCC (2006): Vol. 4, p. 10.33. With regard to the uncertainty of the activity data (animal-population data), cf. Chapters 4.1.2, 5.1.2, 6.1.2, 7.1.2 and 8.1.2 in Rösemann et al. (2019b).

The emissions time series are consistent, since they were calculated with the same method for all years of the report period, and since the input data are also consistent and complete.

5.2.4 Source-specific quality assurance / control and verification (3.A)

With regard to quality control and quality assurance, we refer to Chapter 5.1.7.

As part of verification, the German animal husbandry data for dairy cows, other cattle and swine were compared with the corresponding IPCC default values and with relevant data of neighboring countries, including data of the UK (cf. Table 289 and Table 290). At the time the German 2019 report was being prepared, the results of the other countries' 2019 emission reporting were not yet known. For this reason, data from 2018 reports are being used for those countries, although the German data have been taken from the current 2019 report. The international comparison is being carried out for 2016 (the last time-series year in the 2018 report).

Table 289 shows, for dairy cows, the national mean figure for animal-place-related emission factor (implied emission factor, IEF), GE intake and milk yield (which is the key factor affecting emissions levels). The CH_4-conversion factor is also included. It is used to calculate the fraction of GE intake that is converted into methane energy that is lost with emitted methane (cf. the method description in Chapter 5.2.2.1).

Of the ten countries compared with Germany, Denmark has the highest IEF, while the UK has the lowest. Germany's IEF falls into the middle of the ranking. This also applies to its GE-intake and milk yield figures. With regard to methane conversion factors, three countries (Austria, Czech Republic and Poland) have used the IPCC default value of 6.5 %. The value used by Switzerland is considerably higher than the IPCC default value. The methane conversion factors used by Belgium, Denmark, France, Germany and the Netherlands are lower than the IPCC default value, with the German value coming closest to the IPCC default value.

Table 289: Methane emissions from enteric fermentation of dairy cows, in various countries – a comparison of Implied Emission Factors (IEF) for the time-series year 201 6

	IEF_{CH4} [kg place^{-1} a^{-1}]	CH_4-conversion factor Y_m [MJ MJ^{-1}]	GE intake [MJ place^{-1} d^{-1}]	Milk yield [kg place^{-1} d^{-1}]
Austria	132.23	0.0650	310.2	18.52
Belgium	142.92	0.0610	357.2	21.30
Czech Republic	146.38	0.0650	343.4	22.02
Denmark	155.98	0.0600	396.3	25.74
France	121.87	0.0614	302.9	19.02
Germany	**136.41**	**0.0631**	**330.1**	**21.22**
Netherlands	129.33	0.0584	292.4	NA
Poland	124.65	0.0650	292.4	15.70
Switzerland	137.15	0.0690	303.1	22.98
UK	120.80	0.0651	282.9	20.90
IPCC (2006): Vol. 4, 10.15 through 10.21, 10.29, 10.72	117	0.065	Equation 10.3-10.16	16.44 [a]

Source: Germany: 2019 Submission; other countries: (UNFCCC, 2018b)

[a] Calculated from the annual milk yield assumed by IPCC (2006): Vol. 4, 6,000 kg place^{-1} a^{-1}

Table 290 shows the IEF and the GE intakes for the group of other cattle and for all swine combined.

For other cattle, the IEF values range from 36.4 kg place^{-1} a^{-1} (Netherlands) to 59.4 kg place^{-1} a^{-1} (Austria). The latter value is only slightly higher than the IPCC default value of 57 kg place^{-1} a^{-1}. Germany's value lies close to the median. A similar picture emerges for GE intake.

For swine, all of the countries involved, except for Denmark, Germany, France and Switzerland, use the IPCC default value for the IEF. The four countries that calculate the IEF obtain results that are lower than the IPCC default value. This could indicate that the IPCC default value is too high for the circumstances prevailing in central Europe. France's IEF, in the context of an international comparison, seems unrealistically low. Germany's IEF is of the same order of magnitude as the values of Denmark and Switzerland.

Table 290: Methane emissions from enteric fermentation of other cattle and swine, in various countries – a comparison of Implied Emission Factors (IEF) for the time-series year 2016

	Other cattle		Swine	
	IEF_{CH4} [kg place^{-1} a^{-1}]	GE intake [MJ place^{-1} d^{-1}]	IEF_{CH4} [kg place^{-1} a^{-1}]	GE intake [MJ place^{-1} d^{-1}]
Austria	59.42	139.37	1.50	NA
Belgium	50.37	130.95	1.50	NE
Czech Republic	56.46	132.43	1.50	NA
Denmark	40.85	130.24	1.09	38.73
France	52.89	125.00	0.75	NE
Germany	**49.66**	**118.62**	**1.15**	**35.24**
Netherlands [a]	36.36	91.52	1.50	NA
Poland	49.52	116.16	1.50	n/a
Switzerland [a]	46.55	117.85	1.07	27.18
UK [b]	58.11	112.88	1.50	NE
IPCC (2006): Vol. 4, 10.15 through 10.21, 10.28/29	57	Equation 10.3-10.16	1.5	Equation 10.3-10.16

Source: Germany: 2019 Submission; other countries:

n/a: not available

[a] Other cattle: calculated from CRF data

[b] UK, other cattle: Cattle, not including dairy cows, and not including dairy replacements (including calves selected to be dairy cows)

5.2.5 Source-specific recalculations (3.A)

Table 291 shows, for dairy cows, other cattle and swine, GE intake in comparison to the corresponding data in the 2018 Submission. Differences in the data are due to changes, referred to in Chapter 5.1.3.3, in yield-determining data. The relevant change for fattening pigs for year 2016 is so insignificant that, in the number format chosen here, it has no visible impact on the average value for swine.

Table 291: Comparison of the mean daily GE intake for dairy cows, other cattle and swine (3.A), as reported in the 2018 2019 Submissions

[MJ/animal]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016
Dairy cows, 2019	259.4	278.2	295.0	308.8	309.8	312.9	317.0	319.7	321.3	321.2	324.6	327.2	330.1
Dairy cows, 2018	259.9	278.6	295.7	310.3	310.9	314.1	317.5	320.3	321.9	321.9	325.2	327.9	330.8
Other cattle, 2019	108.3	111.7	116.6	116.4	116.7	116.6	117.3	117.0	117.1	117.6	117.6	118.4	118.6
Other cattle, 2018	103.3	105.5	107.0	105.5	105.1	105.5	105.3	104.7	104.3	104.4	103.8	103.8	103.7
Swine, 2019	30.2	31.8	32.6	33.0	33.3	33.8	33.8	34.0	34.3	34.5	34.8	35.0	35.2
Swine, 2018	30.2	31.8	32.6	33.0	33.3	33.8	33.8	34.0	34.3	34.5	34.8	35.0	35.2

Table 292 compares the pertinent emission factors. Since GE does not enter into the national calculation procedure used for dairy cows, the differences with respect to the 2018 Submission are slight. In some cases, they are not visible in the prescribed number-presentation format. The difference is very considerable for other cattle, however. It is due primarily to the considerably increased feed intake – and, thus, GE intake – for heifers. For swine, a difference occurs only in 2016. It is also very slight, and invisible in the number format used. All changes in the emission factors result from the changes in yield-determining data described in Chapter 5.1.3.3.

Table 292: Comparison of the CH_4 emission factors (enteric fermentation) for dairy cows, other cattle and swine (3.A), referenced to animal place, as reported in the 2018 and 2019 Submissions

[kg place⁻¹ a⁻¹]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016
Dairy cows, 2019	120.1	124.6	128.5	131.5	131.9	132.6	133.6	134.3	134.7	134.7	135.4	135.9	136.4
Dairy cows, 2018	120.2	124.6	128.6	131.8	132.0	132.8	133.6	134.3	134.7	134.8	135.4	135.9	136.4
Other cattle, 2019	45.3	46.7	48.8	48.7	48.8	48.8	49.1	49.0	49.0	49.2	49.2	49.6	49.7
Other cattle, 2018	43.1	44.1	44.7	44.1	43.9	44.1	44.0	43.7	43.5	43.6	43.3	43.3	43.3
Swine, 2019	1.02	1.07	1.09	1.10	1.10	1.11	1.12	1.12	1.12	1.13	1.14	1.14	1.15
Swine, 2018	1.02	1.07	1.09	1.10	1.10	1.11	1.12	1.12	1.12	1.13	1.14	1.14	1.15

Table 293 compares emissions from enteric fermentation, for the aforementioned animal categories, for sheep and for all mammal categories as a whole. The results for cattle and swine reflect primarily the issues referred to in connection with Table 291 and Table 292. In addition, updating of numbers of cattle has had a very minor effect (cf. Chapter 5.1.3.2.3). In the sheep category, no differences emerged between the emissions results reported in the 2018 Submission and those reported in the 2019 Submission.

Table 293: Comparison of the CH_4 emissions (enteric fermentation) for all mammals, and for dairy cows, other cattle, swine and sheep (3.A), as reported in the 2018 and 2019 Submissions

[Tg a⁻¹ CH₄]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2017
Mammals, 2019	1.414	1.201	1.124	1.037	1.034	1.034	1.030	1.018	1.019	1.036	1.044	1.042	1.031
Mammals, 2018	1.387	1.174	1.084	0.997	0.991	0.993	0.986	0.974	0.974	0.989	0.995	0.990	0.978
Dairy cows, 2019	0.763	0.652	0.587	0.557	0.556	0.558	0.559	0.563	0.564	0.575	0.582	0.582	0.575
Dairy cows, 2018	0.764	0.652	0.588	0.558	0.557	0.558	0.559	0.563	0.564	0.575	0.581	0.582	0.575
Other cattle, 2019	0.595	0.498	0.486	0.429	0.427	0.427	0.424	0.408	0.408	0.414	0.415	0.414	0.410
Other cattle, 2018	0.567	0.470	0.446	0.388	0.384	0.385	0.380	0.365	0.362	0.367	0.366	0.362	0.357
Swine, 2019	0.0271	0.0219	0.0238	0.0250	0.0251	0.0257	0.0248	0.0255	0.0265	0.0264	0.0269	0.0262	0.026
Swine, 2018	0.0271	0.0219	0.0238	0.0250	0.0251	0.0257	0.0248	0.0255	0.0265	0.0264	0.0269	0.0262	0.026
Sheep, 2019	0.0207	0.0189	0.0176	0.0169	0.0154	0.0150	0.0143	0.0126	0.0125	0.0119	0.0120	0.0119	0.012
Sheep, 2018	0.0207	0.0189	0.0176	0.0169	0.0154	0.0150	0.0143	0.0126	0.0125	0.0119	0.0120	0.0119	0.012

5.2.6 Planned improvements (3.A)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

5.3 Manure management (3.B)

5.3.1 Category description (3.B)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
-/-	3.B.1. Manure management	Dairy cows	CH_4	2,640.57	0.22%	2,209.96	0.25%	-16.3%
-/-	3.B.1. Manure management	Other cattle	CH_4	2,623.80	0.21%	1,514.40	0.17%	-42.3%
-/-	3.B.1. Manure management	Other cattle	N_2O	1,113.83	0.09%	818.54	0.09%	-26.5%
-/-	3.B.1. Manure management	Dairy cows	N_2O	1,028.51	0.08%	746.05	0.08%	-27.5%
-/-	3.B.2. and 3.B.4. Manure management	Other animals (sheep, goats, horses, poultry)	CH_4	151.19	0.01%	196.08	0.02%	29.7%
-/-	3.B.2. and 3.B.4. Manure management	Other animals (sheep, goats, horses, poultry)	N_2O	127.70	0.01%	138.91	0.02%	8.8%
-/-	3.B.3. Manure management	Swine	CH_4	2,684.67	0.22%	2,370.33	0.27%	-11.7%
-/-	3.B.3. Manure management	Swine	N_2O	376.40	0.03%	494.29	0.06%	31.3%
-/-	3.B.5. Indirect N_2O emission	Manure (atmospheric deposition)	N_2O	1,256.90	0.10%	1,051.73	0.12%	-16.3%

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier 2	M/Q/AS/RS/NS	CS/D
N_2O direct	Tier 2	M/Q/AS/RS/NS	CS/D
N_2O indirect	Tier 1	M/Q/AS/RS/NS	D
NO_X	Tier 2	M/Q/AS/RS/NS	CS
NMVOC	Tier 1	RS/NS	D

The category *Manure management* is not a key category.

In sector 3.B, Germany reports on CH_4, N_2O, NO and NMVOC from manure management.

CH_4 occurs when methanogenic bacteria break down organic substances in anaerobic environments. Direct N_2O emissions are produced by nitrification and denitrification processes that take place during storage of manure and of digestates. NO is produced via nitrification in surface layers of manure storage facilities. NMVOC emissions are released from silage fodder and from manure storage facilities.

Reporting on manure management also covers indirect N_2O emissions. Such emissions can occur in connection with decomposition processes in the soil, and they are generated from reactive nitrogen originating via deposition of NH_3 and NO from management of manure and of digestates, as well as via nitrogen leaching and surface runoff from management of manure and of digestates. For reasons of water protection, seeping/leachage and uncontrolled above-ground runoff from management of manure and of digestates are to be prevented (1991 EU Nitrates Directive; Council of the European Union (1991)). For this reason, no indirect N_2O emissions from leachage / surface runoff have been calculated. This procedure has been followed for all years as of 1990. With regard to total N_2O emissions from the German agricultural sector, this amounts to a conservative assumption, since the nitrogen that is not lost via N_2O from leaching / surface runoff is applied to fields, thereby computationally causing higher N_2O emissions as a result.

The relevant emissions are calculated in relation to a range of factors, including animal category; animal excretions (which, in turn, are a function of animal yield and of diet); the amounts of time spent by relevant animals in various defined areas (pastures, stables); the types of stables used; nitrogen inputs from bedding material (straw); and the type of manure storage involved.

Table 294 shows the changes over time in emissions from all manure management since 1990. In addition, for the initial and end years of the time series, it shows these emissions' shares of relevant total emissions from the German agricultural sector. With regard to the absolute emissions levels, cf. Chapters 5.3.2.2.3, 5.3.3.2.3 and 5.3.4.2.3. The emissions decrease seen since 1990 is due primarily to changes in livestock populations. Decreases of CH_4 and N_2O emissions have also occurred via reliance on manure digestion. The even-greater percentage decrease seen in NMVOC since 1990 is due almost exclusively to reductions in cattle populations.

Table 294: Percentage changes of emissions from manure management (index: MM) since 1990, and such emissions' percentage shares of total agricultural emissions of CH_4, N_2O, GHG and NMVOC

[%]	Change since 1990	Share of total agricultural emissions (CH_4, N_2O, GHG, NMVOC) 1990	2017
$CH_{4,\ MM}$	-22.3	18.6	19.0
N_2O_{MM}, direct	-17.0	8.1	7.3
N_2O_{MM}, indirect	-16.3	3.9	3.5
$CH_{4,\ MM}$ + N_2O_{MM} (as GHG in CO_{2eq})	-20.5	15.2	14.4
$NMVOC_{MM}$	-29.0	97.2	95.2

5.3.2 Methane emissions from manure management (3.B, CH_4)

5.3.2.1 Category description (3.B, CH_4)

Cf. Chapter 5.3.1.

5.3.2.2 Methodological issues (3.B, CH_4)

5.3.2.2.1 Methods (3.B, CH_4)

For all animal categories, CH_4 emissions are calculated in accordance with the Tier 2 method:

Equation14: Calculation of total CH_4 emissions from manure management

$$E_{\mathrm{CH4,MM}} = \sum_{\mathrm{i,\,j}} n_{\mathrm{i}} \cdot EF_{\mathrm{i,\,j}} = \sum_{\mathrm{i,\,j}} n_{\mathrm{i}} \cdot \alpha \cdot \rho_{\mathrm{CH4}} \cdot VS_{\mathrm{i}} \cdot B_{\mathrm{o,i}} \cdot MS_{\mathrm{i,\,j}} \cdot MCF_{\mathrm{i,\,j}}$$

Where

$E_{CH4,\ MM}$	Total methane emissions from manure management (in kg a^{-1} CH_4)
n_i	Number of animal places of animal category i (in places)
$EF_{i,\ j}$	Methane emission factor for animal category i in manure management system j (in kg $place^{-1}$ a^{-1} CH_4)
α	Factor for conversion of time units (α = 365 d a^{-1})
ρ_{CH4}	Density of methane (ρ_{CH4} = 0.67 kg m^{-3})
VS_i	VS excretions for animal category i (in kg $place^{-1}$ d^{-1})
$B_{o,\ i}$	Maximum methane-producing capacity for animal category i (in m^3 kg^{-1} CH_4)
$MS_{i,\ j}$	Relative proportion of housing places, for animal category i, whose excrement occurs in manure management system j (in place $place^{-1}$)
$MCF_{i,\ j}$	Methane-conversion factor for manure management system j (in m^3 m^{-3})[88]

With regard to the number of animal places n_i, the reader's attention is called to Chapter 5.3.2.2.1. The VS excretions are described in Chapter 5.1.3.5. With regard to the relative percentages of storage systems for solid manure, slurry and digestates, and to time allotted to grazing, cf. Chapters 5.1.3.6.1 and 19.3.2. The methane-producing capacity B_o and the methane conversion

[88] The IPCC gives *MCF* in percent (of B_o); in the German inventory, the units m^3 m^{-3}, which are clearer in their reference, are used.

factors *MCF* are discussed in Chapters 5.1.3.6.3 and 5.1.3.6.4. According to IPCC, manure digestion, including storage of manure digestates, is a separate storage type. The B_0 and *MCF* values for it are covered in Chapter 5.1.3.6.5.

5.3.2.2.2 Emission factors (3.B, CH_4)

Table 295 shows the time series for the emission factors referenced to animal place. They have been calculated using Equation14 in Chapter 5.3.2.2.1. The emission factors include the emissions reduction effects resulting via manure digestion.

Table 295: Animal-place-based CH_4 emission factors; manure management (3.B(a))

[kg place^{-1} a^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Dairy cows	16.6	21.3	22.5	23.4	22.7	22.4	22.1	21.5	21.3	20.8	20.8	20.9	21.1	21.1
Other cattle	8.0	8.1	8.4	8.4	8.1	8.0	7.8	7.6	7.6	7.5	7.5	7.5	7.5	7.5
Swine	4.1	4.4	4.5	4.4	4.2	4.2	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
Sheep	0.28	0.27	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
Goats	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Horses	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
Poultry	0.031	0.030	0.032	0.035	0.036	0.036	0.037	0.035	0.034	0.033	0.033	0.034	0.034	0.034

5.3.2.2.3 Emissions (CRF 3.B, CH_4)

Table 296 shows the calculated total CH_4 emissions from manure management, in both absolute values and relative percentage values referenced to 1990.

Table 296: CH_4 emissions from manure management (3.B(a))

	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
[kt a^{-1}]	324.01	293.59	291.56	279.39	269.67	267.95	258.49	254.28	256.80	255.22	256.95	253.37	252.34	251.63
[% of 1990]	100.0	90.6	90.0	86.2	83.2	82.7	79.8	78.5	79.3	78.8	79.3	78.2	77.9	77.7

The progression over time is tied largely to the development in the sizes of animal populations (cf. Chapter 5.1.3.2), with the effects of such trends modified via emissions-increasing growth in yields (cf. Chapter 5.1.3.3) and via increasing emissions reductions as a result of manure digestion; cf. Table 298 below.

Table 297 shows the emissions contributions of dairy cows, other cattle and swine, along with these three animal categories' (taken together, as a group) percentage shares of the total emissions for all animals. The ratios between the emissions of cattle and those of swine have been added as supplementary information.

Table 297: CH_4 from manure management (dairy cows, other cattle, swine); percentage contributions to total CH_4 emissions from manure management; and the ratios between the emissions of cattle and those of swine

[kt a^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Dairy cows	105.6	111.4	102.8	98.9	95.6	94.2	92.6	90.2	89.2	89.0	89.4	89.6	89.1	88.4
Other cattle	105.0	86.7	84.2	74.0	70.8	69.5	67.4	63.6	63.0	63.4	63.2	62.6	62.0	60.6
Swine	107.4	89.3	98.3	99.9	96.4	97.4	91.7	93.3	97.0	95.0	96.6	93.4	93.4	94.8
Total	318.0	287.4	285.3	272.8	262.8	261.1	251.7	247.1	249.3	247.5	249.1	245.5	244.5	243.8
% share	98.1	97.9	97.9	97.6	97.4	97.4	97.4	97.2	97.1	97.0	97.0	96.9	96.9	96.9
Cattle : Swine	2.0	2.2	1.9	1.7	1.7	1.7	1.7	1.6	1.6	1.6	1.6	1.6	1.6	1.6

The CH_4-emissions reductions achieved via manure digestion are shown in Table 298. Without digestion, the so-saved emissions would have been emitted in addition to the quantities shown in Table 296. The percentage reductions refer to the emissions that would have occurred without digestion.

Table 298: Absolute and percentage changes in CH_4 emissions achieved as a result of manure digestion, in comparison to a situation with no digestion and no storage of digestates (negative sign: Emissions reduction)

	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
[kt a^{-1}]	-0.01	-0.08	-0.7	-6.4	-16.4	-21.1	-26.4	-32.4	-35.4	-39.9	-41.5	-41.9	-41.2	-41.6
[%]	-0.003	-0.03	-0.2	-2.3	-5.7	-7.3	-9.3	-11.3	-12.1	-13.5	-13.9	-14.2	-14.0	-14.2

5.3.2.3 Uncertainties and time-series consistency (3.B, CH_4)

Table 280 in Chapter 5.1.6 shows the uncertainties in activity data and emission factors that have been used in estimating the total uncertainty of the German GHG inventory.

The uncertainty for the CH_4 emission factors for manure management is a default value from IPCC (2006): Vol. 4, Table 10.48. With regard to the uncertainty of the activity data (animal-population data), cf. Chapters 4.1.2, 5.1.2, 6.1.2, 7.1.2 and 8.1.2 in Rösemann et al. (2019b).

The emissions time series are consistent, since they were calculated with the same method for all years of the report period, and since the input data are also consistent and complete.

5.3.2.4 Source-specific quality assurance / control and verification (3.B, CH_4)

With regard to quality control and quality assurance, we refer to Chapter 5.1.7.

In the framework of verification, and in an approach similar to that used in Chapter 5.2.4, the results and input data obtained for 2016 were compared with those (for 2016) of neighbouring countries and of the UK (2018 Submission for 2016; UNFCCC (2018a)).

Table 299 shows, for dairy cows, the IEF for CH_4 from manure management, and a number of important influencing factors. In keeping with the CRF requirements, the percentage shares for liquid-manure systems, and the corresponding MCF values, refer only to liquid-manure systems whose liquid manure is not digested in biogas plants.

The IPCC's default value range for the IEF is slightly lower than the median of the IEF values of the countries being compared (24.0 kg $place^{-1}$ a^{-1}). The German IEF lies at the lower end of the IPCC's range. The daily VS excretions calculated for Germany lie at the lower end of the scale (and are just about the same as France's value). They still amount to about 80 % of the average value, however. The German MCF for slurry systems lies somewhat below the median for the countries being compared, and the degree of use of slurry systems in Germany lies slightly above the median.

Table 299: CH_4 emissions from storage of manure from dairy cows, in various countries – a comparison of Implied Emission Factors (IEF) and important emissions-relevant parameters for the time-series year 2016

	IEF_{CH4} [kg place^{-1} a^{-1}]	VS excretions [kg place^{-1} d^{-1}]	Liquid-manure systems (without digestion)	
			Frequency [%]	Mean MCF [%]
Austria	11.95	4.95	32.18	8.72
Belgium	29.42	5.12	47.94	19.00
Czech Republic	22.29	6.33	27.00	17.00
Denmark	25.64	6.81	76.22	5.04
France	13.02	4.14	27.19	16.00
Germany	**21.11**	**4.07**	**53.65**	**15.31**
Netherlands	37.69	4.69	86.98	17.00
Poland	12.11	5.93	10.53	17.00
Switzerland	27.86	4.81	69.61	13.51
UK	36.51	5.40	60.99	17.00
IPCC (2006a)-10.38, 10.77, Western Europe, cool region 10°C/11°C	21 to 23	5.1	35.7	17 to 19

Source: Germany: 2019 Submission; other countries: (UNFCCC, 2018a)

Table 300 shows, for other cattle, the IEF for CH_4 from manure management, and a number of important influencing factors. The German IEF lies slightly above the median. The primary reason for the large fluctuation range seen in the IEF values – apart from differences in VS excretions and MCF values – is that the frequency of use of liquid-manure systems differs very widely. In this area, Germany lies at the midpoint between the median and the third quartile. As was the case in the dairy cow category, Germany's VS excretions value is lower than the average value. It is about the same as Belgium's VS excretions value.

As Table 301 indicates, Germany's IEF for CH_4 from manure management also lies in the middle of the range in the case of swine: It is about the same as the median.

Table 300: CH_4 emissions from storage of manure from other cattle, in various countries – a comparison of Implied Emission Factors (*IEF*) and important emissions-relevant parameters for the year 2016

	IEF_{CH4} [kg place^{-1} a^{-1} CH_4]	VS excretions [kg place^{-1} d^{-1}]	Liquid-manure systems (without digestion)	
			Frequency [%]	Mean MCF [%]
Austria	4.95	2.15	24.83	8.48
Belgium	2.97	1.61	15.91	19.00
Czech Republic	9.17	2.87	42.00	17.00
Denmark	12.73	3.23	31.08	5.04
France	3.26	1.90	3.83	18.46
Germany	**7.52**	**1.53**	**33.01**	**15.37**
Netherlands [a]	7.98	1.24	73.87	17.00
Poland	2.14	1.88	5.06	17.00
Switzerland [a]	6.87	2.48	46.96	13.51
UK [b]	8.60	2.15	18.04	17.00
IPCC (2006a)-10.38, 10.77, Western Europe, cool region 10°C/11°C	6 to 7	2.6	25.2	17 to 19

Source: Germany: 2019 Submission; other countries: (UNFCCC, 2018a)

[b] Calculated from CRF data

[c] UK: Cattle, not including dairy cows, and not including dairy replacements (including calves selected to be dairy cows)

Table 301: CH_4 emissions from storage of manure from swine, in various countries – a comparison of Implied Emission Factors (IEF) and important emissions-relevant parameters for the year 2016

	IEF_{CH4}	VS excretions	Liquid-manure systems (without digestion)	
			Frequency	Mean MCF
	[kg place^{-1} a^{-1} CH_4]	[kg place^{-1} d^{-1}]	[%]	[%]
Austria	1.19	0.27	74.30	3.39
Belgium	4.47	0.22	96.72	19.00
Czech Republic	6.00	NA	76.00	NO
Denmark	3.55	0.18	87.98	13.69
France	4.08	0.20	90.99	20.14
Germany	**4.10**	**0.30**	**77.79**	**22.18**
Netherlands	5.57	0.37	99.04	36.00
Poland	1.99	0.32	24.82	17.00
Switzerland	4.21	0.31	87.23	13.51
UK	5.20	0.25	38.74	17.00
IPCC (2006a)-10.80, 10.81, Western Europe, cool region 10°C/11°C	Sows, boars: 9 to 10 Other: 6	Sows, boars: 0.46 Other: 0.30		17 to 19

Source: Germany: 2019 Submission; other countries: (UNFCCC, 2018a)

Table 302 shows, for poultry, the average IEF, the average VS excretions and the average animal weight, the last of which serves as an indicator of energy requirements and, thus, feed intake and excretions. With regard to IEFs, if one neglects the relatively very high value of the Czech Republic, a range of 0.018 to 0.034 kg place^{-1}a^{-1} results. The highest IEF in this category is reported by Germany. The reason for this is that Germany's VS excretions value is higher than those of other countries (at least of those six countries that report VS excretions). While the German VS excretions figure marks the upper bound of the scale, Germany is part of a group, along with Denmark, France and the Netherlands, that have VS excretions figures that are higher, by factors of 2 to 2.5, than the lower bound of the IPCC-default range. Average poultry weights are reported only by Belgium, the Czech Republic, Denmark and Germany. These values are all of a comparable magnitude; Germany's average poultry weight is closest to Belgium's value.

Table 302: CH_4 emissions from storage of manure from poultry, in various countries – a comparison of Implied Emission Factors (IEF) and important emissions-relevant parameters for the year 2016

	IEF_{CH4} [kg place^{-1} a^{-1}]	VS excretions [kg place^{-1} d^{-1}]	Mean animal weight [kg animal^{-1}]
Austria	0.028	NA	NA
Belgium	0.023	NE	1.56
Czech Republic	0.095	NA	2.00
Denmark	0.030	0.020	2.00
France	0.028	0.020	NE
Germany	**0.034**	**0.025**	**1.68**
Netherlands	0.028	0.020	NA
Poland	0.027	NA	NA
Switzerland	0.018	0.013	NA
UK	0.021	0.013	NE
IPCC (2006a)-10.82, W-Europe, cool region, developed countries	0.02 to 0.09 [a]	0.01 to 0.07 [a]	0.9 to 6.8 [a]

Source: Germany: 2019 Submission; other countries: (UNFCCC, 2018a)

[a] low value: laying hens; high value: turkeys

5.3.2.5 Source-specific recalculations (3.B, CH_4)

Table 303 through Table 305 show, for dairy cows, other cattle, swine and poultry, a comparison of figures for VS excretions, emission factors and emissions as reported in the current Submission and as reported in the 2018 Submission.

For other cattle (especially heifers), the changes in yield-characterizing data that are described in Chapter 5.1.3.3 prove to have such a major impact that considerable differences emerge between the VS excretions reported in the current submission and those reported in last year's submission. The differences for dairy cows are less pronounced. For swine and poultry, differences result only for 2016. They are very slight, however; for swine, they are invisible in the number format chosen.

Table 303: Comparison of VS excretions as reported in the 2019 and 2018 Submissions (3.B(a))

[kg place^{-1} d^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016
Dairy cows, 2019	3.47	3.64	3.78	3.89	3.91	3.93	3.97	3.99	4.01	4.01	4.03	4.05	4.07
Dairy cows, 2018	3.47	3.64	3.79	3.90	3.91	3.94	3.97	3.99	4.01	4.01	4.03	4.05	4.07
Other cattle, 2019	1.40	1.45	1.52	1.51	1.51	1.51	1.52	1.51	1.51	1.51	1.51	1.53	1.53
Other cattle, 2018	1.37	1.40	1.43	1.40	1.39	1.39	1.39	1.38	1.37	1.37	1.37	1.37	1.37
Swine, 2019	0.264	0.278	0.284	0.287	0.290	0.294	0.294	0.295	0.297	0.299	0.302	0.302	0.305
Swine, 2018	0.264	0.278	0.284	0.287	0.290	0.294	0.294	0.295	0.297	0.299	0.302	0.302	0.305
Poultry, 2019	0.0225	0.0218	0.0233	0.0255	0.0262	0.0264	0.0271	0.0263	0.0254	0.0242	0.0248	0.0252	0.0254
Poultry, 2018	0.0225	0.0218	0.0233	0.0255	0.0262	0.0264	0.0271	0.0263	0.0254	0.0242	0.0248	0.0252	0.0253

The differences in the VS excretions are of course reflected in the emission factors referenced to animal place. The updating of the time series for the input data for manure digestion (cf. Chapter 5.1.3.6.5) also has an impact. It is so small, however, that in the number format chosen it is either undetectable per se or is masked by the other changes.

Table 304: Comparison of the animal-place-based CH_4 emission factors, as reported in the 2018 and 2019 Submissions, for manure management (3.B(a))

[kg place^{-1} a^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016
Dairy cows, 2019	16.6	21.3	22.5	23.4	22.7	22.4	22.1	21.5	21.3	20.8	20.8	20.9	21.1
Dairy cows, 2018	16.7	21.3	22.5	23.4	22.6	22.4	22.0	21.4	21.2	20.7	20.7	20.8	20.9
Other cattle, 2019	7.99	8.14	8.45	8.41	8.08	7.95	7.81	7.63	7.58	7.54	7.48	7.50	7.52
Other cattle, 2018	7.93	8.01	8.07	7.97	7.65	7.55	7.36	7.17	7.09	7.04	6.96	6.93	6.93
Swine, 2019	4.05	4.38	4.52	4.39	4.25	4.23	4.12	4.09	4.10	4.06	4.08	4.06	4.10
Swine, 2018	4.05	4.38	4.52	4.39	4.25	4.23	4.12	4.09	4.10	4.06	4.08	4.06	4.09
Poultry, 2019	0.0314	0.0302	0.0321	0.0348	0.0356	0.0358	0.0366	0.0354	0.0341	0.0325	0.0332	0.0337	0.0340
Poultry, 2018	0.0314	0.0302	0.0321	0.0348	0.0356	0.0358	0.0366	0.0354	0.0341	0.0325	0.0332	0.0337	0.0339

The slight changes in the cattle-population data (updating) that are mentioned in Chapter 5.1.3.2.3 have an impact on the emissions comparison.

Table 305: Comparison of CH_4 emissions from manure management as reported in the 2018 and 2019 Submissions (3.B(a))

[kt a^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016
All animals, 2019	**324.0**	**293.6**	**291.6**	**279.4**	**269.7**	**267.9**	**258.5**	**254.3**	**256.8**	**255.2**	**256.9**	**253.4**	**252.3**
All animals, 2018	**322.9**	**291.6**	**287.3**	**275.1**	**265.3**	**263.9**	**253.9**	**249.6**	**251.8**	**250.1**	**251.5**	**247.6**	**245.7**
Dairy cows, 2019	105.6	111.4	102.8	98.9	95.6	94.2	92.6	90.2	89.2	89.0	89.4	89.6	89.1
Dairy cows, 2018	105.9	111.4	102.8	99.0	95.5	94.0	92.2	89.7	88.7	88.4	88.7	88.9	88.1
Other cattle, 2019	105.0	86.7	84.2	74.0	70.8	69.5	67.4	63.6	63.0	63.4	63.2	62.6	62.0
Other cattle, 2018	104.1	85.3	80.4	70.1	67.0	66.0	63.5	59.8	59.0	59.3	58.8	57.8	57.1
Swine, 2019	107.4	89.3	98.3	99.9	96.4	97.4	91.7	93.3	97.0	95.0	96.6	93.4	93.4
Swine, 2018	107.4	89.3	98.3	99.9	96.4	97.4	91.7	93.3	97.0	95.0	96.6	93.4	93.1
Poultry, 2019	3.58	3.36	3.86	4.20	4.57	4.61	4.71	5.13	5.49	5.77	5.84	5.89	5.91
Poultry, 2018	3.58	3.36	3.86	4.20	4.57	4.61	4.71	5.13	5.49	5.77	5.84	5.89	5.89

5.3.2.6 Planned improvements (3.B, CH_4)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

5.3.3 NMVOC emissions from manure management

5.3.3.1 Category description (NMVOC)

Cf. Chapter 5.3.1.

5.3.3.2 Methodological aspects (NMVOC)

5.3.3.2.1 Methods (NMVOC)

IPCC (2006) does not provide any method for calculating NMVOC emissions from manure management. EMEP (2016) provides methods and the relevant parameters. Germany uses the Tier 1 method (EMEP (2016)-3B-17f). The calculation is carried out separately for the various animal categories.

Equation 15: Tier 1 method for calculation of annual NMVOC emissions from manure management

$$E_{\text{NMVOC, MM, i}} = n_i \cdot EF_{\text{NMVOC, MM, i}}$$

Where

$E_{\text{NMVOC, MM, i}}$	NMVOC emissions from manure management for animal category i (in kg a^{-1})
n_i	Number of animal places of animal category i (in places)
$EF_{\text{NMVOC, MM, i}}$	NMVOC emission factor for animal category i (in kg $place^{-1}$ a^{-1})

5.3.3.2.2 Emission factors (NMVOC)

EMEP (2016)-3B-18, Table 3.4, provides different emission factors for feeding with and without silage. For cattle and horses, the German inventory applies the relevant emission factors for feeding with silage; for other animals, it uses the factors for feeding without silage. Table 306 presents a list of the emission factors used in the inventory. In addition, the following approach has been taken – because some emission factors are lacking and some do not fit with the inventory animal categories – for weaners, boars, sheep, horses and pullets (cf. Chapter 3.3.4.2 in Rösemann et al. (2019b)):

- In a conservative approach, the emission factor for sows is used for boars, and the factor for fattening pigs is used for weaners.
- The emission factor for sheep listed in EMEP (2016) has been interpreted as applying to mature sheep. The emission factor for lambs has been set at 40 % of the emission factor for mature sheep.
- The emission factor for horses listed in EMEP (2016) has been interpreted as applying to heavy horses. For light horses and ponies, the emission factor given in EMEP (2016) for mules and asses has been used.
- Due to the similarity in the applicable housing systems, the emission factor for broilers has been used for pullets.

Table 306: NMVOC emission factors used in the inventory, based on EMEP (2016)

[kg $place^{-1}$ a^{-1}]	EF_{NMVOC}
Dairy cows	17.937
Other cattle	8.902
Sows, boars	1.704
Fattening pigs, weaners	0.551
Mature sheep	0.169
Lambs	0.068
Goats	0.542
Heavy horses	7.781
Light horses and ponies	3.018
Laying hens	0.165
Broilers, pullets	0.108
Geese, ducks and turkeys	0.489

5.3.3.2.3 Emissions (NMVOC)

Table 307 lists the NMVOC emissions from manure management that are to be reported under CRF 3s1. In keeping with the Tier 1 method used (cf. Chapter 5.3.3.2.1), the time series directly reflect the trends in numbers of animals (cf. Chapter 5.1.3.2.3). As Table 308 cattle husbandry is responsible for the great majority of the emissions. The reduction in NMVOC emissions seen since 1990, for example, is due almost exclusively to decreases in numbers of cattle (R^2 = 97.5 %). The relative emissions contribution from poultry husbandry has increased sharply, with respect to 1990, as a result of increases in numbers of poultry. At the end of the time series, that contribution is considerably greater than the total contribution from other animals.

Table 307: NMVOC emissions from manure management

[kt a-1]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total	**271.4**	**225.6**	**209.3**	**193.9**	**194.3**	**193.9**	**191.7**	**191.7**	**194.1**	**198.4**	**198.9**	**197.1**	**194.5**	**192.7**
in % of 1990	**100.0**	**83.2**	**77.1**	**71.5**	**71.6**	**71.4**	**70.7**	**70.6**	**71.5**	**73.1**	**73.3**	**72.6**	**71.7**	**71.0**
Dairy cows	114.0	93.8	82.0	76.0	75.7	75.4	75.0	75.2	75.2	76.5	77.1	76.9	75.7	75.3
Other cattle	116.9	94.9	88.7	78.3	77.9	77.8	76.8	74.2	74.1	74.9	75.2	74.3	73.4	71.9
Swine	18.4	14.2	15.0	15.5	15.3	15.4	14.9	15.1	15.5	15.3	15.4	15.0	14.8	14.9
Sheep	0.43	0.39	0.36	0.35	0.32	0.31	0.30	0.26	0.26	0.25	0.25	0.25	0.24	0.24
Goats	0.05	0.05	0.08	0.09	0.10	0.12	0.08	0.08	0.07	0.07	0.07	0.07	0.08	0.08
Horses	3.2	4.1	3.3	3.4	3.5	3.3	3.1	3.1	3.1	3.1	3.0	3.0	2.9	2.9
Poultry	18.3	18.1	19.8	20.3	21.5	21.6	21.6	23.8	26.0	28.2	27.9	27.7	27.4	27.4

Table 308: Percentage contributions to NMVOC emissions, from manure management

[%]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Cattle	85.1	83.6	81.6	79.6	79.1	79.0	79.2	77.9	76.9	76.4	76.5	76.7	76.6	76.4
Poultry	6.8	8.0	9.5	10.4	11.1	11.1	11.2	12.4	13.4	14.2	14.0	14.0	14.1	14.2
Other animals	8.2	8.3	9.0	10.0	9.9	9.8	9.6	9.7	9.7	9.4	9.4	9.3	9.3	9.4

5.3.3.3 Uncertainties and time-series consistency (NMVOC)

EMEP (2016)- 3B-35 highlights the very large uncertainty of the emission factors, but it does not provide any pertinent quantitative information. No German data are available for this area. For the German inventory, the uncertainty (95 % confidence interval) is assumed to be on the order of factor 3; cf. Chapter 3.3.4.2 in Rösemann et al. (2019b). With regard to the uncertainty of the activity data (animal-population data), cf. Chapters 4.1.2, 5.1.2, 6.1.2, 7.1.2 and 8.1.2 in Rösemann et al. (2019b).

The emissions time series are consistent, since they were calculated with the same method for all years of the report period, and since the input data are also consistent and complete.

5.3.3.4 Source-specific quality assurance / control and verification (NMVOC)

With regard to quality control and quality assurance, we refer to Chapter 5.1.7.

5.3.3.5 Source-specific recalculations (NMVOC)

The time series for NMVOC emissions that are shown in Chapter 5.3.3.2.3, Table 307 were calculated with the same calculation method used for these series in the 2018 Submission. The changes in the cattle-population figures that are mentioned in Chapter 5.1.3.2.3 have led to changes in the cattle emissions with respect to the 2018 Submission. These changes are so slight that they are not apparent in Table 307, however.

5.3.3.6 Planned improvements (NMVOC)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

5.3.4 Direct N_2O and NO emissions from manure management (3.B, N_2O & NO)

5.3.4.1 Category description (3.B, N_2O_{direct} & NO)

Cf. Chapter 5.3.1.

5.3.4.2 Methodological issues (3.B, N_2O_{direct} & NO)

5.3.4.2.1 Methods (3.B, N_2O_{direct} & NO)

N_2O emissions from manure management are calculated separately for all animal categories, taking account of the management systems in use (and including manure digestion; cf. Chapter 5.1.3.6.5):

Equation 16: Calculation of N_2O emissions from manure management

$$E_{\text{N2O-N}} = \sum_{\text{i,j}} [(N_{\text{excr, i}} + N_{\text{straw, i, j}}) \cdot MS_{\text{i, j}}] \cdot EF_{\text{N2O-N, j}}$$

Where:

$E_{\text{N2O-N}}$	Total N_2O-N emissions from manure management (kg a^{-1} N_2O-N)
$N_{\text{excr, i}}$	Total N excretions of animal category i (kg a^{-1} N)
$N_{\text{straw, i, j}}$	N input via bedding material, for animal category i and manure management system j (kg a^{-1} N)
$MS_{\text{i, j}}$	Relative share of manure management system j of animal category i (place $place^{-1}$)
$EF_{\text{N2O-N, j}}$	N_2O-N emission factor for manure management system j (kg kg^{-1} N_2O-N)

With regard to total N excretions and total N inputs via bedding material, cf. Chapters 5.1.3.4 and 5.1.3.6.2. With regard to the relative frequencies of manure management systems, cf. Chapters 5.1.3.6.1 and 19.3.2.

NO emissions from manure management are calculated using a method similar to that used to calculate the relevant N_2O emissions.

N_2O and NO emissions from manure application and grazing are reported under 3.D.

5.3.4.2.2 Emission factors (3.B, N_2O_{direct} & NO)

For slurry storage, the default emission factors given in IPCC (2006): Vol. 4, 10.62 have been used (where available): Outdoor storage facilities without natural crust cover (equivalent to "open tank, without natural crust" in Table 309); outdoor storage facilities with natural crust cover; storage below slatted floor. For slurry storage with solid cover, or with artificial floating cover (chaff) – both of which are not mentioned in IPCC (2006): Vol. 4 , a conservative approach is applied whereby the emission factor for outdoor storage with natural crust cover is used. For slurry storage under a plastic film cover, which is also not mentioned in IPCC (2006): Vol. 4, it is assumed that the emission factor for outdoor storage without natural crust can be used.

Systems for storage of solid manure are broken down into the categories tied systems / pens allowing free movement (with storage in heaps) and deep bedding. With regard to housing with use of deep bedding, German agricultural techniques do not include active mixing of the bedding (expert judgement, Brigitte Eurich-Menden et al. cf. Chapters 3.4.3.2.1 and 3.4.3.2.3 in Rösemann et al. (2019b)). For deep bedding, therefore, the IPCC (2006) default value of 0.010 kg N_2O-N (kg $N)^{-1}$ (IPCC (2006): Vol 4, -10.63) is used. For storage of solid manure from tied systems / pens allowing free movement, the emission factor derived by Vandré et al. (2013) has been used in the past (up to and including the 2018 NIR): 0.013 kg N_2O-N (kg $N)^{-1}$. That value is higher than the aforementioned emission factor for deep bedding. It thus runs counter to IPCC (2006) and scientific assessments. As part of quality assurance, therefore, KTBL reviewed the derivation of the emission factor for solid manure. Its reassessment led to the recommendation that the IPCC (2006) default value of 0.005 kg N_2O-N (kg $N)^{-1}$ be used instead (expert judgement, Sebastian Wulf, KTBL, 2018). That recommendation has been implemented in the 2019 report. As a result, the emission factors for deep bedding and solid manure are now consistent with each other.

The inventory calculations for poultry manure are based on the IPCC default emission factor: 0.001 kg N_2O-N (kg $N)^{-1}$ (IPCC (2006): Vol 4, -10.63).

IPCC (2006a)-10.63 treats manure digestion, including storage of digestates, as a separate type of storage, one that produces no N_2O emissions (EF = 0 kg kg^{-1}). This IPCC default approach does not take account of the fact that open systems for storage of digestates emit N_2O. The German inventory thus reports non-zero N_2O emissions from manure digestion, broken down by different types of manure and digestates storage; cf. Chapter 5.1.3.6.5.

Table 309 shows the N_2O-N emission factors used in the 2018 Submission.

Table 309: Emission factors for emissions of N_2O-N from manure management, not including digestion (in relation to total excreted N and straw-bedding N) (3.B(b))

Manure		Emission factor [kg kg^{-1}]
Slurry	Open tank, without natural crust [a]	0.000
	Solid cover [b]	0.005
	Natural crust cover [a]	0.005
	Floating cover (chaff) [b]	0.005
	Floating cover (plastic film) [c]	0.000
	Below slatted floor [a]	0.002
Leachate[d]	Solid cover	0.005
Solid manure		0.005
Deep bedding[a]		0.010
Poultry manure with or without litter[a]		0.001

[a] Source: IPCC (2006): Vol. 4
[b] Worst-case assumption: Like natural crust, since no information is available.
[c] Assumption: With floating plastic film covers, no N_2O formation occurs.
[d] Assumption: Comparable to storage of liquid manure under a solid cover

IPCC (2006): Vol. 4 does not give any emission factors for NO. The Tier 1 emission factors given in EMEP (2016)-3B-17 are animal-place-based. They cannot be used in the GAS-EM inventory model, since GAS-EM, in the context of the N-flow concept (cf. Chapter 5.1.2.4), requires emission factors that refer to emissions-relevant N amounts. Comparative calculations have shown, however that the German total NO emissions from Sector 3.B, as calculated with the Tier 1 emission factors, can be reproduced with the GAS-EM N-flow concept if the NO-N emission factor oriented to N is smaller than the N_2O-N emission factor by an order of magnitude. For this reason, in the inventory, the NO-N emission factor has been set at a level of 10 % of the N_2O-N emission factor. This approach yields NO emissions that are directly proportional to the relevant N_2O emissions.

Neither IPCC nor EMEP gives emission factors for N_2 (which must also be taken into account in the N-flow concept; cf. Chapter 5.1.2.4). Jarvis and Pain (1994) obtained 3:1 as the ratio of N_2 emissions to N_2O-N emissions. Therefore, for purposes of the inventory, it has been assumed that N_2 emission factor is three times as large as the N_2O-N emission factor.

Table 310 shows the time series for the average N2O-N emission factors for the four overarching categories of manure management systems of relevance for reporting. These categories are "slurry-based (without digestion)", "straw-based (without deep bedding and without digestion)", "deep bedding (without digestion)" and "digestion" (of manure). In the interest of clarity, we have used the units g kg^{-1}, instead of the common units for emission factors (kg kg^{-1}; cf. Table 309). These emission factors are defined as the ratio of total N_2O-N emissions from a management system to the sum of animal N excretions in the same management system. Under this perspective, the total N_2O emissions of categories with bedding also include emissions fractions tied to bedding-N. For this reason, the resulting emission factor for deep bedding that is listed in Table 310 is higher than the factor given in Table 309. The same holds, in principle, for straw-based systems without deep bedding and without digestion, although the effect is not perceived, because the relevant values in Table 310 also include the considerably lower emission factor for poultry (cf. Table 309). The N_2O-N emission factors for straw-based systems and systems with digestion show, throughout the entire time series, a pronounced negative trend. For straw-based systems, this results from decreases in N_2O contributions from solid-manure systems in cattle and swine husbandry. Those decreases, in turn, result from changes in numbers of animals in the various housing systems. For digestion systems, the negative trend in the emission factors is due primarily to increasing use of gas-tight storage of digestates (cf. Chapter 5.1.3.6.5). Changes with respect to the 2018 NIR are tied primarily to the lower emission factor for solid manure (cf. Table 309) and to the higher N excretions of heifers that result from correction of the energy-requirements calculation (cf. Chapter 5.1.3.3).

Table 310: Average N_2O-N emission factors, by manure management systems (3.B(b))

[g kg^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Slurry-based [a]	3.12	3.46	3.43	3.45	3.48	3.49	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51
Straw-based [b]	4.88	4.62	4.47	4.44	4.32	4.28	4.24	4.10	4.05	3.98	3.98	3.96	3.96	3.94
Deep bedding [a]	11.16	11.27	11.23	11.11	11.00	10.94	10.88	10.83	10.80	10.77	10.75	10.74	10.74	10.73
Digestion	5.80	5.43	5.22	4.90	4.07	3.80	3.52	3.23	2.58	2.45	2.34	2.30	2.27	2.27

[a] Without digestion

[b] Without deep bedding and without digestion

5.3.4.2.3 Emissions (3.B, N_2O_{direct} & NO)

Table 311 shows the direct total N_2O emissions from manure management (including storage of digested manure) and breaks them down by system categories. The sharp emissions decrease in the first half of the 1990s is due primarily to reductions of livestock populations following German reunification. Additional influencing factors include shifts, over time, in the distributions of management systems (cf. Chapters 5.1.3.6.1 and 19.3.2), and gradually (over the years) increasing emissions reductions achieved via manure digestion (cf. Chapter 5.1.3.6.5).

Table 311: Direct N_2O emissions from manure management (MM), total and by system categories (3.B(b))

[kt a^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
MM total	8.88	7.96	7.79	7.82	7.86	7.88	7.76	7.63	7.53	7.52	7.56	7.48	7.44	7.38
in % of 1990	100.0	89.6	87.7	88.0	88.5	88.7	87.4	85.9	84.8	84.6	85.1	84.3	83.7	83.0
Slurry-based [a]	4.47	4.71	4.57	4.26	3.99	3.92	3.74	3.62	3.63	3.56	3.58	3.54	3.54	3.52
Straw-based [b]	3.50	2.31	2.17	2.07	2.05	2.04	2.01	1.96	1.98	1.97	2.00	1.99	1.98	1.95
Deep bedding [a]	0.91	0.94	1.01	1.24	1.28	1.29	1.28	1.22	1.21	1.22	1.22	1.19	1.18	1.16
Digestion	0.00	0.00	0.04	0.25	0.54	0.63	0.73	0.82	0.71	0.76	0.76	0.76	0.74	0.74

[a] Without digestion

[b] Without deep bedding and without digestion

Table 312 shows the corresponding contributions from the three most important animal categories (dairy cows, other cattle and swine). Table 313 shows the percentage contributions of dairy cows, other cattle and swine to the total direct N_2O emissions from manure management. The absolute and relative contributions of cattle have decreased considerably over the years, because the numbers of animals have decreased, while the opposite kind of trend is seen for swine, as a result of the increase in the swine population that has occurred with respect to 1990. The lower emissions levels seen for both cattle and swine, with respect to the 2018 NIR, result directly from use of the lower emission factor for solid manure (cf. Table 309).

Table 312: Direct N_2O emissions from manure management for dairy cows, other cattle and swine (3.B(b))

[kt a-1]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Dairy cows	3.45	3.06	2.88	2.77	2.69	2.66	2.62	2.59	2.50	2.49	2.51	2.53	2.52	2.50
Other cattle	3.74	3.27	3.22	3.06	3.06	3.05	3.01	2.89	2.84	2.87	2.87	2.84	2.81	2.75
Swine	1.26	1.16	1.26	1.54	1.65	1.71	1.68	1.70	1.72	1.69	1.71	1.64	1.64	1.66

Table 313: Percentage contributions of dairy cows, other cattle and swine to the total direct N_2O emissions from manure management

[%]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Dairy cows	38.9	38.4	36.9	35.5	34.2	33.7	33.8	33.9	33.3	33.1	33.3	33.8	33.9	33.9
Other cattle	42.1	41.1	41.4	39.1	38.9	38.7	38.8	37.8	37.8	38.1	37.9	37.9	37.8	37.2
Swine	14.2	14.6	16.2	19.7	21.0	21.8	21.6	22.2	22.8	22.5	22.6	22.0	22.0	22.5
Total	95.2	94.1	94.5	94.2	94.1	94.2	94.2	94.0	93.8	93.7	93.8	93.7	93.7	93.7

Table 314 shows the absolute and percentage reductions in N_2O emissions achieved via manure digestion, in comparison to a situation with no digestion and storage of digestates. Negative values denote an emissions increase. The primary reason for the increase is that storage of digestates, if it is not gas-tight, generates higher N_2O emissions than does conventional storage of manure. Furthermore, storage of digested poultry manure generally produces higher N_2O emissions than does storage of undigested poultry manure. The fraction of storage systems with gas-tight storage has increased significantly over the years (cf. Chapter 5.1.3.6.5). Only in the period as of 2006/2007 has this trend led to reductions in N_2O emissions for total manure digestion, however.

Table 314: Absolute and percentage changes in direct N_2O emissions as a result of manure digestion, in comparison to a situation with no digestion and storage of digestates (negative values: Emissions reduction)

	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
[kt a-1]	0.0001	0.0008	0.005	0.03	-0.04	-0.10	-0.17	-0.27	-0.44	-0.52	-0.58	-0.59	-0.59	-0.59
[%]	0.001	0.010	0.07	0.4	-0.6	-1.2	-2.2	-3.4	-5.5	-6.5	-7.1	-7.4	-7.3	-7.4

Table 315 shows the total NO emissions in source category 3.B. Because the NO and N_2O emission factors are proportional to each other, the trends for NO are identical to those for N_2O.

Table 315: NO emissions from manure management

[kt a-1]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
	1.211	1.085	1.062	1.066	1.072	1.074	1.059	1.040	1.027	1.025	1.031	1.020	1.014	1.006

5.3.4.3 Uncertainties and time-series consistency (3.B, N_2O_{direct} & NO)

Table 280 in Chapter 5.1.6 shows the uncertainties in activity data and emission factors that have been used in estimating the total uncertainty of the German GHG inventory.

The estimate of the uncertainty of the N_2O emission factors (95 % confidence interval) is based on the default values in IPCC (2006): Vol. 4, Table 10.21. See also in this regard Chapters 4.2.2.4 and 14.4.1 in Rösemann et al. (2019b). With regard to the uncertainty of the activity data (animal-population data), cf. Chapters 4.1.2, 5.1.2, 6.1.2, 7.1.2 and 8.1.2 in Rösemann et al. (2019b).

Due to a lack of data on the uncertainty of the NO emission factor, the uncertainty of the N_2O emission factor is used as that uncertainty.

The emissions time series are consistent, since they were calculated with the same method for all years of the report period, and since the input data are also consistent and complete.

5.3.4.4 Source-specific quality assurance / control and verification (3.B, N_2O_{direct} & NO)

With regard to quality control and quality assurance, we refer to Chapter 5.1.7.

In the framework of verification, and in an approach similar to that used in Chapter 5.2.4, the 2016 N-excretions and N_2O-emissions figures for manure management in Germany were compared with the corresponding figures of neighboring countries and the UK; cf. Table 316 and Table 317.

With regard to N excretions, Germany's values for dairy cows and other cattle lie above the median, plausibly close to the values of other countries, especially Belgium (for dairy cows) and the UK (for other cattle). The German N-excretions figure for swine is the second-highest, after the Czech Republic's very high value. These results bring up the question of how to define the average value for the entire swine population. Germany calculates the average value in conformance with the rules for an AAP place that is occupied 365 days of the year – cf. Chapter 3.1.2.2 in Rösemann et al. (2019b). The lower N-excretions values given by the other countries may be due in part to non-AAP-consistent inclusion of vacancy periods.

With regard to poultry, Germany and the Czech Republic lie at the upper end of the value range. A lack of data on the compositions of the total populations in the various countries hampers direct comparisons, since the various types of poultry have widely differing excretion levels (cf. the range pursuant to EMEP (2016))

Table 316: N excretions per animal place, for dairy cows, other cattle, swine and poultry of various countries, for the time-series year 2016

	Dairy cows [kg place^{-1} a^{-1}]	Other cattle [kg place^{-1} a^{-1}]	Swine [kg place^{-1} a^{-1}]	Poultry [kg place^{-1} a^{-1}]
Austria	103.33	45.65	9.48	0.54
Belgium	118.70	53.50	9.31	0.59
Czech Republic	136.12	67.90	14.64	0.75
Denmark	147.03	42.49	7.69	0.56
France	114.00	59.48	10.04	0.48
Germany	**121.83**	**49.07**	**13.12**	**0.73**
Netherlands [a]	77.50	40.05	6.96	n/a
Poland	83.00	33.94	10.34	0.46
Switzerland [a]	111.62	39.39	9.68	0.47
UK [b]	107.59	48.32	NA	0.58
IPCC (2006a)-10.59, 10.72, 10.78,10.80, 10.81, 10.82	105.1 [c]	50.6 [c]	9.3 / 30.4 [c,d]	0.52 [c, e]
EMEP (2016)-3B-29	105	41	12.1 / 34.5 [d]	0.36 to 1.64

Source: Germany: 2019 Submission; other countries: (UNFCCC, 2018b)

a Netherlands and Switzerland, other cattle: calculated from CRF data

b UK: Cattle data differentiate between dairy cows (dairy cows and dairy replacements, including calves selected to be dairy cows) and the remaining "other cattle"

c IPCC weights: calculated pursuant to IPCC (2006): Vol. 4, with the IPCC's standard values for weight and N excretions and, in the case of poultry, with the German animal counts in the various poultry sub-categories (2017 Submission)

d IPCC (2006): Vol. 4: Sows and boars: 30.4, other: 9.3; EMEP (2016): Sows: 34.5, fattening pigs: 12.1

e Poultry: Assumptions for lacking values: Weight of geese = 1/2 the standard weight for turkeys IPCC (2006): Vol. 4, N excretions of geese = standard N excretions of turkeys (IPCC 2006a); weight of pullets = 1/2 the standard weight of laying hens IPCC (2006): Vol. 4; N excretions of pullets = standard N excretions of laying hens IPCC (2006): Vol. 4

Table 317 shows a comparison of the IEFs for direct N_2O emissions from manure management for dairy cows, other cattle, swine and poultry. The data sets given by the various countries all show very wide ranges. The fluctuation ranges cannot be explained on the basis of the available data. For dairy cows, other cattle and swine, Germany's values lie on the median or near it. For poultry, international comparisons are hardly feasible, because – in contrast to the situation with dairy cows, other cattle and swine – the ratio between the maximum (Czech Republic) and minimum (France) is extremely large for the poultry data. Germany's value is the third-highest, and it is considerably higher than the values of the majority of its neighbours. Germany's high value for poultry can be explained in that the German poultry IEF also includes N_2O emissions from digestion of poultry manure, and from related storage of digestates; the effective emission factor for such digestion and storage is considerably higher than the emission factor for conventional storage of poultry manure.

Table 317: IEFs of various countries for direct N_2O emissions from manure management for dairy cows, other cattle, swine and poultry, in 2016

	Dairy cows [kg place^{-1} a^{-1}]	Other cattle [kg place^{-1} a^{-1}]	Swine [kg place^{-1} a^{-1}]	Poultry [kg place^{-1} a^{-1}]
Austria	0.712	0.360	0.045	0.00080
Belgium	0.703	0.547	0.031	0.00092
Czech Republic	1.283	0.928	0.116	0.01125
Denmark	1.037	0.367	0.064	0.00088
France	0.387	0.184	0.006	0.00070
Germany	**0.598**	**0.340**	**0.072**	**0.00129**
Netherlands [a]	IE	n/c	IE	n/a
Poland	0.585	0.235	0.081	0.00072
Switzerland [a]	0.116	0.093	0.003	0.00072
UK [b]	0.498	0.618	0.176	0.00484

Source: Germany: 2019 Submission; other countries: (UNFCCC)

n/a: not available; n/c: cannot be calculated

[a] Netherlands and Switzerland, other cattle: calculated from CRF data

[b] UK: Cattle data differentiate between dairy cows (dairy cows and dairy replacements, including calves selected to be dairy cows) and the remaining "other cattle"

5.3.4.5 Source-specific recalculations (3.B, N_2O_{direct} & NO)

Table 318 shows the N_2O emissions from manure management in comparison to the corresponding results in the 2018 Submission. The underlying N-excretions data are shown in Table 319: The values are higher than the corresponding figures in the 2018 NIR. Nonetheless, N_2O emissions are considerably lower than as reported in the 2018 NIR, primarily due to use of the lower N_2O emission factor for solid manure (cf. Chapter 5.3.4.2.2). This effect masks the impacts of all other updating (numbers of animals, cf. Chapter 5.1.3.2.3; animal performance data, cf. Chapter 5.1.3.3; activity data for manure digestion, cf. Chapter 5.1.3.6.5).

Table 318: Comparison of direct total N_2O emissions from manure management, as calculated in the 2018 and 2019 Submissions

[kt a^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016
2019	8.881	7.959	7.785	7.818	7.861	7.880	7.764	7.629	7.529	7.516	7.558	7.482	7.437
2018	12.894	10.569	10.076	9.887	9.921	9.951	9.784	9.597	9.470	9.452	9.496	9.389	9.299

Table 319: Comparison of total N excretions as calculated in the 2018 and 2019 Submissions (cf. Chapter 5.1.3.4)

[kt a^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016
2019	1639.2	1412.0	1388.8	1337.3	1336.1	1342.8	1331.4	1336.1	1356.2	1373.7	1391.8	1388.2	1381.5
2018	1611.4	1385.1	1347.6	1297.4	1292.5	1301.2	1286.4	1291.2	1309.4	1324.7	1340.7	1334.2	1326.1

The NO emissions, because they are directly proportional to N_2O emissions (cf. Chapter 5.3.4.2.2), have changed with respect to the corresponding figures in the 2018 Submission in the same manner that the N_2O emissions have changed. Table 320 presents a comparison of the time series for total NO emissions.

Table 320: Comparison of total NO emissions from manure management, as calculated in the 2018 and 2019 Submissions

[kt a-1]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016
2019	1.211	1.085	1.062	1.066	1.072	1.074	1.059	1.040	1.027	1.025	1.031	1.020	1.014
2018	1.758	1.441	1.374	1.348	1.353	1.357	1.334	1.309	1.291	1.289	1.295	1.280	1.268

5.3.4.6 Planned improvements (3.B, N_2O_{direct} & NO)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

5.3.5 Indirect N_2O emissions as a result of manure management (3.B)

5.3.5.1 Category description (3.B, $N_2O_{indirect}$)

Cf. Chapter 5.3.1.

5.3.5.2 Methodological issues (3.B, $N_2O_{indirect}$)

5.3.5.2.1 Methods (3.B, $N_2O_{indirect}$)

Indirect N_2O emissions via leaching from manure management are not reported for Germany; cf. Chapter 5.3.1.

The indirect N_2O emissions resulting from deposition of NH_3 and NO from manure management (including storage of digestates of manure; not including application) are calculated, in keeping with IPCC (2006): Vol. 4- 11.21, in proportion to the deposited N quantity:

Equation17: Indirect N_2O emissions from manure management

$$E_{\mathrm{N2O indirect, MM}} = \frac{44}{28} \cdot (E_{\mathrm{NH3\text{-}N, MM}} + E_{\mathrm{NO\text{-}N, MM}}) \cdot EF_4$$

Where:

$E_{\mathrm{N2O, indirect,-MM}}$	Indirect N_2O emissions from deposition of NH_3-N and NO-N from manure management (kg a^{-1})
$E_{\mathrm{NH3\text{-}N, MM}}$	Total NH_3-N emissions from manure management (kg a^{-1})
$E_{\mathrm{NO\text{-}N, MM}}$	Total NO-N emissions from manure management (kg a^{-1})
EF_4	N_2O-N emission factor; cf. Chapter 5.3.5.2.2

A general description of the method used to calculate NH_3 and NO emissions from housing systems and manure storage is provided in Chapter 3.3.4.3 in Rösemann et al. (2019b). For details, we refer to the relevant animal-specific chapters in Rösemann et al. (2019b); cf. Table 321.

Table 321: Animal-specific details on NH_3 and NO emissions from housing systems and from manure storage, as provided in Rösemann et al. (2019)

Animal category	Chapter	Animal category	Chapter
Dairy cows	4.3.8	Mature sheep	6.3.5
Calves	4.4.6	Lambs	6.4.5
Heifers	4.5.7	Goats	6.6.5
Male beef cattle (for fattening)	4.6.7	Heavy horses	7.3.5
Suckler cows	4.7.6	Light horses / ponies	7.4.5
Male cattle > 2 years	4.8.6	Laying hens	8.3.8
Sows	5.3.7	Broilers	8.4.7
Weaners	5.4.7	Pullets	8.5.8
Fattening pigs	5.5.7	Geese	8.6.6
Boars	5.6.7	Ducks	8.7.8
		Turkeys	8.8.6

5.3.5.2.2 Emission factor (3.B, $N_2O_{indirect}$)

The emission factor EF_4 for indirect N_2O emissions resulting from deposition of NH_3 and NO via manure management and management of digestates of manure (not including application) amounts to 0.01 kg N_2O-N (kg N)$^{-1}$ IPCC (2006): Vol. 4, 11.24, Tab. 11.3).

5.3.5.2.3 Emissions (3.B, $N_2O_{indirect}$)

Table 322 shows the indirect N_2O emissions resulting from deposition of reactive nitrogen via NH_3 and NO emissions from manure management – as reported in the present submission and, in anticipation of Chapter 5.3.5.5, as reported in last year's submission. The emissions for the entire time series were calculated with the same method used for last year's submission. The differences between the two submissions result from updating of numbers of animals, of yield data, of the quantities of straw bedding used for male cattle older than 2 years, and of the input data on manure digestion (cf. Chapters 5.1.3.2.3, 5.1.3.3, 5.1.3.6.2, 5.1.3.6.5). Updating of the N_2O emission factor for solid manure (cf. Chapter 5.3.4.2.2) has also had an effect, in that it means that more N is available for NH_3 and NO emissions.

In general, the trend for deposition-related indirect N_2O emissions from manure management follows the trend for direct N_2O emissions; cf. Chapter 5.3.4.2.3. For an explanation of the differences with respect to last year's submission, cf. Chapter 5.3.5.5.

Table 322: Indirect N_2O emissions as a result of deposition of NH_3 and NO from manure management (2019 and 2018 Submissions)

[kt a^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
2019	4.218	3.560	3.569	3.575	3.579	3.586	3.507	3.512	3.568	3.589	3.619	3.576	3.547	3.529
2018	4.167	3.509	3.493	3.496	3.491	3.501	3.417	3.421	3.473	3.489	3.514	3.465	3.433	

5.3.5.3 Uncertainties and time-series consistency (3.B, $N_2O_{indirect}$)

Table 280 in Chapter 5.1.6 shows the uncertainties in the activity data and the emission factor that have been used in estimating the total uncertainty of the German GHG inventory.

The emission-factor uncertainty (95 % confidence interval) from the calculation of deposition-related indirect N_2O emissions from agricultural soils (cf. Chapter 5.5.4) has been used here as well. With regard to estimation of the uncertainty of the activity data (available quantity of reactive nitrogen), cf. Chapter 3.3.4.3.6 in Rösemann et al. (2019b) .

The emissions time series are consistent, since they were calculated with the same method for all years of the report period, and since the input data are also consistent and complete.

5.3.5.4 Source-specific quality assurance / control and verification (3.B, $N_2O_{indirect}$)

With regard to quality control and quality assurance, we refer to Chapter 5.1.7.

5.3.5.5 Source-specific recalculations (3.B, $N_2O_{indirect}$)

With regard to the source-specific recalculations, cf. Chapter 5.3.5.2.3.

5.3.5.6 Planned improvements (3.B, $N_2O_{indirect}$)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

5.4 Rice cultivation (3.C)

No rice is cultivated in Germany (not occurring – NO).

5.5 Agricultural soils (3.D)

5.5.1 Category description (3.D)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-e.)	(fraction)	Trend 1990-2017
L/T	3.D. Agricultural soils		N_2O	28,654.99	2.34%	26,648.35	2.99%	-7.0%

Gas	Method used	Source for the activity data	Emission factors used
N_2O	Tier 1 / Tier 2	M/AS/RS/NS	D, CS
NO_X	Tier 1	RS/NS	D
NMVOC	Tier 1	RS/NS	D

The source category *agricultural soils* is a key category for *N_2O emissions*, in terms of both emissions level and trend.

Microbial transformations of N compounds (nitrification and denitrification) lead to emissions of N_2O from soils. A distinction is made between direct and indirect N_2O emissions. The reported direct emissions in sector 3.D include N_2O emissions resulting from:

- application of mineral fertiliser
- application of manure (including manure digestates)
- application of digestates of energy crops
- application of sewage sludge
- grazing
- crop residues
- cultivation of organic soils

Emissions from application of compost or of residues from digestion of biowaste other than manure and energy crops are not reported here. Such emissions are taken into account instead in the emission factors used in the sector "Biowaste treatment" (5.B); cf. Chapters 7.3.1.2 and 7.3.2.2.

Furthermore, no N_2O emissions from mineralization of organic soil substance are reported (NA), since no carbon-stocks changes occur in Germany in mineral soils remaining as cropland and as grassland (in the strict sense): Chapter 6.5, CRF 4.B.1; grassland (in the strict sense): Chapter 6.6, CRF 4.C.1). Consequently, no mineralization / immobilization of nitrogen, in combination with increases / losses of organic substance in mineral soils in continuing agricultural use, takes place.

The indirect N_2O emissions in Sector 3.D result from deposition of reactive nitrogen and from leaching and surface runoff.

Table 323 shows the changes, over time, in emissions from use of agricultural soils since 1990. In addition, it shows, for the initial and final years of the time series, the emissions' shares of the relevant total emissions in the German agricultural sector.

Table 323: Percentage change in emissions from use of agricultural soils (Index: soils) since 1990, and percentage shares of total agricultural sector emissions of N_2O and GHG

[%]	Change Since 1990	Share of total agricultural emissions (N_2O, GHG, NMVOC) 1990	2017
N_2O_{soils}, direct	-6.3	69.5	69.9
N_2O_{soils}, indirect	-7.2	18.5	18.4
Total of N_2O_{soils}	-6.5	88.0	88.3
ditto, as GHG (in CO_2 eq.)	-6.5	36.2	40.2
$NMVOC_{soils}$	25.2	2.8	4.8

5.5.2 Methodological aspects, and emissions (3.D)

5.5.2.1 Methods and emission factors (3.D)

5.5.2.1.1 Direct N_2O emissions (3.D.a)

Direct N_2O emissions resulting from application of N-containing substrates, and from crop residues, are calculated with a Tier 1 method, pursuant to IPCC (2006): Vol. 4, 11.7, in proportion to the N quantities applied (cf. Chapter 5.1.5.1). The emission factor, pursuant to IPCC (2006): Vol. 4, 11.11, Table 11.1, is 0.01 kg N_2O-N per kg of applied nitrogen.

The emissions from N excretions during grazing are calculated, in accordance with IPCC (2006): Vol. 4, 11.7, in proportion to the N quantity excreted on pasture (cf. Chapter 5.1.5.1). The relevant emission factor for cattle is EF = 0.02 kg N_2O-N per kg of excreted nitrogen. For sheep, goats and horses, the N_2O-N emission factor is 0.01 kg kg^{-1}. (For swine and poultry, the inventory assumes that there are no N excretions outdoors.)

Direct N_2O emissions from cultivation of organic soils are calculated in proportion to the relevant area, which is broken down into the categories of cropland and grassland (cf. Chapter 5.1.5.1.2). The average German emission factor for cropland (10.7 kg N_2O-N per hectare and year) has been derived from the German data that Leppelt et al. (2014) used for their European-wide study. For drained grassland, Tiemeyer et al. (2016) derived a German emission factor of 2.3 kg N_2O-N per hectare and year. The study of Tiemeyer et al. (2016) is based on data sets, from 6 publications, comprising a total of 122 whole-year measurements for 12 different peatland areas in Germany. As a result of the year-to-year variance in the cropland and grassland areas, the average emission factor varies over time; cf. Table 324.

Table 324: Average N_2O-N emission factors for cultivated organic soils

[kg kg^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
N_2O-N	4.24	4.27	4.31	4.37	4.61	4.66	4.71	4.77	4.82	4.84	4.85	4.87	4.89	4.91

5.5.2.1.2 Indirect N_2O emissions resulting from deposition of reactive nitrogen via use of agricultural soils (3.D)

Indirect N_2O emissions resulting from deposition of reactive nitrogen are calculated, pursuant to IPCC (2006a)-11.21, in proportion to the N quantity deposited. The method used is basically in keeping with the approach described in Chapter 5.3.5.2.1. With regard to the emission factor, cf. Chapter 5.3.5.2.2 (0.01 kg N_2O-N (kg N)$^{-1}$). The total deposited N quantity of relevance for the calculations in Sector 3.D comprises the N quantities of the NH_3 and NO emissions (cf. Chapter 5.1.5.1.3) from:

- application of mineral fertiliser,
- application of manure (including manure digestates),
- application of digestates of energy crops,
- application of sewage sludge,
- grazing.

A description of the calculation of indirect N_2O emissions resulting from deposition of NH_3-N and NO-N is provided in Chapter 12.1 in Rösemann et al. (2019b). The German inventory does not use the IPCC default values for $Frac_{GASM}$ and $Frac_{GASF}$. Instead, it calculates the NH_3 and NO emissions that lead to deposition of reactive nitrogen by multiplying the relevant applied N quantity / N excretions on pasture by the pertinent emission factors:

With regard to application of the various types of mineral fertiliser, cf. Chapter 11.1.2 in Rösemann et al. (2019b). Calculation of NH_3 and NO emissions from manure application (including application of manure digestates) and from grazing is described in the chapters in Rösemann et al. (2019b) that are listed in Table Table 321 in Chapter 5.3.5.2.1. With regard to application of digestates of energy crops, and of sewage sludges, we refer to Chapters 10.2 and 11.4.2 in Rösemann et al. (2019b).

5.5.2.1.3 Indirect N_2O emissions resulting from leaching and surface runoff (3.D)

The indirect N_2O emissions resulting from leaching and surface runoff are calculated, with the Tier 1 method pursuant to IPCC (2006): Vol. 4, 11.21, as the product of the N_2O-N conversion factor 44/28, the leached N quantity, and the emission factor (0.0075 kg N_2O-N (kg N)$^{-1}$; cf. IPCC (2006): Vol. 4, 11.24, Table 11.3). The leached N quantity amounts to 30 % of the total consisting of the applied N quantity and the N quantity from crop residues; cf. Chapter 5.1.5.1.4).

A detailed description of the calculation of indirect N_2O emissions resulting from leaching and surface runoff is provided in Chapter 12.2 in Rösemann et al. (2019b)

5.5.2.1.4 NO emissions

The method for calculating NO emissions is similar to that for calculating N_2O emissions (cf. Chapter 5.5.2.1.2). For application of mineral fertiliser and manure, and for animal excretions in pasture, EMEP (2016)-3D, Table 3-1, gives a unified NO emission factor of 0.04 kg NO_2 per kg of applied nitrogen (cf. also EMEP (2016)-3D-13). This emission factor has been rounded to two decimal places, and it is based on the emission factor of Stehfest and Bouwman (2006), which amounts to 0.012 kg kg^{-1} in NO-N units. The inventory uses the original emission factor of Stehfest and Bouwman (2006) and, within the meaning of EMEP (2016)-3D, Table 3-1 and p. 13 and Annex A2.3, also uses it for N excretions during grazing and from application of sewage sludge.

5.5.2.1.5 NMVOC emissions

IPCC (2006) does not provide any method for calculating NMVOC emissions from agricultural crops. In keeping with EMEP (2016)-3D-29 ff, Germany calculates the pertinent NMVOC emissions separately by crops:

Equation 18: Calculation of annual NMVOC emissions from agricultural crops pursuant to EMEP (2016)

$$E_{\text{NMVOC, cult,i}} = A_i \cdot m_{\text{FM,i}} \cdot x_{\text{DM,i}} \cdot t_i \cdot EF_{\text{NMVOC, cult,i}}$$

Where

$E_{\text{NMVOC, cult, i}}$	NMVOC emissions from agricultural crop i (in kg a^{-1})
A_i	Area under cultivation with crop i (in ha)
$m_{\text{FM, i}}$	Average fresh-matter yield from crop i (in kg ha^{-1} a^{-1})
$x_{\text{DM, i}}$	Dry-matter content of crop i (in kg kg^{-1})
t_i	Fraction of the year during which crop i emits NMVOCs (in a a^{-1})
$EF_{\text{NMVOC, cult, i}}$	NMVOC emission factor for crop i (in kg kg^{-1})

With regard to areas under cultivation, fresh-matter yields, dry-matter content and relative duration of emissions, cf. Chapter 5.1.5.3. The emission factors for wheat, rye, rape and grass were obtained from EMEP (2016)-3D-16, Table 3-3; cf. Table 325. For the crop categories "grass clover ley, alfalfa, forage grass" and "pastures and meadows", the EMEP emission factor for grass has been used. For the remaining crops, the EMEP emission factor for wheat has been used.

Table 325: NMVOC emission factors for agricultural crops

Crop	Emission factor [kg kg^{-1} h^{-1}]
Wheat	$2.60 \cdot 10^{-8}$
Rye	$1.41 \cdot 10^{-7}$
Rape	$2.02 \cdot 10^{-7}$
Grass (15 °C)	$1.03 \cdot 10^{-8}$

5.5.2.2 *Frac* values (3.D)

Germany reports on $Frac_{GASF}$, $Frac_{GASM}$ and $Frac_{leach}$.

In the German inventory, $Frac_{LEACH}$ is an input value. It shows the relative fraction of N inputs into the soil that is lost via leaching and surface runoff. The German inventory uses the IPCC default value $Frac_{LEACH}$ = 0.30 kg kg^{-1} (IPCC (2006): Vol. 4, 11.24, Tab. 11.3), cf. Chapter 5.1.5.1.4.

The quantities $Frac_{GASF}$ and $Frac_{GASM}$, on the other hand, are not used in the inventory. For reporting purposes, however, they are determined retroactively from the input and output data for the completed emission calculation.

$Frac_{GASF}$, pursuant to IPCC (2006): Vol. 4, 11.21, Equation 11.9, denotes the fraction of the N quantity applied via mineral fertiliser that is emitted as NH_3-N and NO-N; cf. Table 326. In such emissions, NH_3 is the predominant influencing factor. Because different NH_3 emission factors are used for different mineral fertiliser types, the $Frac_{GASF}$ value depends on the mineral-fertiliser mix prevailing in the year in question. Because urea has a relatively high emission factor (EMEP, 2016), $Frac_{GASF}$ correlates very well with the ratio of urea-N to total-mineral-fertiliser-N; 13.1 cf. Chapter 13.1 in Rösemann et al. (2019b).

Table 326: $Frac_{GASF}$ time series and weighted average throughout the entire time series (3.D)

[kg kg^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Mean
$Frac_{GASF}$	0.042	0.045	0.047	0.050	0.052	0.062	0.052	0.056	0.053	0.056	0.056	0.059	0.060	0.059	0.050

$Frac_{GASM}$, pursuant to IPCC (2006): Vol. 4, 11.21, Equation 11.9, expresses the fraction of the N quantity applied via manure (including digestates from manure digestion), digestates from digestion of energy crops, sewage sludge and grazing that is emitted as NH_3-N and NO-N; cf. Table 327. (The $Frac_{GASM}$ definition in CRF Table 3.D does not conform to this definition.)

Table 327: $Frac_{GASM}$ time series and weighted average throughout the entire time series (3.D)

[kg kg^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Mean
$Frac_{GASM}$	0.197	0.186	0.180	0.174	0.172	0.171	0.171	0.172	0.168	0.166	0.163	0.161	0.162	0.162	0.177

5.5.2.3 Emissions (3.D)

Table 328 presents an overview of the contributions of the various individual sub-sources to overall N_2O emissions from agricultural soils. The indirect emissions also include the contributions resulting from application of digestates from digestion of energy crops.

Table 328: Overview of N_2O emissions from agricultural soils (3.D)

[kt a-1]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total emissions	**96.2**	**84.0**	**89.2**	**84.2**	**86.9**	**83.4**	**82.8**	**88.1**	**86.7**	**88.3**	**91.0**	**92.7**	**90.0**	**89.4**
Total direct emissions	**75.9**	**66.6**	**70.8**	**66.9**	**69.0**	**66.1**	**65.7**	**69.7**	**68.8**	**69.9**	**72.1**	**73.3**	**71.1**	**70.8**
Total indirect emissions	**20.3**	**17.4**	**18.4**	**17.3**	**17.8**	**17.3**	**17.1**	**18.4**	**17.9**	**18.4**	**18.9**	**19.4**	**18.8**	**18.6**
Mineral fertiliser	34.0	28.1	31.7	27.9	28.4	24.4	24.7	28.1	25.8	25.9	26.3	28.6	26.9	26.1
Manure	18.6	16.2	15.9	15.3	15.4	15.5	15.4	15.5	15.8	16.0	16.3	16.2	16.2	16.1
Digestates of energy crops	0.0	0.0	0.1	0.7	1.6	2.1	2.6	3.2	3.6	4.3	4.5	4.7	4.7	4.7
Sewage sludge	0.4	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3
Grazing	6.5	5.2	5.1	4.5	4.4	4.3	4.3	4.2	4.2	4.3	4.3	4.4	4.3	4.3
Crop residues	7.6	7.8	8.8	9.2	9.7	10.1	9.0	8.8	9.5	9.5	10.8	9.5	9.3	9.8
Organic soils	8.7	8.8	8.8	8.8	9.2	9.3	9.3	9.4	9.5	9.5	9.5	9.5	9.5	9.5
Indirect, deposition, not including EC [a]	5.8	4.9	4.9	4.5	4.5	4.6	4.3	4.6	4.4	4.5	4.5	4.7	4.6	4.5
Indirect, deposition, EC [a]	0.0	0.0	0.0	0.1	0.3	0.4	0.5	0.6	0.7	0.8	0.8	0.8	0.8	0.8
Indirect, leaching, not including EC [a]	14.4	12.5	13.4	12.4	12.6	11.9	11.6	12.4	12.1	12.2	12.6	12.8	12.3	12.3
Indirect, leaching, EC [a]	0.0	0.0	0.0	0.2	0.4	0.5	0.6	0.7	0.8	1.0	1.0	1.1	1.1	1.1

[a] EC: Digestates of energy crops

The total N_2O emissions decreased in the first half of the 1990s. In subsequent years, through 2013, no clear trend emerges. A considerable increase occurred from 2013 to 2015. Thereafter, until 2017, a considerable decrease occurred.

The annual fluctuations in total emissions are shaped largely by fluctuations in N_2O emissions from application of mineral fertiliser. Those fluctuations, in turn, result from year-to-year variations in the N quantity contained in the mineral fertilisers used (cf. Table 272 in Chapter 5.1.5.1.1). Along with an increase in mineral-fertiliser application, the factors that contributed to the noticeable increase in total emissions that occurred from 2013 to 2014 include an increase of N_2O emissions from crop residues that resulted from the unusually large harvests of 2014 (cf. Table 272 in Chapter 5.1.5.1.1). Although in 2015 N_2O emissions from crop residues returned to their 2013 level, total N_2O emissions increased again noticeably from 2014 to 2015, due to a considerable increase in mineral fertiliser use. The decrease in mineral-fertiliser application that then occurred is the main reason for the decrease in total emissions that took place from 2015 through 2017. In the last ten years of the time series, quantity increases in application of digestates of manure and of digestates of energy crops have an impact.

Table 329 presents, for the first and last years of the time series, the percentage contributions of the various individual sub-sources to the total N_2O emissions from agricultural soils.

Table 329: N_2O from agricultural soils: Shares of sub-sources

[%]	1990	2017
Mineral fertiliser	35.4	29.2
Manure (including digestates from manure digestion)	19.3	18.0
Digestates of energy crops	0.0	5.3
Sewage sludge	0.4	0.3
Grazing	6.8	4.8
Crop residues	7.9	10.9
Organic soils	9.1	10.7
Total indirect N_2O	21.1	20.8

The results of the NO-emissions calculations are shown in Table 330. With regard to the sources, cf. Chapter 5.5.2.1.2. Table 330 shows the emissions from application of energy-crop digestates separately, in order to highlight their relative importance. The trend for the total emissions largely follows that for the N_2O emissions. (For purposes of reporting in CRF 3s2, the NO values are converted into NO_2, via multiplication by the molar ratio 46/30.)

Table 330: NO emissions from agricultural soils

[kt a-1]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total	**92.4**	**77.9**	**83.1**	**76.6**	**78.7**	**73.0**	**74.2**	**80.9**	**78.2**	**79.9**	**81.4**	**85.4**	**82.3**	**80.9**
Digestates of energy crops	0.0	0.0	0.1	1.2	2.6	3.4	4.2	5.3	5.8	7.1	7.4	7.7	7.7	7.8
Other sources	92.4	77.9	83.0	75.4	76.1	69.6	70.0	75.6	72.3	72.9	74.0	77.7	74.6	73.1

Table 331 shows the development of NMVOC emissions over time. The annual changes – and, thus, the increasing trend that continued until 2014 – are primarily tied to variations in harvest yields. The yields of 2014 were the largest seen to date.

Table 331: NMVOC emissions from agricultural crops

	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
[kt a-1]	7.69	8.19	8.79	9.17	9.83	10.63	9.49	8.99	10.02	10.32	11.34	9.85	9.63	9.68
in % of 1990	100.0	106.5	114.2	119.2	127.8	138.1	123.4	116.9	130.3	134.2	147.4	128.0	125.2	125.8

5.5.3 Source-specific quality assurance / control and verification (3.D)

With regard to quality control and quality assurance, we refer to Chapter 5.1.7.

For purposes of verification, Table 332 and Table 333, in an approach similar to that used in Chapter 5.2.4, compare the German inventory's N_2O-N emission factors and Frac values $Frac_{GASF}$, $Frac_{GASM}$ and $Frac_{LEACH}$ with the corresponding data of countries that are neighbouring countries or whose agricultural practice in this regard is similar to that of Germany. For the reasons given in Chapter 5.2.4, the year chosen for the comparison is the time-series year 2016.

Table 332: Comparison of the N_2O-N emission factors used in the German inventory with those of neighboring countries, for the time-series year 2016

N_2O-N	Mineral fertiliser	Manure	Crop residues	Organic soils	Grazing	Deposition	Leaching
	[kg kg-1]	[kg kg-1]	[kg kg-1]	[kg ha-1]	[kg kg-1]	[kg kg-1]	[kg kg-1]
Austria	0.0100	0.0100	0.0100	8.2000	0.0155	0.010	0.0075
Belgium	0.0100	0.0097	0.0100	8.0000	0.0195	0.010	0.0075
Czech Republic	0.0100	0.0100	0.0100	NO	0.0183	0.010	0.0023
Denmark	0.0100	0.0100	0.0100	8.7883	0.0180	0.010	0.0046
France	0.0100	0.0100	0.0100	8.0183	0.0188	0.010	0.0075
Germany	**0.0100**	**0.0100**	**0.0100**	**4.8893**	**0.0191**	**0.010**	**0.0075**
Netherlands	0.0130	0.0086	0.0104	n/c	0.0330	0.010	0.0075
Poland	0.0100	0.0100	0.0100	8.0000	0.0191	0.010	0.0075
Switzerland	0.0099	0.0100	0.0100	8.0000	0.0190	0.026	0.0075
UK	0.0072	0.0046	0.0100	8.0000	0.0047	0.010	0.0075
IPCC (2006): Vol. 4, 11.11, 11.24, IPCC et al. (2014b) [a]	0.0100	0.0100	0.0100	8.00 (13 / 4.3 / 8.2 / 1.6) [a]	0.02 (cattle, swine, poultry); 0.01 (other animals)	0.0100	0.0075

Source: Germany: 2019 Submission; other countries: (UNFCCC, 2018a)

* n/c: not comparable; see text

[a] IPCC et al. (2014b) Wetlands Supplement, Table 2.5 (cropland, drained / grassland, drained, nutrient-poor / grassland, deep-drained, nutrient-rich / grassland, shallow-drained, nutrient-rich)

For application of mineral fertiliser and of manure, and for crop residues, Germany, like most other countries, uses the IPCC (2006) default emission factor of 0.01 kg kg^{-1}.

For N_2O-N from organic soils, most countries use the IPCC (2006) default emission factor of 8 kg ha^{-1}. While the German value lies considerably below that default value, it is based on national emission factors for cropland and grassland; cf. Chapter 5.5.2.1.1. The Netherlands report their emission factor in different units (0.02 kg N_2O-N pro kg N). Due to a lack of the necessary data, it is not possible to convert that factor into units of kg N_2O-N per ha. It should be noted, however, that that Dutch emission factor leads to an N_2O-emissions figure that is very similar to that reported in the previous Dutch Submission (2016 Submission), which still reported the factor in units of kg N_2O-N per ha and gave it as 4.4342 kg ha^{-1} (cf. the German 2018 NIR, Chapter 5.5.3, Table 307). That value is closer to the current German emission factor than are all other values listed in Table 332.

Clearly enough, most of the emission factors for N_2O-N resulting from grazing are based on a combination of the two default values of IPCC (2006). The effects of the share for "other animals," which has the lower emission factor, vary from country to country. The German value is close to the default value for cattle, swine and poultry. This fact makes it clear that the population fractions for the other animals are relatively small.

For the indirect N_2O-N emissions from deposition of reactive nitrogen, and from leaching and surface runoff, Germany, like most of the other countries, uses the relevant IPCC (2006) default values.

Table 333: Comparison of Germany's Frac values with those of neighboring countries, for the time-series year 2016

[kg kg^{-1}]	$Frac_{GASF}$	$Frac_{GASM}$	$Frac_{LEACH}$
Austria	0.06	0.17	0.15
Belgium	0.07	0.18	0.30
Czech Republic	0.10	0.20	0.30
Denmark	0.05	0.09	0.28
France	0.07	0.10	0.30
Germany	**0.06**	**0.16**	**0.30**
Netherlands	0.05	NA	0.13
Poland	0.10	0.20	0.30
Switzerland	0.06	0.20	0.18
UK	0.04	0.08	0.20
(IPCC, 2006): Vol. 4, 11.24	0.10	0.20	0.30

Source: Germany: 2019 Submission; other countries: (UNFCCC, 2018a)

The scattering seen in the $Frac_{GASF}$ data can be attributed to the variation, among the neighboring countries, seen in the relative shares of different fertiliser types (with their different NH_3 emission factors). The German value is close to the median. Those countries that, like Germany, do not use the default value given in IPCC (2006): Vol. 4 calculate $Frac_{GASF}$ values that lie below the default value given in IPCC (2006): Vol.4 default value.

A considerable spread is also seen in the values for $Frac_{GASM}$ and $Frac_{LEACH}$. Germany's value for $Frac_{GASM}$ lies somewhat below the median. For $Frac_{LEACH}$, Germany, like a number of other countries, uses the default value given in IPCC (2006): Vol.4 default value.

5.5.4 Uncertainties and time-series consistency (3.D)

The activity-data and emission-factor uncertainties, for direct and indirect N_2O emissions, that enter into the estimate of the total uncertainty of the German GHG inventory are listed in Table 280 in Chapter 5.1.6.

The emission-factor uncertainties for direct N_2O from mineral fertiliser, organic fertiliser (manure, digestates, sewage sludge), crop residues and grazing are default figures from IPCC (2006) Vol. 4 -11.11, Table 11.1. With regard to the uncertainty of the activity data (N quantities), cf. Chapters 11.1.1, 11.2.1, 11.3.1, 11.4.1, 11.5.1 and 11.7.1.6 in Rösemann et al. (2019a).

The activity-data and emission-factor uncertainties for direct N_2O emissions from drained organic soils have been derived from national data; cf. Chapters 11.6.1 and 11.6.2 in Rösemann et al. (2019b).

For NO from application of mineral fertiliser and manure, and for N excretions in pasture, a 95 % confidence interval of -88 % to +160 % (with respect to the emission factor) can be derived from the information in EMEP (2016)-3D, Table 3-1. EMEP (2016) does not provide a 95 % confidence interval for application of sewage sludge. Since the emission factor is tied to the same source as the emission factor for application of mineral fertiliser and manure and for N excretions (Stehfest & Bouwman, 2006), however, the aforementioned 95 % confidence interval of -88 % to +160 % is used here as well. As in the case of N_2O, the same emission-factor uncertainty is used for application of digestates as is used for application of mineral fertiliser. With regard to the uncertainties for the activity data (N quantities), we refer to the discussion on N_2O emissions above.

With regard to the uncertainties in connection with the indirect N_2O emissions, cf. Chapters 12.1 and 12.2 in Rösemann et al. (2019b).

For the Tier 1 emission factor for NMVOC, EMEP (2016)-3D, Table 3-1, gives a 95 % confidence interval that ranges, with respect to the emission factor, from -74 % to +300 %. No information on the uncertainty of the activity data is available.

The emissions time series are consistent, since they were calculated with the same method for all years of the report period, and since the input data are also consistent and complete.

5.5.5 Source-specific recalculations (3.D)

Table 334 compares the N_2O emissions from agricultural soils as reported in the 2019 Submission with those as reported in the 2018 Submission.

Table 334: Total N_2O from agricultural soils, in the 2018 and 2019 Submissions (3.D)

[kt a^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016
2019	96.2	84.0	89.2	84.2	86.9	83.4	82.8	88.1	86.7	88.3	91.0	92.7	90.0
2018	95.3	83.2	88.1	83.2	85.8	82.3	81.7	87.0	85.6	87.1	89.8	91.4	88.7

Table 335 shows the changes in N_2O emissions with respect to the figures given in the 2017 Submission. For reasons of space limitations, the numbers are given only to three decimal places. In some cases, slight changes are not shown as such, but are indicated as "0.000"; the number "0" means that no changes have occurred.

Table 335: Change, between the 2018 Submission and the 2019 Submission, in total N_2O emissions (direct + indirect) from use of agricultural soils (negative values: reduction from the Submission 2018 to the Submission 2019)

[kt a^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016
Total	0.881	0.747	1.059	1.013	1.093	1.050	1.116	1.110	1.147	1.195	1.248	1.310	1.242
Mineral fertiliser	0	0	0	0	0	0	0	0	0	0	0	0	0
Manure	0.472	0.409	0.542	0.517	0.554	0.533	0.569	0.564	0.586	0.607	0.630	0.658	0.673
Application of digestates of EC [a]	0	0	0	0	0	0	0	0	0	0	0	0.000	-0.065
Sewage sludge	0	0	0	0	0	0	0	0	0	0	0	0	-0.001
Grazing	0.142	0.127	0.230	0.220	0.246	0.232	0.249	0.251	0.261	0.274	0.288	0.306	0.310
Crop residues	0.022	0.013	0.014	0.017	0.019	0.021	0.018	0.019	0.018	0.018	0.020	0.018	0.019
Organic soils	0	0	0	0	0	0	0	0	0	0	0	0	0
Indirect: deposition, not including EC [a]	0.119	0.088	0.122	0.114	0.118	0.113	0.120	0.116	0.118	0.123	0.129	0.136	0.136
Indirect: deposition, EC [a]	0	0	0	0	0	0	0	0	0	0.002	0.004	0.005	-0.005
Indirect: leaching, not including EC [a]	0.127	0.109	0.151	0.145	0.156	0.150	0.160	0.159	0.165	0.172	0.178	0.187	0.190
Indirect: leaching, EC [a]	0	0	0	0	0	0	0	0	0	0	0	0.000	-0.015

[a] EC: Digestates of energy crops

[b] Leaching: Leaching and surface runoff of digestates of energy crops

In the area of direct N_2O emissions, no differences in emissions have occurred with regard to mineral fertiliser and organic soils. The differences in emissions for the other sources are a direct result of the updating of N quantities described in Chapter 5.1.5.1.1.

The deposition-related indirect N_2O emissions (not including indirect N_2O emissions from digestion of energy crops) have increased considerably with respect to the 2018 Submission. This results primarily from updating of the N_2O emission factor for solid-manure systems, as well as from the higher N excretions for heifers (cf. Chapter 5.1.5.1.1), which translate into higher N availability for NH_3 and NO emissions. The updating of statistical data on frequency of application techniques, and the updating of the NH_3 emission factor for application using a trailing hose in short vegetation, have a much smaller effect on the deposition-relevant NH_3 emissions from manure application; cf. Chapter 3.5.2 in Rösemann et al. (2019).

The differences in the indirect N_2O emissions from leaching and surface runoff follow the differences in the available N quantities; cf. Chapter 5.1.5.1.1.

Table 336 compares the total NO emissions with the corresponding data from the 2018 Submission. In Table 337, the differences between the two submissions are broken down by sub-sources. Here as well, the numeral "0" means that no changes have occurred. Since the NO emissions are generally calculated on the basis of their being proportional to the available N quantity, the non-zero differences reflect the updating of the N quantities as described in Chapter 5.1.5.1.1.

Table 336: Comparison of total NO emissions from agricultural soils (3.D)

[kt a^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016
2019	92.4	77.9	83.1	76.6	78.7	73.0	74.2	80.9	78.2	79.9	81.4	85.4	82.3
2018	91.5	77.1	82.1	75.5	77.6	72.0	73.1	79.8	77.0	78.7	80.1	84.0	81.1

Table 337: Change, between the 2018 Submission and the 2019 Submission, in NO emissions from use of agricultural soils (negative values: reduction from the Submission 2018 to the Submission 2019)

[kt a^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016
Total	**0.887**	**0.772**	**1.074**	**1.025**	**1.107**	**1.061**	**1.135**	**1.129**	**1.171**	**1.218**	**1.266**	**1.327**	**1.246**
Mineral fertiliser	0	0	0	0	0	0	0	0	0	0	0	0	0
Manure	0.771	0.668	0.886	0.845	0.906	0.871	0.931	0.923	0.958	0.994	1.031	1.077	1.101
Application of digestates of EC [a]	0	0	0	0	0	0	0	0	0	0	0	-0.001	-0.107
Sewage sludge	0	0	0	0	0	0	0	0	0	0	0	0	-0.001
Grazing	0.116	0.104	0.188	0.180	0.201	0.190	0.204	0.206	0.213	0.224	0.235	0.251	0.253

[a] EC: Digestates of energy crops

5.5.6 Planned improvements (3.D)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

5.6 Prescribed burning of savannas (clearance of land by prescribed burning) (3.E)

Land clearance by prescribed burning is not practiced in Germany (NO).

5.7 Field burning of agricultural residues (3.F)

Field burning of agricultural residues was already prohibited in Germany in 1990, at the beginning of the emissions-reporting period. Approvals for such burning are issued only in exceptional cases (for example, in cases of insect infestation), and only at the municipal level. Since no official data on such cases are available, Germany reports no emissions (NO) under 3.F. For details, cf. Chapter 11.8 in Rösemann et al. (2019b).

5.8 CO_2 emissions from liming and urea application (3.G-I)

5.8.1 Category description

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
-/-	3.G. Liming	0	CO_2	2,200.79	0.18%	1,939.18	0.22%	-11.9%
-/-	3.H. Urea application	0	CO_2	479.60	0.04%	768.75	0.09%	60.3%
-/-	3.I. Other carbon-containing fertilisers	0	CO_2	503.22	0.04%	216.07	0.02%	-57.1%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 1	NS	D

The source category *CO_2 from liming* is not a key category for CO_2 emissions.

Liming, i.e. addition of carbonates to the soil, reduces the soil's acidity. It enhances plant growth, releasing CO_2 in the process. Lime fertilisers include all carbonates of calcium and magnesium, either as pure substances or as additives. The reports differentiate between dolomite and the other lime fertilisers, in order to take account of how the two groups differ in carbonate carbon content, as well as in their CO_2 emission factors. With regard to the latter group, application of calcium ammonium nitrate is considered separately. The resulting CO_2 emissions are reported under CRF 3.I ("Other lime-containing fertilisers"), while the CO_2 emissions from application of other lime fertilisers and dolomite are reported under CRF 3.G. The reported CO_2 emissions comprise, in keeping with the requirement in (IPCC (2006): Vol. 4, Chapter 11.3 and CRF Table 3.G-I, both emissions from agriculture and emissions from liming in the forestry sector.

Nitrogen fertilization with urea leads to CO_2 emissions via reactions involving urease and water. Germany reports such CO_2 emissions in Sector 3.H, without deducting CO_2 bound via industrial production of urea fertiliser.

The CO_2 emissions from liming and urea application that are reported in this chapter represent 100 % of the CO_2 emissions of the agricultural sector. Table 338, which complements the above table, shows the change over time in the sum of these CO_2 emissions since 1990, as well as, for the initial and final years of the time series, the emissions' percentage shares of total GHG emissions from the German agricultural sector.

Table 338: Percentage change in the sum of CO_2 emissions from liming and urea application since 1990, and percentage shares of total GHG emissions from the German agricultural sector

[%]	Change Since 1990	Share of total agricultural GHG emissions 1990	2017
Total CO_2 from liming and urea application	-8.2	4.0	4.4

5.8.2 Methods and emissions

The Tier 2 method given in IPCC (2006): Vol. 4, 11.27 is based on use of the Tier 1 equation (equation 11.12 in IPCC (2006): Vol. 4, 11.27), whereby the fertiliser quantity is multiplied by the emission factor. Since no specific German emission factors are available for dolomite and limestone, the default emission factors given in IPCC (2006): Vol. 4, 11.27 are used: 0.13 kg CO_2-C per kg dolomite ($CaMg(CO_3)_2$) and 0.12 kg CO_2-C per kg limestone ($CaCO_3$). In the case of calcium ammonium nitrate, CO_2 is produced from the $CaCO_3$ fraction, a process for which the limestone emission factor of 0.12 kg CO_2-C per kg $CaCO_3$ has been used. On that basis, an emission factor of 0.02748 kg CO_2-C per kg with respect to the total applicable mass of calcium ammonium nitrate can be derived; cf. Chapter 11.9.2 in Rösemann et al. (2019b).

For purposes of entry into the CRF tables, the so-calculated CO_2-C emissions are converted into CO_2 units via multiplication by the molar ratio 44/12 (IPCC (2006): Vol. 4, 11.27). These CO_2 emissions may be seen as the highest emissions possible, since the aforementioned emission factors are based on the conservative assumption that all of the carbon contained in the fertilisers is converted into CO_2.

Table 339 shows the CO_2 emissions from liming over time, both as a sum total and broken down in accordance with the three reported lime fertiliser categories.

Table 339: CO_2 emissions from liming (3.G, 3.I)

[kt a^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total	2704.0	1744.9	2224.9	1727.4	1834.7	1795.4	1737.6	1885.7	1948.7	2003.5	2242.2	2214.7	1952.5	2155.2
in % of 1990	100.0	64.5	82.3	63.9	67.9	66.4	64.3	69.7	72.1	74.1	82.9	81.9	72.2	79.7
Limestone	1837.1	1135.3	1668.1	1323.6	1460.4	1470.7	1392.2	1526.2	1611.0	1673.7	1922.5	1894.0	1669.9	1882.6
Dolomite	363.7	202.6	162.0	93.3	72.4	90.8	79.4	87.7	83.3	94.4	88.7	78.5	63.7	56.6
Calcium ammonium nitrate	503.2	407.0	394.8	310.5	301.9	233.9	266.0	271.8	254.5	235.5	230.9	242.3	218.8	216.1

The Tier 1 method for CO_2-C emissions from urea application (IPCC (2006): Vol. 4, 11.32) calculates the emissions in proportion to the quantity of urea applied (cf. Chapter 5.1.5.2). The proportionality factor used is the CO_2-C emission factor, which is derived stoichiometrically. It is given by IPCC (2006): Vol. 4, 11.32 as 0.2 kg CO_2-C per kg urea. Conversion into units of CO_2, as required for the CRF tables, is analogous to the conversion for CO_2 from liming; see above. Table 340 presents the resulting time series.

Table 340: CO_2 emissions from urea application (3.H)

	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
[kt a^{-1}]	479.6	477.2	578.5	598.0	647.9	795.0	587.4	749.9	624.8	695.0	697.8	856.3	820.4	768.7
in % of 1990	100.0	99.5	120.6	124.7	135.1	165.8	122.5	156.4	130.3	144.9	145.5	178.5	171.1	160.3

5.8.3 Source-specific quality assurance / control and verification

With regard to quality control and quality assurance, we refer to Chapter 5.1.7.

In the framework of verification, and in an approach similar to that used in Chapter 5.2.4, the 2016 CO_2 emissions from liming and urea application in Germany (current 2018 Submission) were compared with those of neighboring countries and the UK (2018 Submission, UNFCCC (2018a)); cf. Table 341.

Table 341: Comparison of the CO_2 IEF values used in the German inventory with those of neighboring countries, for the time-series year 2016

[kg CO_2-C per kg of fertiliser]	Limestone	Dolomite	Other lime-containing fertilisers	Urea application
	[kg kg^{-1}]	[kg kg^{-1}]	[kg kg^{-1}]	[kg ha^{-1}]
Austria	0.12	NO	NA	0.20
Belgium	0.12	0.13	NO	0.20
Czech Republic	0.12	0.13	NO	0.20
Denmark	0.12	NO	0.03000	0.20
France	0.12	0.13	NO	0.20
Germany	**0.12**	**0.13**	**0.02748**	**0.20**
Netherlands	0.12	0.13	NO	IE
Poland	0.12	0.13	NO	0.20
Switzerland	0.12	0.13	NO	0.20
UK	0.12	0.13	NO	0.20
IPCC (2006): Vol. 4, 11.27	0.12	0.13		0.20

Source: Germany: 2019 Submission; other countries: (UNFCCC, 2018a)

It is clear that all countries that report CO_2 emissions from liming with dolomite and limestone use the default emission factors given by IPCC (2006): Vol. 4. Use of other lime-containing fertilisers is reported only by Denmark and Germany. If the German IEF were rounded to two decimal places, it would be equivalent to the Danish value. All of the countries compared, with the exception of the Netherlands, calculate CO_2 emissions from urea application, using the default value given in IPCC (2006): Vol. 4.

5.8.4 Uncertainties and time-series consistency

Table 280 in Chapter 5.1.6 shows the activity-data and emission-factor uncertainties, for CO_2 from liming and urea application, that have been used in estimating the total uncertainty of the German GHG inventory. For derivation of the uncertainties, cf. Chapters 11.9.1 and 11.9.2 in Rösemann et al. (2019b).

The uncertainty of the activity data does not include the uncertainty that results because a) normally, not all of the carbon applied is converted into CO_2, and b) the pertinent conversion rate cannot be quantified. The calculated emissions thus represent the maximum possible emissions in the framework of the uncertainties listed in Table 280 in Chapter 5.1.6.

The emissions time series are consistent, since they were calculated with the same method for all years of the report period, and since the input data are also consistent and complete.

5.8.5 Source-specific recalculations

Since the activity data and methods have not been changed, no recalculations are required.

5.8.6 Planned improvements

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

5.9 CH_4 and N_2O from digestion of energy crops (digesters and systems for storage of digestates) (3.J)

5.9.1 Category description

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
-/T	**3.J Other**		**CH_4**	0.27	0.00%	1,357.94	0.15%	500,719.0%
-/-	3.J. Other		N_2O	0.12	0.00%	266.68	0.03%	217,867.9%

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier 2	Q/RS/NS	CS/D
N_2O direct	Tier 2	Q/RS/NS	CS/D
N_2O indirect	Tier 1	Q/RS/NS	D
NO_X	Tier 2	Q/RS/NS	CS

The source category "CH_4 and N_2O from digestion of energy crops (digesters and systems for storage of digestates)" is not key category in terms of trend.

Digestion of energy crops is carried out primarily for purposes of energy generation. For this reason, the emissions occurring during digestion itself (digester) and through storage of digestates (CH_4, N_2O and NO; cf. Chapter 5.1.4.1) are reported on as a separate source category (CRF 3s2/J). The emissions resulting via use of digestates as fertiliser are reported in conjunction with reporting on emissions from application of other fertilisers, under 3.D.2.c.

In a procedure analogous to that used for manure, the indirect N_2O emissions connected to storage of digestates of energy crops are calculated as a result of deposition of reactive nitrogen. In addition, it is assumed, as in the case of manure, that no indirect N_2O emissions result from leaching / surface runoff from storage systems.

Table 342, which complements the table above, shows, for the first and last years of the time series, the percentage shares of emissions of CH_4, N_2O and GHG from digestion of energy crops (digesters and systems for storage of digestates) with respect to total agricultural emissions of CH_4, N_2O and GHG. Table 342 does not show percentage changes in emissions since 1990; because of the low prevalence of energy-crop digestion in 1990, such data are of limited use, as the table above shows. The emissions increase over time is a direct result of the growth in quantities of substrate.

Table 342: Percentage shares of emissions from digestion of energy crops (digester + system for storage of digestates; Index: EC) with respect to total agricultural emissions of CH_4, N_2O and GHG

[%]	Share of total agricultural emissions (CH_4, N_2O, GHG)	
	1990	2017
$CH_{4,EC}$	0.0	4.1
N_2O_{EC}	0.0	0.9
$CH_{4,EC}$ + N_2O_{EC} as GHG (in CO_{2eq})	0.0	2.5

5.9.2 Methodological issues

The procedure for calculating CH_4 emissions and direct N_2O emissions is analogous to that for calculation of emissions from solid-manure digestion (cf. Chapter 5.1.3.6.5), with the exception that it does not take pre-storage into account.

As for manure (cf. Chapter 5.3.5), indirect N_2O emissions from storage of digestates of energy crops are calculated as a result of deposition of reactive nitrogen. In the case of energy crops, such nitrogen originates in NH_3 and NO emissions from systems for storage of digestates of energy crops. Also as for the manure category, NO emissions from systems for storage of digestates are calculated via a procedure similar to that for calculation of N_2O emissions (cf. Chapter 5.3.4.2). With regard to calculation of NH_3 emissions from systems for storage of residues from digestion of energy crops, we refer to Chapter 10 in Rösemann et al. (2019b).

5.9.3 CH_4 emission factor and emissions (3.J, CH_4)

Table 343 shows the chronological sequence for the CH_4 emission factor for digestion of energy crops (digesters and systems for storage of digestates), related to the dry-matter quantities that are input into the digestion process along with energy crops (cf. Chapter 5.1.4.2). In the interest of clarity, we have used the units g kg^{-1}, instead of the kg kg^{-1}, the common units for emission factors. The decrease in the emission factor over time results from increasing use of gas-tight storage for digestates (cf. Chapter 5.1.4.2). For such storage, only the CH_4 leakage rate has to be taken into account, instead of the higher emission factor for open storage.

Table 343: CH_4 emission factor for digestion of energy crops (digesters and systems for storage of digestates), related to the dry-matter quantities input into digestion along with energy crops

[g kg^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
	3.23	3.19	3.14	3.08	2.93	2.88	2.83	2.78	2.67	2.65	2.63	2.62	2.62	2.62

The CH_4 emissions from digestion of energy crops (digesters and systems for storage of digestates) are shown in Table 344. The increasing trend results from strong increases in the quantities of energy crops being digested, especially since 2005. It has been slowed by the increasing use of gas-tight storage of digestates, especially in the transition from 2011 to 2012. For details, cf. Chapter 5.1.4.2.

Table 344: CH_4 emissions from digestion of energy crops (digesters and systems for storage of digestates)

[kt a^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
	0.01	0.14	1.18	9.78	20.82	26.25	32.44	39.75	41.77	50.13	52.00	53.98	53.62	54.32

5.9.4 N_2O emission factors and emissions (3.J, N_2O)

The emission factors for direct N_2O emissions from digestion of energy crops (systems for storage of digestates) are shown in Table 345. These data represent the average values for gas-tight and open storage. In their decreasing trend, they represent the increasing use that has occurred, over the years, of gas-tight storage, which emits no N_2O. In the interest of clarity, we have used the units g kg^{-1}, instead of the kg kg^{-1}, the common units for emission factors. The emission factors in Table 345 are to be applied to the N quantities that are input, along with energy crops, into the digestion process (cf. Chapter 5.1.4.2).

Table 345: Implied N_2O-N emission factor for direct N_2O emissions from digestion of energy crops (systems for storage of digestates), related to the N quantities input via energy crops

[g kg^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
	5.00	4.77	4.53	4.21	3.41	3.15	2.89	2.63	2.03	1.91	1.81	1.78	1.76	1.76

The emission factor for indirect N_2O emissions as a result of deposition of NH_3 and NO from storage of digestates of energy crops, like that for the comparable process in connection with manure, is set at EF = 0.01 kg kg^{-1} (IPCC (2006). Vol. 4, 11.24, Tab. 11.3). To obtain the relevant emissions, this emission factor has to be multiplied by the N quantities that are deposited – which are given in Chapter 5.1.5.1.3.

The calculated direct and indirect N_2O emissions are presented in Table 346. The trend reflects the sharp increase that has occurred in digested quantities of energy crops (cf. Chapter 5.1.4) – especially since 2005. The marked emissions decrease seen from 2011 to 2012 results from a disproportional increase in use of gas-tight storage; cf. Chapter 5.1.4.2.

Table 346: N_2O emissions from storage of digestates of energy crops

[kt a^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total	**0.000**	**0.005**	**0.041**	**0.327**	**0.593**	**0.702**	**0.810**	**0.918**	**0.777**	**0.885**	**0.877**	**0.894**	**0.883**	**0.895**
N_2O_{direct}	0.000	0.005	0.039	0.311	0.564	0.668	0.770	0.873	0.739	0.841	0.834	0.851	0.840	0.851
$N_2O_{indirect}$	0.000	0.000	0.002	0.016	0.029	0.034	0.040	0.045	0.038	0.043	0.043	0.044	0.043	0.044

5.9.5 NO emission factors and emissions (3.J, NO)

As for the case of manure (cf. Chapter 5.3.4.2.2), the relevant NO emissions are calculated in proportion to the direct N_2O emissions, via use of the NO-N emission factor, which is to be applied to the input N quantity; that factor is set to 10 % of the N_2O-N emission factor.

Table 347 shows the trend in NO emissions from digestion of energy crops (systems for storage of digestates).

Table 347: NO emissions from storage of digestates from digestion of energy crops

[kt a^{-1}]	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
	0.000	0.001	0.005	0.042	0.077	0.091	0.105	0.119	0.101	0.115	0.114	0.116	0.114	0.116

5.9.6 Category-specific quality assurance / control and verification (3.J)

With regard to quality control and quality assurance, we refer to Chapter 5.1.7.

Verification cannot be carried out, due to a lack of other German data sources. Neither can an international comparison be carried out, as a substitute, since other countries do not have comparable levels of use of digestion of energy crops.

5.9.7 Uncertainties and time-series consistency (3.J)

Table 280 in Chapter 5.1.6 shows the activity-data and emission-factor uncertainties, in connection with digestion of energy crops, that have been used in estimating the total uncertainty of the German GHG inventory. For derivation of the uncertainties, cf. Chapters 10.1 and 10.2.2 in Rösemann et al. (2019b).

The emissions time series are consistent, since they were calculated with the same method for all years of the report period, and since the input data are also consistent and complete.

5.9.8 Category-specific recalculations (3.J)

In keeping with updating, with respect to the 2018 Submission, of the time series for the activity data (quantities of energy crops, gas-tight storage: cf. Chapter 5.1.4.2), the entire time series for CH_4 and N_2O emissions (cf. Chapters 5.9.3 and 5.9.4) have been recalculated, with the same method used for the 2018 Submission. Table 348 compares the results of the 2019 Submission with those of the 2018 Submission. The numeral "0" means that no changes have occurred.

Table 348: Comparison GHG emissions from digestion of energy crops (digesters and systems for storage of digestates), as reported in the 2018 and 2019 Submissions (3.J)

CO_2eq	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016
2019 [kt]	0.39	4.94	41.7	341.9	697.1	865.4	1052.3	1267.4	1275.7	1516.9	1561.2	1616.0	1603.6
2018 [kt]	0.39	4.94	41.7	341.9	697.1	865.4	1052.3	1267.4	1275.7	1516.9	1561.2	1614.1	1627.2
2019 – 2018 [kt]	0	0	0	0	0	0	0	0	0	0	0	1.8	-23.6
2019 – 2018 [%]	0	0	0	0	0	0	0	0	0	0	0	0.1	-1.5

5.9.9 Planned improvements (3.J)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

6 Land Use, Land Use Change and Forestry (CRF Sector 4)

6.1 Overview (CRF Sector 4)

6.1.1 Categories and total emissions and sinks, 1990 – 2017

In the sub-category "Forestry and other land use" within the LULUCF sector (Common Reporting Framework Sector 4), Germany reports on positive (source) and negative (sink) CO_2 emissions from carbon pools[89]

- above-ground and below-ground biomass
- dead wood, litter
- organic and mineral soils,
- harvested wood products (4.G)

for the land-use categories

- Forest Land (4.A.1)
- Cropland (4.B.1)
- Grassland (4.C.1)
- Wetlands (4.D.1)
- Settlements (4.E.1)

as well as the relevant land-use changes between these categories (CRF 4.A.2 - 4.E.2). In the category Other Land (4.F), no anthropogenic emissions occur, since the relevant land areas are not used. No land-use changes to Other Land occur, since, by definition, land cannot be reassigned to the category "unused land" once it is in use.

The following are also inventoried:

- CO_2 emissions from
    - industrial peat extraction (4.D.1)
- N_2O emissions from
    - organic soils in land-use categories 4.A, 4.D, 4.E (emissions from the categories 4.B Cropland and 4.C Grassland are reported under Agriculture in CRF 3.D.a.6)
    - direct (CRF 4.(III)) and indirect (CRF 4.(IV)) emissions from humus mineralisation in mineral soils as a result of land-use changes and / or land cultivation.
    - industrial peat extraction (4.(II))
    - wildfires (4.(V))
- CH_4 emissions from
    - organic soils (4.(II))
    - drainage ditches of organic-soil areas (4.(II))
    - industrial peat extraction (4.(II))
    - wildfires (4.(V))

- In reporting on emissions/removals of greenhouse gases in each land-use category, a distinction is made between areas which, during the reporting period,

- undergo no land-use changes, and thus remain, in unchanged form, in the land-use category ("remaining as" categories 4.A.1 - 4.F.1)

[89] CO_2 emissions from wildfires are taken into account implicitly, via carbon-stock changes in Forest Land.

- undergo land-use changes: From the time of conversion onward, these areas are reported in the category to which they were converted. Within those land-use categories, the converted areas are then reported in conversion categories (4.A.2 - 4.F.2) for a total of 20 years. After these 20 years, the areas are reported under the relevant "remaining as" categories.

Figure 50, Figure 51 and Figure 52 provide an overview, for the present 2019 Submission, of the development over time of greenhouse-gas emissions (sum of CO_2, CH_4 and N_2O emissions, as CO_2 equivalents) in categories 4.A-4.E, differentiated by sub-categories, pools and greenhouse gases. The x-axis consists of all the years covered by the report, while the y-axis consists of a scale for emissions (positive values) and removals (negative values), expressed in kilotonnes of CO_2 equivalents (kt CO_2-eq.).

The marked changes in emission levels in the years 2002 and 2008 result from changes in emission factors for forest biomass and wood use. Wood use increased in the inventory period 2002 through 2008 and then decreased in the period 2008 through 2012 (cf. Chapter 6.4.2.2.1). The time series reflect the changes in forest biomass and the trends in land-use changes (cf. Chapter 6.3.5). The land-use changes have been determined on the basis of data sets for the reference years 1990, 2000, 2005, 2008, 2012 and 2014 (cf. Chapter 6.3). Between the reference years, the land-use changes have been linearly interpolated. As a result, constant, average land-use changes emerge for the periods between reference years (cf. Table 387). The values as of the year 2015 were extrapolated from those for 2014. This method conforms with the IPCC guidelines. Between the periods, land-use changes can vary in their intensity and direction.

The course of net emissions from 1990 through 2017 shows that, without exception, the sector **functioned as a sink** during that period. The main reason for this is found in the land-use category Forest Land. The predominant pool is forest biomass, although forest soils also contributed significantly to the sink effect. Harvested wood products, via their function as carbon stocks, also contributed to the sink function. The sink is offset primarily by emissions from agriculturally used areas in the land-use categories Cropland and Grassland. Over the years, these two categories have been constant sources, with little variation, as a result of continuous high emissions from drained organic soils. The land-use category Wetlands contributes to emissions primarily via industrial peat extraction.

The predominant GHG is carbon dioxide (CO_2), which functions as a significant net sink. Releases of methane (CH_4) and nitrous oxide (N_2O), by contrast, are relatively small. Detailed descriptions of the pertinent emissions and their time series are presented in the relevant chapters for the land-use categories (Chapter 6.4.1, Chapter 6.5.1, Chapter 6.6.1, Chapter 6.7.1, Chapter 6.8.1 and Chapter 6.10.1).

Figure 50: Time series for GHG emissions and removals (sum of CO_2, CH_4 and N_2O) [kt CO_2-eq.] in the LULUCF sector since 1990, by sub-categories

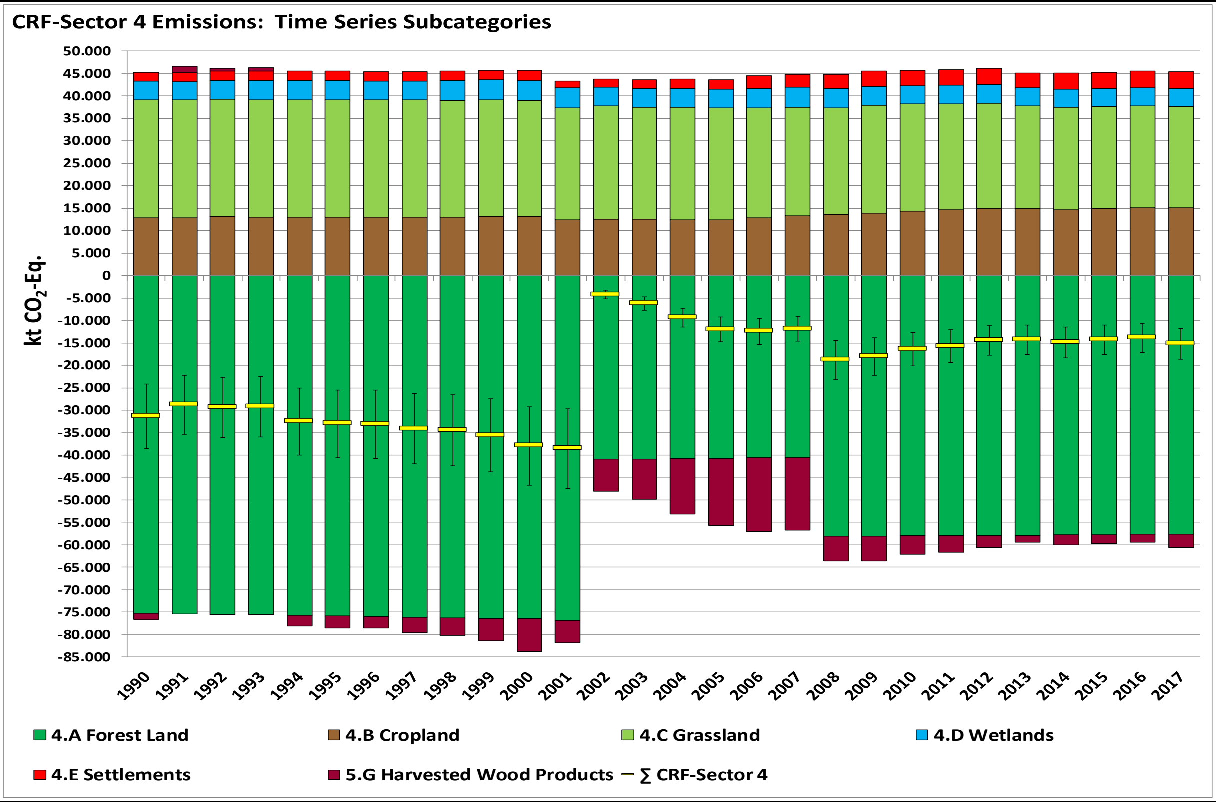


Figure 51: Time series for GHG emissions and removals (sum of CO_2, CH_4 and N_2O) [kt CO_2-eq.] in the LULUCF sector since 1990, by pools

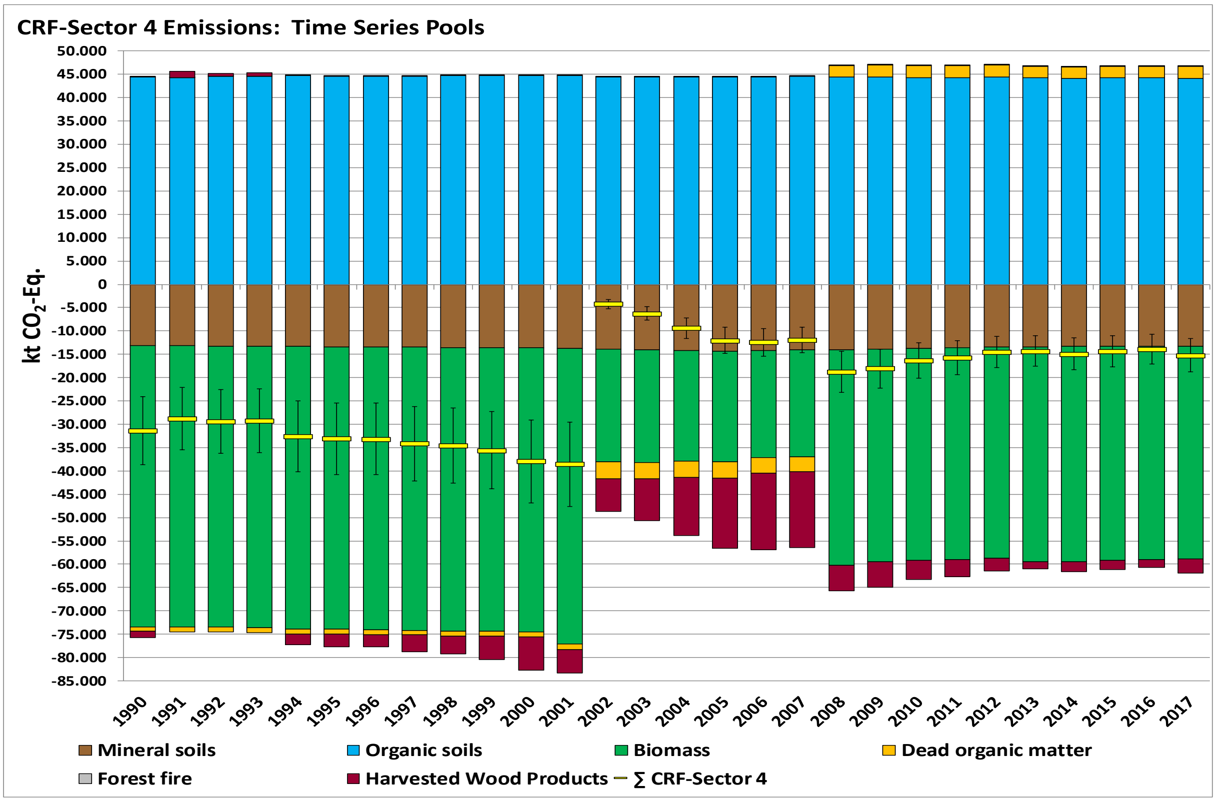
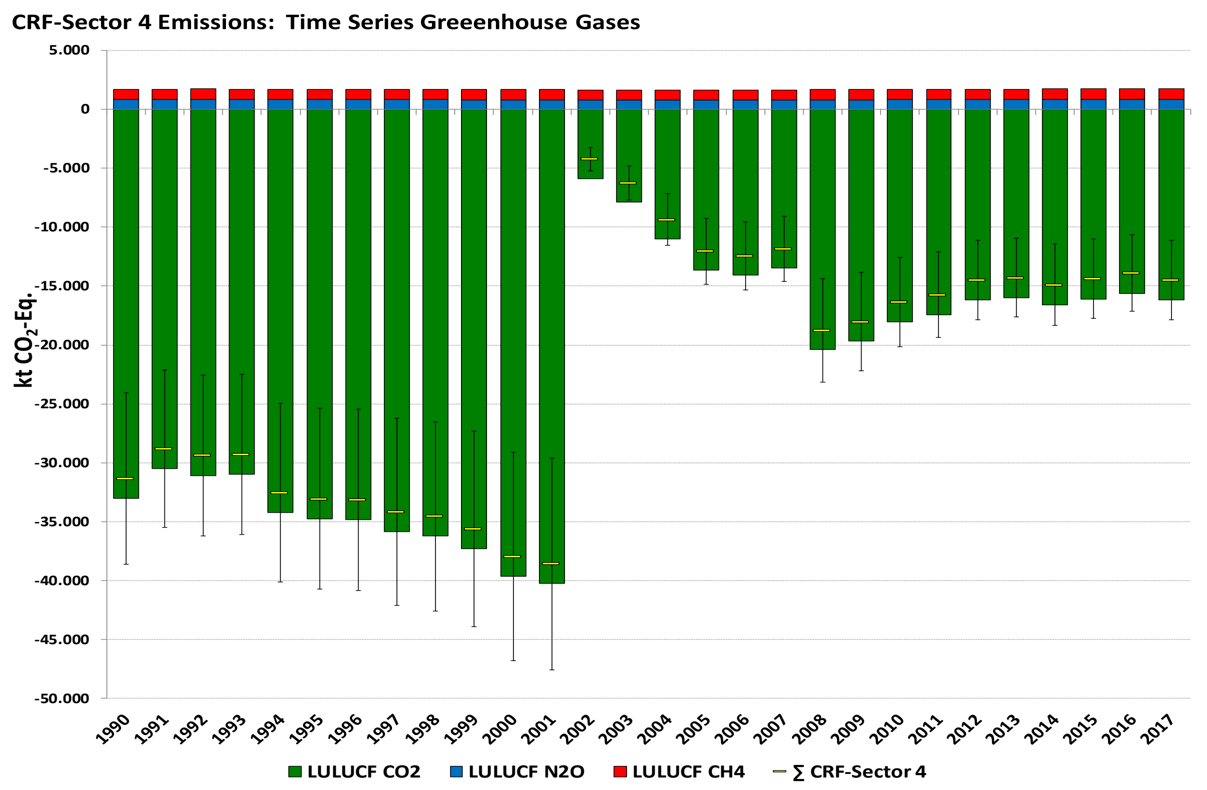


Figure 52: Time series for GHG emissions and removals (sum of CO_2, CH_4 and N_2O) [kt CO_2-eq.] in the LULUCF sector since 1990, by greenhouse gases (GHG)



The pertinent calculation shows that the total uncertainty of the German LULUCF inventory (not including harvested wood products) is 23.40 %. The relevant details are presented in the relevant chapters for the individual land-use categories and in Chapter 6.1.2.10.

6.1.2 Methodological issues

Germany has adopted the land-use-classification scheme that the 2006 IPCC Guidelines require for CRF Sector 4. The implementation is outlined in Table 349, while precise relevant definitions and descriptions are provided in Chapter 6.2 (cf. also Chapter 6.3).

Table 349: Correlation of the German reporting categories with the IPCC land-use categories

IPCC category	German LULUCF categories
4.A Forest Land	Forest Land
4.B Cropland	Cropland
4.C Grassland	Grassland (in the strict sense) Woody Grassland
4.D Wetlands	Terrestrial Wetlands Peat extraction
	Waters
4.E Settlements	Settlements
4.F Other Land	Other Land
4.G Harvested Wood Products	Harvested wood products

Basic elements of the LULUCF inventory, and the steps required to prepare it

1. **Land-use matrix$_{annual}$ *[Area_ann]***: Annual calculation of the total areas for the sub-categories "land use remaining" and "land-use conversion," in each of the categories Forest Land, Cropland, Grassland (in the strict sense), Woody Grassland, Terrestrial Wetlands, Waters, Peat extraction, Settlements and Other Land, and differentiated, by mineral and organic soils, for all time series. The relevant land uses, and the specific areas assigned to them, were explicitly determined for the years 1990, 2000, 2005, 2008, 2012 and 2014. For the time periods between those years, the applicable areas were linearly interpolated (cf. Chapter 6.3), while for the period as of 2015 the areas were extrapolated. **This approach is in conformance with the IPCC guidelines.**

2. **Emission factors for total carbon stocks in the year of a land-use change *[EF_ann]***: The emission factors for the various pools, differentiated by land-use categories, are shown in Table 350 (mineral soils), Table 364 (biomass), Table 365 (forest biomass (deforestation), dead wood and litter) and in Chapter 6.1.2.2.2 (organic soils). Except in the Forest Land and Cropland categories, carbon stocks per area unit remain constant over time. As a result, carbon stocks change constantly when land use changes.

3. **Carbon-stock changes for annual land-use changes *[E_ann]*** are calculated using the equation ***E_ann [kt C] = EF_ann [Mg C ha^{-1}]* Area_ann [kha]***, under the assumption that the entire carbon-stock change occurs in the year of the land-use change.

4. **Introduction of a twenty-year transition period *[Area_20y]***: The land-use-matrix calculation is referenced to the year 1970, to make it possible to determine land-use-change areas for years prior to the actual reporting period (cf. Chapter 6.3.4). Identified conversion areas are assigned to the relevant land-use-change category, in the year in which the land-use change takes place, and they remain in that category for 20 years. Consequently, as of the second reporting year, the areas in the remaining categories are smaller, and those in the conversion categories larger, than those in the annual land-use matrix. The relevant areas are shown in the CRF tables Table 385 and Table 386.

5. **Emission factors *[EF]* and implied emission factors *[IEF]* for the twenty-year transition period *[IEF_20y]***: These factors are listed in the CRF tables. Annual emission factors are converted into emission factors, and implied emission factors, that are appropriate for the land-use-matrix areas with 20-year transition periods. The calculations can be checked, step-by-step, in the relevant spreadsheet-program worksheets. Conversion of ***EF_ann*** to ***IEF_20y***, following inclusion of the mineral-soil and organic-soil areas for emissions from pools, yields adjusted EFs, i.e. implied emission factors (IEFs). Although the absolute emissions remain unchanged as this occurs, the IEFs are influenced by the annual net changes of the areas in the conversion categories. In the process, the following equations are used:

   - **Mineral soils**: The entire carbon-stock change as a result of a land-use change is linearly distributed over the 20-year transition period, using the equation ***IEF_20y = EF_ann / 20***; i.e. only one twentieth of the total emissions are added annually.
   - **Organic soils**: The same quantity of CO_2 is emitted each year – both in the conversion categories and in the remaining categories of the new land uses; ***IEF_20y = EF_ann***.
   - **Net carbon-stock change, carbon-stock increases and decreases in biomass and in dead organic matter, except in the case of land-use changes to Forest Land**: All emissions are completely accounted for in the year of the land-use change, in line with the equation ***IEF_20y = E_ann / Area_20y***. The emissions that

occur in a specific reporting year are thus adjusted to the larger area of the respective conversion category.

- **Net carbon-stock change, carbon-stock increase in biomass and in dead organic matter in connection with land-use changes to forest land**: The entire carbon-stock change resulting from a land-use change is determined with the equation ***IEF_20y = EF_ann***; i.e., the relevant carbon sink is allocated to the entire land-use-change area each year.
- **N_2O from loss of organic matter in mineral soils, as a result of land-use changes to Cropland**: The method used is the same as the one used for calculation of carbon-stock losses in mineral soils. The entire carbon-stock change as a result of a land-use change is linearly distributed over the 20-year transition period, in keeping with the equation ***IEF_20y = E_ann / Area_20y***; i.e. only one twentieth of the total emissions are added each year.

6. For purposes of reporting under the UN Framework Convention on Climate Change, **total carbon-stock changes for areas with 20-year transition periods** are also calculated using the following equation: ***E_20y [kt C] = IEF_20y [t C/ha]* Area_20y [kha]***.
7. **Calculation of CO_2 emissions** on the basis of the carbon-stocks values for the NIR, via multiplication of carbon-stock changes by the factor -44/12.
8. The 2019 Submission was compiled in accordance with the following provisions:

- 2006 IPCC Guidelines (IPCC 2006)
- 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (IPCC 2014a)
- 2013 Supplement to the IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands (IPCC 2014b)

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6.1.2.1 Carbon emissions from mineral soils (4.A to 4.F)

6.1.2.1.1 Overview of methods used

The area of the mineral soils was calculated as the difference between the national total areas and the areas covered by organic soils (Chapter 6.1.2.2).

Changes in carbon and nitrogen stocks in mineral soils are calculated, pursuant to Equation 2.25 in the 2006 IPCC Guidelines (IPCC, 2006), as the difference between the stocks prior to relevant land-use changes and the stocks after the changes. The emission factors have been derived on a country-specific basis. In land-use categories 4.B – 4.F (Cropland, Grassland in the strict sense, Woody Grassland, Wetlands, Settlements and Other Land), representative area-weighted carbon stocks were defined for mineral soils with depths to 30 cm, from usage-differentiated profile data for soils in Germany. Those carbon stocks were differentiated by parent material, soil type, climate region and land use. The values for forest soils were obtained from the Forest Soil Inventories (cf. Chapter 6.4.2.5.3). Thus, the reporting on mineral soils applies a Tier 2 approach.

In the framework of the Forest Soil Inventories, an annual carbon-stock change of 0.41 ± 0.11 t C ha^{-1} a^{-1} was determined for category 4.A.1, Forest Land remaining Forest Land (cf. Chapter 6.4.2.5.4). This quantity is added to the previous year's stocks, on an annual basis, and is reported as a removal.

For mineral soils with no land-use change, in land-use categories 4.B, 4.C, 4.D, 4.E and 4.F, it is assumed that the pertinent soil carbon emissions and removals are equal in size, so that the systems are in balance. The reasons for this assumption are described in Chapters 6.5.2.3 and 6.6.2.3.

The EU Commission, in its "Member State recommendations on reporting systems for cropland & grazing land management emissions & removals" {ECOFYS 2017}, had recommended that a system be developed, for Germany, that would be able to record and report on carbon-stock changes in soils that result from cultivation measures aimed at lowering emissions, or at sequestering carbon, in categories 4.B and 4.C / cropland and grazing land management. This recommendation is being implemented; pertinent means of creating such a system are currently being developed and reviewed.

The category Grassland (4.C) has two sub-categories: Grassland (in the strict sense), and grassland areas with woody plants and shrubs that do not fall within the forest definition. The conversion areas between those two sub-categories are treated like land-use changes.

The category Wetlands (4.D) has three sub-categories: Terrestrial Wetlands, peat-extraction areas (only as a remaining category) and Waters (flooded land). The area transitions between those two sub-categories are treated like land-use changes. Mineral soils occur only in the two sub-categories Terrestrial Wetlands and Waters. No carbon-stock changes are assumed in connection with land-use changes from and to Waters. As a result, no carbon-stock changes in mineral soils occur in connection with land-use changes between the relevant sub-categories (notation key "NO").

For each conversion category, the carbon-stock changes in mineral soils resulting from land-use changes are calculated as the difference between the carbon stocks of the final land-use category and the carbon stocks of the initial land-use category. Since the carbon stocks in forest soils (4.A) change annually, the inventory calculations are based on the actual annual values for the years in question. Pursuant to IPCC Default (IPCC 2006), the total changes are linearly distributed over a period of 20 years. The sum of all carbon-stock changes from land-use changes in Germany's mineral soils is calculated, for a 20-year period, as follows:

$$\Delta C = \sum_{n=1}^{7} (C_{final} - C_{initial})$$

ΔC:	Change in carbon stocks as a result of land-use changes in mineral soils of an IPCC land-use category [t C $(20*a)^{-1}$]
C_{final}:	Final soil-carbon stocks [t C]
$C_{initial}$:	Initial soil-carbon stocks [t C]
n:	Conversion categories

The carbon stocks of mineral soils in the various land-use categories, and the carbon-stock changes derived from those stocks and used as emission factors, are shown for 2017 in Table 350; the pertinent derivations are described in the following chapters.

Table 350: Mean carbon stocks in Germany's mineral soils, by land use [t C ha^{-1}], and related carbon-stock changes, as a result of land-use changes, for the year 2017

Mean carbon stocks in Germany's mineral soils in 2017								
	Forest Land	Cropland	Grassland (in the strict sense)	Woody Grassland	Terrestrial Wetlands	Waters	Settlements	Other Land
[t C ha^{-1}]	*66.31*	60.03	77.43	73.18	74.00		58.67	55.60
Carbon-stock change in 20 years [t C ha^{-1} (20 a)$^{-1}$]								
Initial\final	**Forest Land**	**Cropland**	**Grassland (in the strict sense)**	**Woody Grassland**	**Terrestrial Wetlands**	**Waters**	**Settlements**	**Other Land**
Forest Land		*-6.28*	*11.12*	*6.87*	*7.69*	0	*-7.64*	*-10.71*
Cropland	*6.28*		17.40	13.15	13.97	0	-1.35	NO
Grassland (in the strict sense)	*-11.12*	-17.40		-4.25	-3.43	0	-18.76	NO
Woody Grassland	*-6.87*	-13.15	4.25		0.82	0	-14.51	NO
Terrestrial Wetlands	*-7.69*	-13.97	3.43	-0.82		0	-15.32	NO
Waters	0	0	0	0	0		0	NO
Settlements	*7.64*	1.35	18.76	14.51	15.32	0		NO
Other Land	*10.71*	4.42	21.83	17.58	18.39	0	3.07	

Values in italics: Changing from year to year

Negative: Carbon losses; positive: Carbon sequestration; NO: not occurring

To take account of the 20-year transition period, the total stock change for each conversion category in question (EF_ann, cf. Table 350) is divided by 20. This yields the implied emission factors for the conversion categories (IEF_20y; cf. Table 351). In the case of land-use changes to and from Forest Land, and because carbon stocks in mineral forest soils change from year to year, an implied emission factor (IEF) has to be derived for each conversion category. These IEF, which vary from year to year, are obtained in each case from the contributions of the land-use changes in the previous 20-year periods, weighted by emissions. The emissions are calculated as the products of the IEF_20y and the areas of the 20-year conversion categories (cf. also "Basic elements of the LULUCF inventory, and the steps required to prepare it" in Chapter 6.1.2). For this reason, the values that Table 327 lists in connection with land-use changes to/from forest land are not the quotients obtained by dividing the relevant values in Table 326 by 20 (in this respect, they are unlike the corresponding values in all other conversion categories).

Table 351: Implied emission factors [t C ha^{-1} a^{-1}] for determination of annual carbon-stock changes in Germany's mineral soils, following land-use changes, for the year 2017

Emission factors$_{\text{mineral soils}}$ [t C ha^{-1} a^{-1}] for the year 2017								
Initial\final	**Forest Land**	**Cropland**	**Grassland (in the strict sense)**	**Woody Grassland**	**Terrestrial Wetlands**	**Waters**	**Settlements**	**Other Land**
Forest Land		*-0.042*	*0.759*	*0.517*	*0.674*	0	*-0.179*	0
Cropland	*0.070*		0.870	0.658	0.699	0	-0.068	NO
Grassland (in the strict sense)	*-0.718*	-0.870		-0.213	-0.172	0	-0.938	NO
Woody Grassland	*-0.538*	-0.658	0.213		0.041	0	-0.725	NO
Terrestrial Wetlands	*-0.639*	-0.699	0.172	-0.041		0	-0.766	NO
Waters	0	0	0	0	0		0	NO
Settlements	*0.141*	0.068	0.938	0.725	0.766	0		NO
Other Land	*0.248*	0.221	1.091	0.879	0.920	0	0.154	

Values in italics: Changing from year to year

Negative: Carbon losses; positive: Carbon sequestration; NO: not occurring

6.1.2.1.2 Database and procedure

The following data sources build the basis for the determination of the mean carbon stocks in mineral soils, weighted by climate region, and considered from a complete-coverage perspective, as a function of land use:

- Soil map of Germany (Bodenübersichtskarte; BÜK) at scale 1:1,000,000 (BÜK 1000; BGR 1995, 1997, Düwel et al. 2007)
- Soil profiles from BÜK 1000 cf. 2.3; FISBo BGR (BGR 2011)
- "Gehalte an organischer Substanz in Oberböden Deutschlands – Bericht über länderübergreifende Auswertung von Punktinformationen im FISBo BGR" ("Stocks of organic matter in Germany's topsoils – report on Länder-overarching evaluation of point data in the FISBo BGR") (DÜWEL et al. 2007)
- Results of the Forest Soil Inventory II (BZE II; Wellbrock et al. (2016))
- Data sets of the Basic Digital Landscape Model (Basis-Digitalen Landschaftsmodell; B-DLM) of the ATKIS® official topographic-cartographic information system, for the years 2000, 2005, 2010 (AdV 2000; 2005; 2010)
- IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Agriculture, Forestry and Other Land Use (IPCC, 2006)

The emission factors for the various land-use categories were determined with the help of a fallback system. This means that

- where specifically collected soil data are available for a given land-use category (BZE II data; data from the BGR study (Düwel et al., 2007)), they are used for the determination of the soil organic carbon stocks in the relevant categories, either as they are or in combination with data from the BÜK 1000;
- where such data are not available, determination is based on estimates from the BÜK 1000.

In keeping with the different data situations for the various land-use categories, the area-weighted, use-specific and soil-specific carbon stocks were determined separately for the various categories.

The BÜK 1000 soil map divides Germany's soils into 71 differently characterised soil categories / legend units. Those units, known as "dominant soil associations" (DSA), comprise dominant and secondary soil types. They are characterised on the basis of dominant soil types that are representative for the areas in question and that have been assigned selected soil profiles. Along with descriptive parameters, the profile descriptions include information about key soil characteristics, such as humus and nitrogen content and physical soil parameters (Düwel et al., 2007). The data set on which the present calculations are based includes, inter alia, derived specific measurements and according thresholds, in the form of class information pursuant to KA 4 ((Arbeitsgruppe Boden, 1994), for carbon (C_t), inorganic carbon (C_i), nitrogen (N_t), rock content and bulk density.

The mean carbon stocks of a dominant soil association can be calculated from these data by multiplying the carbon content by soil mass and correcting for skeleton and carbonate content. For determination of the mean carbon stocks in mineral soils of the categories Cropland, Grassland, Wetlands, Settlements and Other Land, the BÜK 1000 was merged with the Basis-DLM (Chapter 6.3.2.1). The land-use-specific area data and soil-characteristics data of the BÜK 1000 (bulk density, skeleton content) were combined with the organic-carbon data produced by the BGR study "Gehalte organischer Substanz in Oberböden Deutschlands: Länderübergreifende Auswertung von Punktinformationen im FISBo BGR" ("Concentrations of organic matter in

Germany's topsoils – report on Länder-overarching evaluation of point data in the FISBo BGR") (Düwel et al., 2007).

Düwel et al. (2007) list typical concentrations of organic matter (C_{org}) and humus in Germany's topsoils, for a total of 15 groups of soil parent material and 4 climate zones. Those listings are based on complete-coverage evaluation of data for ca. 14,000 profiles, broken down by land use (Cropland, Grassland and Forest Land) and by climate region.

In addition, that study assigns the 71 legend units of the BÜK, on the basis of their pedo-lithological characteristics, to those 15 groups of soil parent material (Düwel et al., 2007), with the result that those groups link to the legend units of the BÜK 1000.

6.1.2.1.3 Forest Land

The mean carbon stock value for mineral soils of up to 30 cm depth, as determined in the Forest Soil Inventories, was assigned to all areas that fall under the definition of "forest land" according to the National Forest Inventory (based on the Federal Forest Act) or, respectively, under the forest definition according to the IPCC, as selected by Germany.

Upon completion of the Forest Soil Inventories (BZE), as of the 2013 Submission, it was possible to base the LULUCF inventory calculations on the results of this work regarding soil organic carbon stocks and their change rates. The so-derived mean carbon stocks for mineral soils, to a depth of 30 cm, are 61.8 ± 3.7 t ha^{-1} for the year 2006. The mean annual change rate determined for the period between the inventories amounts to 0.41 ± 0.22 t ha^{-1} a^{-1} (cf. Chapter 6.4.2.5). To determine the carbon stocks of forest mineral soils for the various reporting years, the mean change rate was added to / deducted from the 2006 average soil organic carbon stocks of all German mineral forest soils. This yielded the following time series for the report period beginning in 1990 (Table 352):

Table 352: Mean carbon stocks [to 30 cm soil depth, in t C ha^{-1} ± 1.96 * standard error] in mineral forest soils

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
$C_{Stocks\_Forest\ soil}$ [t C ha^{-1}]	55.24 ± 6.44	57.29 ± 6.68	59.34 ± 6.92	61.39 ± 7.16	63.44 ± 7.40	63.85 ± 7.45	64.26 ± 7.49	64.67 ± 7.54	65.08 ± 7.59	65.49 ± 7.64	65.90 ± 7.69	66.31 ± 7.73

These values form the basis for all relevant calculations within this inventory, for the respective years.

6.1.2.1.4 Cropland

Cropland with annual crops

For Cropland with annual crops, the BGR study asserts that its values are valid to a soil depth of 30 cm. As a result, it was possible to apply the carbon-content data from the BGR study to all dominant soil associations of the BÜK 1000.

Table 353: Area [ha], mean area-based carbon stocks [t C ha^{-1}] and pertinent uncertainties (upper and lower uncertainty bounds in %) for croplands with annual crops

Mineral soils	Soil organic carbon stocks [t C ha^{-1}]	Uncertainty bounds upper [%]	Uncertainty bounds lower [%]
$Cropland_{annual}$	59.77	50.07	32.67

Cropland with perennial crops

With regard to croplands with perennial crops (such as fruit trees, grapevines), it was assumed that such areas are not plowed and are covered to a degree of 75 % with grass. For that reason, calculations of mean carbon stocks for such areas were based on the profile characteristics for grassland. The relevant approach is described in Chapter 6.1.2.1.5. Table 354 shows the values obtained for such areas.

Table 354: Area [ha], mean area-based carbon stocks [t C ha^{-1}] and pertinent uncertainties (upper and lower uncertainty bounds in %) for croplands with annual crops

Mineral soils	Soil organic carbon stocks [t C ha^{-1}]	Uncertainty bounds	
		upper [%]	lower [%]
Cropland with perennial crops	72.64	68.18	46.40

Soil organic carbon stocks for Cropland

The mean carbon stocks for mineral soils in Cropland are obtained as follows:

$$C_{min\ \mathrm{cropl.}} = \frac{\left(C_{cropland\ annual} * A_{cropland\ annual} + C_{cropland\ perennial} * A_{cropland\ perennial}\right)}{A_{cropland\ annual} + A_{cropland\ perennial}}$$

$C_{min\_cropland}$: Mean area-related carbon stocks of all German mineral cropland soils [t C ha^{-1}]

$C_{cropland\_annual}$: Mean area-related carbon stocks of all German mineral cropland soils with annual crops [t C ha^{-1}]

$C_{cropland\_perennial}$: Mean area-related carbon stocks of all German mineral cropland soils with perennial crops [t C ha^{-1}]

$A_{cropland\_annual}$: Cropland area with annual crops on mineral soils in Germany [ha]

$A_{cropland\_perennial}$: Cropland area with perennial crops on mineral soils in Germany [ha]

Table 355 shows the mean carbon stocks, for mineral soils under cropland, that have been used as a basis for all pertinent calculations within the inventory.

Table 355: Mean area-based carbon stocks [t C ha^{-1}] and pertinent uncertainties (upper and lower uncertainty bounds in %) for croplands

Mineral soils	Soil organic carbon stocks [t C ha^{-1}]	Uncertainty bounds		Distribution function
		upper [%]	lower [%]	
Cropland	60.03	50.50	32.99	Log-normal

6.1.2.1.5 Grassland

The land-use category "Grassland" comprises the sub-categories "Grassland in the strict sense" and "Woody Grassland" (cf. Chapter 6.2.3). Calculations for both sub-categories are carried out on the basis of the same data. Differences between the soil organic carbon stocks of these sub-categories thus result only from differences in spatial distribution of land uses and corresponding differences in percentage shares in soil-parent-material groups and climate zones.

For grassland areas, the BGR study asserts that its values are valid to a depth of 10 cm (Düwel et al., 2007). The soil organic carbon stocks were correlated with the characteristics of the mineral-soil profiles of the BÜK 1000 via relationships with soil-parent-material groups, as follows: The soil-carbon-stocks data of the BGR study (DÜWEL et al. 2007) were assigned to the uppermost horizon, in keeping with the thickness as listed (maximum thickness of 10 cm). For that horizon, the bulk density and the skeleton content were taken from the BÜK 1000, as were the data for all characteristics and thicknesses of deeper horizons and depth layers, to a depth of 30 cm. The relevant results are shown in Table 356.

Table 356: Mean area-based carbon stocks [t C ha^{-1}] and pertinent uncertainties (upper and lower uncertainty bounds in %) for grasslands

Mineral soils	Soil organic carbon stocks [t C ha^{-1}]	Uncertainty bounds		Distribution function
		upper [%]	lower [%]	
Grassland in the strict sense	77.43	77.87	45.93	Log-normal
Woody Grassland	73.18	83.27	42.94	Log-normal

6.1.2.1.6 Terrestrial Wetlands, Settlements and Other Land

The mean carbon stocks of mineral soils in Terrestrial Wetlands (the "Wetlands" category is subdivided into Terrestrial Wetlands, Waters and Peat-Extraction areas) were determined through a procedure similar to that used for Grassland. Consequently, the procedure is described in Chapter 6.1.2.1.5. Differences in carbon stocks, between Grassland and Terrestrial Wetlands, result solely from differences in spatial distribution of category areas.

The database on which the BÜK 1000 is based lists no dominant profiles for soils on settlement areas and other land. Such profiles are listed only for Forest Land, Cropland and Grassland locations. Even for such locations, profiles are not available for all dominant soil associations, however. Therefore, the profiles for grassland locations were used as substitute dominant profiles for soils in Settlement and Other-Land locations (due to Grassland soils' relative similarity to soils in gardens and parks). For dominant soil associations without dominant grassland profiles and key pedological data, the horizons seen in forest-soil profiles were used. This was because settlement soils – and, especially, soils in Other Land areas – are often disturbed and lack the deeply developed A horizons in their topsoil layers that are typical of agriculturally cultivated grasslands or croplands. For a total of 42 of the 71 dominant soil profiles, this approach led to changes – mostly reductions – in carbon stocks in comparison with Grassland. In addition, the spatial distribution of Settlement areas and Other Land in the soil landscape has a clear influence on the mean carbon stocks of mineral soils – on the one hand, with respect to Grassland soils and, on the other, on these categories' (4.E and 4.F) soil organic carbon stocks in relation to each other.

The mean carbon-stocks values are listed in Table 357.

Table 357: Mean area-based carbon stocks [t C ha^{-1}], and pertinent uncertainties (upper and lower uncertainty bounds in %), in mineral soils of Terrestrial Wetlands, Settlements and Other Land

Mineral soils	Soil organic carbon stocks [t C ha^{-1}]	Uncertainty bounds		Distribution function
		upper [%]	lower [%]	
Terrestrial Wetlands	74.00	52.48	43.85	Log-normal
Settlements	58.67	84.97	45.11	Log-normal
Other Land	55.60	92.86	44.56	Log-normal

The emission factors derived from these mean carbon stocks, which are weighted by climate region, land use and areas, are listed in Table 350 and Table 351 in Chapter 6.1.2.1. The emission factors are listed with statistical indexes, for the description of uncertainties, in Table 436 and Table 441 in Chapter 6.7.3 and 6.8.3, respectively.

The value for the soil organic carbon stocks in soils under Settlements (58.67 t ha^{-1}) is accounted for completely in the case of land-use changes, i.e. it is offset against the mineral soil stocks of the old / new land use, without any proportional deduction for potential soil sealing (pursuant to the methods described in Chapter 6.1.2.1). The method of determining the carbon stocks for settlement soils is thus in conformance with the 2006 IPCC Guidelines. The resulting values fulfill the requirements of a Tier 2 method, since

- they are derived on a country-specific basis
- they take account of soil sealing
- they are conservative

Justification:

1. The carbon stocks in settlement soils were derived from the only nationwide soil map available for Germany (BÜK 1000 (BGR 1997)), in conjunction with the map of Germany's soil parent material (BAG 5000 (BGR 2008)). The resulting value is thus the most suitable value – area-weighted by soil type, parent material and climate zone – that can currently be determined for soil organic carbon stocks in Settlements soils in Germany. It may be used as an index for all settlement and transport areas, including sealed ground areas. German law mandates special protection for topsoil (Section 202 German Building Code (BauBG) (BauBG (2004)), requiring topsoil to be stored, preserved and protected in unmixed form in the case of construction activities. In cases involving sealing, the topsoil must be laid down laterally, must not be contaminated and must not be mixed (German soil protection act (BBodSchG) (1998); Closed Cycle Management Act (KrWG) (2012); and 16 pertinent Länder construction codes). Consequently, when an area is to be sealed, its soil is normally excavated and distributed over the neighbouring areas of the construction site, which are to remain unsealed. The carbon stocks of the affected area thus remain unchanged.
2. EDELMANN (2013) studied the soil organic carbon stocks in terrestrial and semiterrestrial soils, comprising a total of 146 representative profiles, in the Berlin metropolitan area, in order to obtain sums of organic carbon stocks as a function of area use. To this end, he divided the metropolitan area into "built-up areas" and "green and open areas." The "built-up areas" (56,481 ha) consist of the sum of unsealed (27,291,4 ha ≙ 48.3 %) and sealed areas (29,190 ha ≙ 51.7 %) (EDELMANN (2013); cf. Table 334/333?). While the studies of unsealed areas were mostly carried out by the author himself, the studies of sealed areas were carried out by the Berlin Senate, during subway construction in Berlin. The sample is considered to be representative of the substrate under the fully sealed asphalt surface. The substrate consists of sands, slags, asphalt fragments, tar fragments, concrete, brick fragments and trash (EDELMANN (2013), p. 112). The average soil organic carbon stocks of sealed areas, at 0.65 %, are considerably lower than those of unsealed areas (2.1 %), although they have a considerably higher bulk density (EDELMANN, 2013). From these figures, average soil organic carbon stocks of 37.1 t C ha^{-1} $(30\ cm)^{-1}$ are calculated for the sealed areas, and stocks of 85 t C ha^{-1} $(30\ cm)^{-1}$ are calculated for the unsealed areas. Table 333 summarizes the results of this study, with respect to a soil depth of 30 cm. As Table 358 shows, the soil organic carbon stocks in the built-up areas, taking account of sealed areas, amounted to an average of 60.3 t C ha^{-1} up to 30 cm soil depth, and for green and open areas, to an average of 67.2 t C ha^{-1} up to 30 cm soil depth resulting in an average value for the entire Berlin area of 62.6 t C ha^{-1} up to 30 cm soil depth. These values are all larger than the corresponding values derived from the soil map, even though the calculation took sealed areas into account. Furthermore: Berlin's location in the center of a major soil landscape with predominantly oligotrophic sandy soils, and with low levels of precipitation, suggests that the soil organic carbon stocks determined for the Berlin metropolitan area very likely are lower than the nationwide average for Germany. From this it can be concluded that the value derived from the soil map, 58.67 t C ha^{-1} to 30 cm soil $depth^{-1}$, is conservative.

Table 358: Areas [ha], area shares [%] and soil organic carbon stocks [t C ha^{-1} to 30 cm soil depth^{-1}] in Berlin city soils, differentiated by land use (modified in accordance with EDELMANN (2013))

Type of land use	Area	Area share		SOC stocks
		Land-use-specific	City area	
	[ha]	%		[Mg ha^{-1}]
Built-up areas				
Residential use	13,766.5	24.4	16.2	89.4
Mixed use	751.1	1.3	0.9	48.6
Core-area use	85.5	0.2	0.1	48.7
Commercial and industrial use	2,171.5	3.8	2.5	45.7
Common and special use, use for sports	5,292.7	9.4	6.2	114.1
Supply and disposal facilities	353.4	0.6	0.4	48.7
Weekend homes and allotment-like use, allotments (garden plots)	3,246.4	5.7	3.8	89.4
Traffic areas	1,624.3	2.9	1.9	23.4
Sealed soils	29,190.0	51.7	34.3	37.1
∑	**56,481.3**	**100.0**	**66.3**	**60.3**
Green and open areas				
Forest Land	15,614.3	54.4	18.3	60.0
Grassland	1,130.6	3.9	1.3	66.1
Cropland	2,277.0	7.9	2.7	47.7
Parks and green areas	4,272.5	14.9	5.0	102.0
City squares / promenades	62.7	0.2	0.1	64.2
Cemeteries	1,021.7	3.6	1.2	82.3
Fallow land free of vegetation	175.0	0.6	0.2	30.5
Fallow land with meadow-like vegetation	1,563.1	5.5	1.8	73.1
Fallow land with mixture of meadows, shrubbery and trees	2,299.6	8.0	2.7	58.4
Tree nurseries / horticultural land	262.9	0.9	0.3	111.7
∑	**28,679.3**	**100.0**	**33.7**	**67.2**
City area				
∑	**85,160.6**		**100.0**	**62.6**

6.1.2.1.7 Uncertainties

The carbon-stock data from the BGR study (Düwel et al., 2007) are backed by descriptive statistics. The values for the 25th and 75th percentiles, i.e. the upper and lower threshold values for the carbon stocks, were derived from those statistics. The values for bulk density, skeleton content and carbon stocks of horizons without available values from the topsoil study of the BGR (Düwel et al., 2007) were derived through KA 4, based on the dominant-profile descriptions in the BÜK 1000 and pertinent class information (BGR 1997). Individual profiles (dominant profiles from the BÜK 1000 (BGR 1997)) do not support conclusions relative to the heterogeneity of soil parameters within the legend units (Düwel et al., 2007). Therefore, the potential range of carbon and nitrogen stocks in dominant soil associations (DSA) of the BÜK 1000 (BGR 1997) and associated uncertainties were estimated through the construction of extreme constellations of the respective class values:

- DSA carbon stocks$_{\text{maximum}}$: C_{org} content$_{\text{maximum}}$, bulk density$_{\text{maximum}}$, skeleton content$_{\text{minimum}}$
- DSA carbon stocks$_{\text{minimum}}$: C_{org} content$_{\text{minimum}}$, bulk density$_{\text{minimum}}$, skeleton content$_{\text{maximum}}$

The so-determined minimum and maximum soil organic carbon stocks formed the relevant upper and lower bounds and, in combination with the location scale, show the steep-left distribution that is typical for such data.

The uncertainties pertaining to soil organic stocks of mineral forest soils, and their changes over time, were calculated statistically from soil inventory measurements (Wellbrock et al. (2016); cf. Chapter 6.4.3.3).

6.1.2.1.8 Planned improvements

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

6.1.2.2 Emissions from organic soils (3.D; 4.A through 4.F; 4.(II))

CO_2, N_2O and CH_4 emissions from organic soils are reported in the land-use categories Forest Land, Cropland, Grassland (in the strict sense), Woody Grassland, Terrestrial Wetlands (industrial peat extraction) and Settlements (N_2O from drained organic soils is reported under Cropland and Grassland in CRF Sector 3.D.a.6). Reporting also covers methane emissions from drainage ditches, as well as carbon losses in connection with dissolved organic carbon (DOC). In Germany, the majority of organic soil areas is drained.

Emissions are calculated by multiplying the peatland areas per sub-category by pertinent use-specific emission factors. For land-use changes, the emission factor for the final category is used right away:

$$EC_{orgsoil} = \sum_{n=1}^{7}(A_n * EF_n)$$

$EC_{orgsoil}$:	Carbon emissions from organic soils in a land-use category [kt C]
A_n:	Peatland area subject to a certain land use [kha]
EF_n:	Land-use-specific emission factor [$t\ C\ ha^{-1}\ a^{-1}$]
n:	Conversion categories or remaining categories

The present inventory is based on highly detailed maps showing the locations and drainage of organic soils in Germany. In addition, this submission makes use of extensive measurement data on GHG emissions from organic soils in Germany that have been generated, using standardised measurement protocols, in the "Organic Soils" ("Organische Böden") project (www.organische-boeden.de), a collaborative research project of the Johann Heinrich von Thünen Institute (Federal Research Institute for Rural Areas, Forestry and Fisheries), as well as in predecessor projects (a small quantity of the data was obtained from the relevant national literature). The database for the activity data and emission factors, and the relevant derivations, meet the criteria for an IPCC Tier 3 method. However, a national Tier 2 method was developed for the inventory to ensure transparency and consistency with other activity data and carbon pools.

6.1.2.2.1 Activity data

On behalf of the Thünen Institute, until 2013 an "Organic Soils Map" ("Karte organischer Böden") (Parametrized area data on the organic soils in Germany) was developed that is fully in line with the IPCC definition of organic soils (Roßkopf et al., 2015):

- Spatial resolution / scale: heterogenous, for process-related reasons, ~1:10,000 – 1:200,000; grid width 25 m.
- Temporal resolution: Regionally varying, depending on the database involved (from the beginning of of the 20th century to the present).
- Data records: In close cooperation with government agencies of the German Länder, the existing soil data, peatland cadastres and data sets available from geological, silvicultural and agricultural maps were harmonised, and then incorporated in the inventory process as complete as possible, and at the highest level of resolution possible.

- Data selection (minimal criterion): In keeping with the "Bodenkundliche Kartieranleitung" (soil mapping instructions; KA 5, Arbeitsgruppe Boden (2005), 2005)) and the IPCC (2006) Guidelines for reporting on organic soils, the organic soil classes were identified that primarily describe soils with a 9 % minimum content of organic carbon (15 % organic soil matter) in a mixed sample of the upper 20 cm.

The new organic-soils area encompasses a total of 1.824 million ha. The new organic soils map supplants the previously used soil map of Germany (BÜK 1000), which was drawn to a coarse scale of 1:1,000,000 (BGR 1997), and which did not include any shallow peat soils or peats mixed with mineral soils (old total area: 1.725 million ha). Because the area allocations in the new organic soils map are much more precise than those in the old map, the area fractions for the various land-use categories have changed with respect to the NIR submissions prior to 2015. Grassland in the strict sense is now far and away the predominant use. In order to take account of small-scale structures, the resolution of the grid for determining land-use categories on organic soils has been greatly increased (cf. Chapter 6.3). This makes it possible to report a highly precise time series of land uses and land-use changes on organic soils.

Table 359 shows the organic soils areas, by land-use categories, along with the applicable drained-area fractions, for the year 2016. The drained fractions of organic soils areas, by land-use categories, were derived from the regional distribution of water levels in Germany's organic soils (Bechtold et al., 2014). Those levels have been obtained, inter alia, from the map of organic soils and from long-term measurements of water levels in organic soils. The drained fraction of organic soils consists of those areas with an average annual water level lower than 0.1 m below ground level.

The area for organic soils under agricultural use, as reported in the agricultural sector (CRF Table 3.D.a.6), differs from that area as reported in the LULUCF sector. The difference is due to organic soils areas under grassland. The cropland-soil areas under cultivation are the same in both sectors subject to reporting obligations. In the LULUCF sector, the areas of the sub-categories "Grassland (in the strict sense)" and "Woody Grassland" are subsumed under Grassland. Woody Grassland areas are not agricultural land in the strict sense. For this reason, such areas are not listed under 3.D.a.6. In addition, Grassland in the strict sense includes areas (71,405 ha) that have not been drained. No anthropogenic emissions are induced by such areas. For this reason, such areas have not been taken into account in calculation of emissions from organic soils in the agricultural sector. For a consistent representation of Germany's total area in the LULUCF sector, both undrained areas and Woody Grassland areas have to be included.

For determination of CH_4 from drainage ditches, a ditch-area fraction ($Frac_{ditch}$) of 1.3 % was determined, using the ATKIS Basis-DLM. This figure applies for all land-use categories.

Table 359: Organic soil areas, by land-use categories, along with the applicable drained-area fractions, for the year 2017.

	Areas of organic soils [ha]	Drained fraction [%]
Forest Land	148,425	77.4
Cropland	383,345	100.0
Grassland (in the strict sense)	923.1178.688	92.3
Woody Grassland	151,178	98.3
Terrestrial Wetlands	99,816	76.6
Waters	19,705	0
Peat extraction	19,857	100.0
Settlements	78,479	100.0
Other Land	0	0.00
∑	**1,823,922**	

6.1.2.2.2 Emission factors

The emission factors have been developed in keeping with the 2013 IPCC Wetlands Supplement (IPCC et al., 2014b). The emission factors for CO_2 from soils (CO_2-C on-site), CH_4 from soils (CH_{4_land}) and N_2O were developed from national annual measurements. For CO_2 from dissolved organic carbon (CO_2-C_{DOC}) and CH_4 from drainage ditches (CH_{4_Ditch}), the default from the 2013 IPCC Wetlands Supplement (IPCC et al., 2014b) were used.

CO_2 from soils (CO_2-$C_{on\text{-}site}$):

The database consists of representative, quality-checked, national annual measurements (208 measurement years, 95 sites, 13 different peatland areas) obtained on areas with an average annual water level of 0 cm or more below ground level (no overflow). This data set exhibits a linear correlation, across all land-use categories, with average annual water levels. Via linear regression, it is thus possible to calculate CO_2 emissions from soil (CO_2-$C_{on\text{-}site}$), for each 25 x 25 m pixel of the map of the regional distribution of water levels in Germany's organic soils (Bechtold et al., 2014) with an average annual water level lower than 0.1 m below ground level. The uncertainty of the water-level map was taken into account in the uncertainties calculation. The average value from the map of the results was derived as the emission factor, while the 95th percentile was derived from the uncertainties calculation. Table 360 presents an overview of the national emission factors and compares them to the standard value given in the 2013 IPCC Wetlands Supplement (IPCC et al., 2014b). The table shows both the nationally derived portion of the CO_2 emission factor and the fully aggregated emission factor that is used in the inventory.

Table 360: Emission factors for CO_2-$C_{organic\_drained}$ from drained organic soils

Land use	NIR	NIR	IPCC Wetlands Supplement
	Soil-CO_2-C_{onsite}	CO_2-$C_{total\_organic\_drained}$	CO_2-$C_{total\_organic\_drained}$
	t CO_2-C ha^{-1} a^{-1}	t CO_2-C ha^{-1} a^{-1}	t CO_2-C ha^{-1} a^{-1}
Forest Land / Woody Grassland	2.6 (2.0 - 3.3)(IPCC)	2.9 (2.3 - 3.6)	2.9 (2.3 - 3.6)
Cropland	7.8 (4.1 - 4.9)	8.1 (4.4 - 9.5)	8.2 (6.8 - 9.7)
Grassland, Settlements	7.1 (3.0 - 9.2)	7.4 (3.3 - 9.5)	6.4 (5.3 - 7.6)
Terrestrial Wetlands	6.2 (2.3 - 9.2)	6.5 (2.5 - 9.5)	/
Peat-extraction areas	1.2 (1.2 - 1.4)	1.6 (1.5 - 1.8)	3.1 (1.4 - 4.5)

CH_4 from soil (CH_{4_land}):

The database consists of representative, quality-checked, national annual measurements (197 measurement years, 97 sites, 15 different peatland areas) obtained on areas with an average annual water level of 0 cm or more below ground level (no overflow). The emission factor was derived in a manner similar to that used for the emission factor for CO_2 from soil (CO_2-C on-site). Because methane emissions grow exponentially with rising water levels, an exponential function was used. Land-use-dependent exponential functions for Forest Land, Grassland and Wetlands were developed. Cropland and Peat-extraction areas proved to be too dry for achievement of any correlation with water levels. For this reason, the average values of the measurements were adopted for these two land-use categories. Table 361 presents an overview of the national emission factors and compares them to the default value given in the 2013 IPCC Wetlands Supplement (IPCC et al., 2014b). The table shows both the nationally derived portion of the CH_4 emission factor and the fully aggregated emission factor that is used in the inventory.

Table 361: Emission factors for $CH_{4\_organic}$ from drained organic soils

Land use	NIR	NIR	IPCC Wetlands Supplement
	CH_{4_land}	$CH_{4\_organic\ (land+ditch)}$	CH_{4_land}
	kg CH_4 ha^{-1} a^{-1}	kg CH_4 ha^{-1} a^{-1}	kg CH_4 ha^{-1} a^{-1}
Forest Land / Woody Grassland	3.7 (-2.1 - 70)	6 (0.3 - 72)	2.5 (-0.6 - 6)
Cropland	11.4 (-2.7 - 73)	26 (8.8 - 88)	0 (-2.8 - 3)
Grassland, Settlements	10.4 (3.6 - 69)	23 (12 - 81)	16 (2.4 - 29)
Terrestrial Wetlands	17 (1.5 - 150)	20 (4.1 - 151)	/
Peat-extraction areas	4.2 (-0.4 - 13)	11 (3.9 - 22)	6.1 (1.6 - 11)

N_2O:

The database consists of representative, quality-checked, national measurements that cover at least a year in each case (94 sites, 20 different peatland areas) and were obtained on areas with an average annual water level of 0.1 m or more below ground level (no overflow). The national database is part of the European data sets in Leppelt et al. (2014). Since no functional relationships were identified, the average measurement values for the various land-use categories were defined as the emission factors. Table 362 presents an overview of the national emission factors for N_2O and compares them to the default value given in the 2013 IPCC Wetlands Supplement (IPCC et al., 2014b).

Table 362: Emission factors for N_2O from drained organic soils

Land use	NIR	IPCC Wetlands Supplement
	kg N_2O-N ha^{-1} a^{-1}	kg N_2O-N ha^{-1} a^{-1}
Forest Land / Woody Grassland	1.8 (0.1 - 5.3)	2.8 (-0.6 - 6.1)
Cropland	10.7 (1.6 - 41.4)	13 (8.2 - 18)
Grassland, Settlements	2.7 (0 - 8.9)	8.2 (4.9 - 11)
Terrestrial Wetlands	0.4 (-0.1 - 1.6)	/
Peat-extraction areas	0.9 (0.3 - 1.4)	0.3 (0 - 0.6)

6.1.2.2.3 Implied emission factors (IEF)

In the framework of inventory preparation, the emissions from organic soils are calculated with implied emission factors – including specific factors for each GHG and for each land-use category. The emission factors shown in Chapter 6.1.2.2.2 apply for drained organic soils. However, in the determination of emissions from a specific land-use category, undrained, wet areas also have to be taken into account, whereas IEF for peat-extraction areas also need to account for emissions from peat that has been extracted and applied. These aspects lead to the implied emission factors for the calculation of GHG emissions from organic soils shown in Table 363. In some cases, these factors differ considerably from the factors presented in Chapter 6.1.2.2.2.

Table 363: Implied emission factors for CO_2-C, CH_4 and N_2O-N from organic soils (4.A- 4.E; 4(II)), for the year 2017

Land use	CO_2-C t CO_2-C ha^{-1} a^{-1}	CH_4 kg CH_4 ha^{-1} a^{-1}	N_2O-N kg N_2O-N ha^{-1} a^{-1} CH_4
Forest Land	-2.244	4.642	2.188
Cropland	-8.100	26.000	10.700
Grassland	-6.828	21.221	2.491
Woody Grassland	-2.852	5.900	1.770
Terrestrial Wetlands	-4.977	15.314	0.306
Peat-extraction areas	-29.184	11.191	0.852
Settlements	-7.400	23.000	2.700

6.1.2.3 Carbon emissions from biomass (4.B to 4.F)

6.1.2.3.1 General information

In the framework of the German GHG inventory, emissions from the above-ground and below-ground biomass pools are listed for

- the remaining Cropland category (with uses changing between annual, herbaceous and perennial woody crops), and
- the conversion categories Forest Land, Cropland, Grassland, Woody Grassland, Wetlands, Waters, Settlements and Other Land.

For the remaining categories of Cropland, Grassland, Woody Grassland, Wetlands and Settlements, no carbon-stock changes are listed in cases in which crops (annual or perennial) do not change, since,

- pursuant to the 2006 IPCC Guidelines IPCC (2006), in these sub-categories an equilibrium condition is assumed for the carbon fluxes of the annual phytomass pool. With the gain-loss method, therefore, $\Delta C = 0$ (Equation 2.7 in the 2006 IPCC Guidelines, IPCC (2006)).
- For the woody perennial plants on these areas, this is based on the representative "equilibrium carbon stocks" that have been determined for Germany. On the basis of the work of Pöpken (2011), these carbon stocks in biomass were determined for hedges and field copses, and for all areas with cultivated woody crops, such as orchard and vineyard areas, tree nurseries, Christmas tree plantations and short-rotation plantations. This was done by summing over all different age classes, types and compositions of the various woody crop areas (Chapter 6.1.2.3.4 and Chapter 6.1.2.3.5). For example, the mean carbon stocks in fruit trees are calculated on the basis of a complete tree count with differentiation by tree type and age (< 1 – > 25 years; cf. Chapter 6.1.2.3.4.1). In each case, when these stocks are set in relation to the area concerned, as a function of rotation period, this leads to the mean emission factor for the woody crop concerned. As a rule, annual growth increments in cultivated woody plants are assumed to be acompletely pruned away. Since the rotation periods for woody crops tend to be relatively short (about 10 – 15 years for fruit trees), such plantations tend to rejuvenate frequently. Such rejuvenation occurs from the category pool used to derive the pertinent emission factors, however. The processes of planting, growth, pruning, harvest and rejuvenation reach a state of dynamic equilibrium. This also applies to the woody-crop biomass of vineyards, tree nurseries, Christmas tree plantations, short-rotation plantations, hedges and field copses. In connection with land-use changes, the carbon stocks from planting of woody-crop biomass are therefore accounted for completely in the year of the land-use change.

At present, the existing system for assessing land-use changes does not allow for a spatially explicit and complete verification of changes in annual and perennial crops. As a result,

1. the Cropland category currently cannot be subdivided into two sub-categories ($Cropland_{annual}$, $Cropland_{perennial}$), and land-use changes within the Cropland category, between annual and perennial crops, and to other land-use categories, cannot be reported (similar to the situation with Grassland);
2. in the case of land-use changes to and from Cropland, an area-weighted emission factor has to be derived for the entire Cropland phytomass, since it is unclear whether annual or perennial Cropland is the initial or the final land use.

For this reason, carbon-stocks changes for perennial crops can only be estimated on the basis of area changes determined statistically for all of Germany, under the assumption that the annual area differences for permanent crops solely represent land-use changes within the Cropland category (cf. Chapter 6.5.2.3.2). Connections to other land-use categories cannot be proven, and thus they cannot be reported. As a result, the estimation of the carbon-stock changes of phytomass in the Cropland remaining category uses the methods described in the following chapter, although it does so on the basis of the spatially and qualitatively non-specific area differences shown in official statistical data, i.e. without relating the changes to other land-use categories (cf. Table 364).

In its "Member State recommendations on reporting systems for cropland & grazing land management emissions & removals" {ECOFYS 2017}, the EU Commission recommended that activity-data sources be developed for Germany, and that a system be implemented for georeferenced identification of perennial Woody Grassland areas within the Cropland category, as well as of their area changes. This recommendation is being implemented; intensive efforts are currently underway to develop a solution for this methodological issue.

6.1.2.3.2 Calculation methods

The carbon-stock changes resulting from land-use changes are determined, and reported, for both annual and perennial biomass. In the process, removals and emissions of CO_2 are determined via the relevant carbon-stock changes in above-ground and below-ground biomass separately, on the basis of national data. In each case, a carbon-stock change takes place completely in the year of the relevant land-use change (cf. also Chapter 6.1.2).

The carbon-stock changes in biomass are estimated by subtracting the biomass carbon stock before the land-use conversion from the stock after the conversion, with reference to the area affected by the change (in keeping with Equation 2.16, 2006 IPCC Guidelines, IPCC (2006)):

$$\Delta C_{Bio} = \sum_{n=1}^{7} \left(A_n * EF_{final} - A_n * EF_{initial}\right)$$

ΔC_{Bio}: Change in the biomass carbon stock for a given land-use category [Mg]

A_n: Area on which the land-use change has occurred [ha]

EF_{final}: Plant-specific biomass carbon stock after conversion [$Mg\ ha^{-1}$]

$EF_{initial}$: Plant-specific biomass carbon stock prior to conversion[$Mg\ ha^{-1}$]

n: Conversion categories

The biomass-stocks changes are calculated in keeping with the gain-loss method (2006 IPCC Guidelines). Chapter 6.3 outlines the determination of the relevant activity data, while the derivation of the country-specific emission factors and their uncertainties is described in Chapter 6.1.2.3.3, Chapter 6.1.2.3.4 Chapter 6.1.2.3.5 and in the chapters for the individual land-use categories. The reporting on biomass is equivalent to a Tier 2 method.

The carbon stocks in the biomass of Cropland and Grassland vary annually and are calculated for each year on the basis of harvest statistics, with the same data sources and algorithms that are used for calculating crop residues in CRF Sector 3.D. The pertinent differences obtained in the above-described manner lead to the emission factors shown in Table 364.

Table 364: Emission factors [t C ha^{-1} a^{-1}] for determination of carbon-stock changes in the year of the change, in above-ground and below-ground biomass, by type of land-use change, for the year 2017

Mean carbon stocks in above-ground and below-ground biomass										
	Forest Land[90]	Cropland	Grassland (in the strict sense)	Woody Grassland	Terrestrial Wetlands	Waters	Settlements	Other Land	Cropland$_{annual}$	Cropland$_{perennial}$
[t C ha^{-1}]	*54.66*	*6.70*	6.81	43.16	18.93	0	12.49	0	*6.64*	*11.66*
Emission factors for biomass [t C ha^{-1} a^{-1}]										
Initial\final	Forest Land[91]	Cropland[92]	Grassland (in the strict sense)[92]	Woody grassland[92]	Terrestrial Wetlands[92]	Waters[92]	Settlements[92]	Other Land	Cropland$_{annual}$[93]	Cropland$_{perennial}$[93]
Forest Land		*-47.96*	*-47.85*	*-11.5*	*-35.73*	*-54.66*	*-42.17*	NO		
Cropland	*3.45*		*0.11*	*36.46*	*12.23*	*-6.70*	*5.79*	NO		
Grassland (in the strict sense)	*3.24*	*-0.11*		36.35	12.12	-6.81	5.68	NO		
Woody Grassland	*1.91*	-36.46	-36.35		-24.23	-43.16	-30.67	NO		
Terrestrial Wetlands	*3.48*	*-12.23*	-12.12	24.23		-18.93	-6.44	NO		
Waters	*3.64*	*6.70*	6.81	43.16	18.93		12.49	NO		
Settlements	*3.39*	*-5.79*	-5.68	30.67	6.44	-12.49		NO		
Other Land	*3.64*	*6.70*	6.81	43.16	18.93	0	12.49			
Cropland$_{annual}$[93]										*5.02*
Cropland$_{perennial}$[93]									*-5.02*	

Remark: The carbon stocks for Forest Land and Cropland vary over time (values in italics), while those for the other land-use categories are constant.

[90] Soil organic carbon stocks of deforestation areas
[91] Annual carbon-stock change, over 20 years
[92] One-time carbon-stock change
[93] Only the "remaining as" Cropland category

For calculating stocks in the conversion of Forest Land into other land uses (deforestation), the average value for deforestation areas in Germany, in the National Forest Inventories of 2002 and 2012, was used as a basis for the relevant reporting years. For the relevant methods and value derivation, cf. Chapter 6.4.2.2. New values for dead wood stocks were also determined via the BWI 2012. While Table 366 shows the entire quantity of biomass that is lost in connection with deforestation, Table 365 shows the relevant change sum (the sum of the loss (forest land; losses) and the gain (the biomass stocks in some other land-use category; gains).

Table 365: Time series for mean carbon stocks in phytomass pools of deforestation areas [t C ha^{-1}]

Year	Phytomass – carbon [t C ha^{-1}] (EF 1)					
	Bio_{total}	Bio_{above}	Bio_{below}	Litter	Dead wood	Σ deforestation
1990	28.93	24.53	4.39	19.00	1.88	49.81
1995	28.93	24.53	4.39	18.94	1.88	49.75
2000	28.93	24.53	4.39	18.88	1.88	49.69
2005	54.66	46.48	8.18	18.81	1.82	75.29
2010	54.66	46.48	8.18	18.75	1.99	75.39
2011	54.66	46.48	8.18	18.74	1.99	75.38
2012	54.66	46.48	8.18	18.73	1.99	75.37
2013	54.66	46.48	8.18	18.71	1.99	75.36
2014	54.66	46.48	8.18	18.70	1.99	75.34
2015	54.66	46.48	8.18	18.69	1.99	75.33
2016	54.66	46.48	8.18	18.68	1.99	75.32
2017	54.66	46.48	8.18	18.66	1.99	75.31

The uncertainty for tree biomass stocks is 24.95 % (half of the 95 % confidence interval). The results are based on a normal distribution. This also applies to the values for the dead organic matter pool; for dead wood, half of the 95% confidence interval is 56.76 %, while for litter it is 3.15 %. The uncertainties for the emission factors listed in Table 364 are set forth in the chapters for the relevant land-use categories (Chapter 6.4.3, Chapter 6.5.3, Chapter 6.6.3, Chapter 6.7.3, Chapter 6.8.3 and Chapter 6.1.2.3).

6.1.2.3.3 Derivation of the emission factors for phytomass of annual crops and herbaceous plants

The carbon stocks of the above-ground and below-ground phytomass of herbaceous plants of a) cropland and grassland crops and b) grassland (in the strict sense) are derived annually, on the basis of harvest surveys of the Federal Statistical Office. This is the only Germany-wide, consistent (in terms of both content and chronology) data source that supports derivation, on a complete-coverage basis, of representative emission factors for herbaceous plants from agricultural production in Germany.

The mean carbon stocks of cropland and horticultural crops are determined on the basis of harvest data and area under cultivation for a total of 65 field crops. These include:

- Winter wheat, spring wheat, rye, triticale, maslin, winter barley, spring barley, oats, mixed grains other than maslin, grain maize;
- Field peas, broad beans;
- Potatoes, sugar beets, fodder beets;
- Winter oilseed rape;
- Clover, alfalfa, grass, silage maize; and

- Cauliflower, broccoli, Chinese cabbage, kale, kohlrabi, Brussels sprouts, red cabbage, white cabbage, savoy, oak-leaf lettuce, iceberg lettuce, endive, lamb's lettuce, head lettuce, lollo lettuce, radicchio, romana lettuce, arrugula, other lettuce types, spinach, rhubarg, asparagus, celery, fennel, celeriac, horseradish, carrots, radishes, (larger) radishes, red beets, pickling cucumbers, slicing cucumbers, edible pumpkins, zucchini, sweet corn, bush beans, broad beans, runner beans, split peas, peas, bunching onions, onions, parsley, leeks and chives.

For Grassland (in the strict sense), the data consists of harvest and cultivation-area data for all statistically recorded

- meadows
- mowed pastures
- pastures
- mountain pastures and rough pastures

The dry biomass of individual plant parts is derived from harvest data, pursuant to Rösemann et al. (2015), using relevant ratios and water-content data from various sources. The data and methods used are consistent with those used to calculate nitrogen in crop residues (CRF 3.D.a.4).

For calculation of biomass carbon stocks, an average carbon content of 45 % by weight was assumed – and used instead of the IPCC default value (50 % by weight) – since Osowski et al. (2004) list carbon contents of 44 to 48 % by weight for plants in central Europe and since Pöpken (2011), in her studies of cultivated trees (carried out for the German inventory), also found average values of 45 to 46 % by weight.

With the help of all these data, mean carbon stocks are calculated with respect to area. For each specific crop, this is done by multiplying the relevant areas under cultivation ([ha]) by the pertinent yields ([Mg biomass ha^{-1}]). The resulting products (on a by-crop basis; absolute harvested quantities of individual herbaceous plants or parts thereof [Mg]) are converted to dry matter and carbon content, summed and then divided by the relevant area sum ([ha]. This approach yields area-weighted, yield-weighted averages, for herbaceous plants from agricultural production [Mg C ha^{-1}], that are representative for Germany. These area-based mean carbon stocks [Mg C ha^{-1}] in the above-ground and below-ground phytomass of field crops and grasses are used as emission factors. This approach is in keeping with the methods set forth in the 2006 IPCC Guidelines.

The results for herbaceous plants of Cropland and horticultural areas are shown in Table 366, while those for Grassland (in the strict sense) are shown in Table 367.

As Table 366 shows, the values for phytomass of herbaceous Cropland and horticultural land plants show a positive, significant trend over time. For this reason, the calculations of carbon-stock changes due to land-use changes are always based on the current pertinent value for the year in question.

Table 366: Area-based carbon stocks [t C ha^{-1} ± half of the 95 % confidence interval] of herbaceous phytomass on Cropland and horticultural land

Year	Cropland$_{annual}$ Soil organic carbon stocks [t C ha^{-1}] Phytomass$_{total}$	Phytomass$_{above-ground}$	Phytomass$_{below-ground}$
1990	5.17 ± 0.61	3.72 ± 0.51	1.45 ± 0.33
1995	5.54 ± 0.65	4.12 ± 0.57	1.42 ± 0.32
2000	5.89 ± 0.69	4.40 ± 0.60	1.49 ± 0.33

2005	6.08 ± 0.71	4.58 ± 0.63	1.50 ± 0.34
2010	5.96 ± 0.70	4.51 ± 0.62	1.45 ± 0.32
2011	6.09 ± 0.71	4.55 ± 0.62	1.54 ± 0.35
2012	6.43 ± 0.75	4.84 ± 0.66	1.59 ± 0.36
2013	6.32 ± 0.74	4.81 ± 0.66	1.51 ± 0.34
2014	7.21 ± 0.84	5.45 ± 0.75	1.76 ± 0.40
2015	6.48 ± 0.76	4.95 ± 0.68	1.53 ± 0.34
2016	6.36 ± 0.75	4.81 ± 0.66	1.55 ± 0.35
2017	6.64 ± 0.78	4.96 ± 0.68	1.68 ± 0.38

For Grassland (in the strict sense), the carbon stocks in the phytomass of herbaceous plants show no significant trend over time, and the annual changes are considerably smaller than the uncertainties. For this reason, mean carbon stocks for the phytomass of Grassland (in the strict sense) are estimated and, in a consistent manner, used as a basis for the calculations for all the years concerned (cf. Table 367). The mean carbon stocks over time were determined via bootstrapping. Bootstrapping is a resampling procedure in which statistical indexes are calculated on the basis of samples (in the present case, the mean carbon stocks of the above-ground and below-ground phytomass of herbaceous grassland plants for the years 1990 – 2015). This procedure is especially useful in cases in which the theoretical distribution of the statistics is not known, and one parameter (in the present case, the mean) of the population (i.e. not the sample) and its average divergence from the true parameter, have to be estimated. The so-calculated values for herbaceous plants of Grassland (in the strict sense) are shown in Table 367. They serve as a basis for all relevant calculations in the inventory. The standard error of the calculated means for the population is 2.3 % (half of the 95 % confidence interval).

Table 367: Area-related carbon stocks [t C ha^{-1}] of Grassland (in the strict sense) (± half of the 95 % confidence interval)

Land-use category	Soil organic carbon stocks [t C ha^{-1}]		
	Biomass$_{total}$	Biomass$_{above-ground}$	Biomass$_{below-ground}$
Grassland (in the strict sense)	6.81 ± 2.06	3.78 ± 1.37	3.03 ± 1.54

6.1.2.3.4 Derivation of emission factors for perennial woody crops

In the framework of the research project "Development of methods for determining the biomass of perennial woody plants, outside of forests" ("Methodenentwicklung zur Erfassung der Biomasse mehrjährig verholzter Pflanzen außerhalb von Waldflächen"), country-specific carbon-stock data were collected for above-ground and below-ground biomass of orchards, vineyards and Christmas-tree plantations in Germany. The mean carbon stocks of the plants in tree nurseries were then estimated on the basis of these data and of results of the National Forest Inventory. Mean tree biomass values for short-rotation plantations were derived from literature data, on a country-specific basis.

6.1.2.3.4.1 Fruit trees

In the framework of the aforementioned research project, with trees taken from Germany's two main fruit-growing regions (Altes Land ("Old country"): northern Germany, and Lake Constance region: southern Germany), a total of 100 fruit trees (91 apple trees, 6 cherry trees and 3 plum trees), of differing ages and types, were destructively tested. In addition, the following data were collected from 210 living apple trees:

- Diameter at stem base
- Diameter at breast height
- height

A regression procedure applied to all collected data yielded a highly significant relationship between tree age and mean stem diameter (=(diameter at stem base + diameter at breast height)/2), for each age class:

Equation 19: Regression equation for estimating mean stem diameter [cm] of apple trees, as a function of tree age [a]

$$S_{mean\ apple} = 14.2986 * \left(1 - e^{(-0.0528x)}\right)$$

S_{mean_apple}: Mean stem diameter, apple tree [cm]

x: Tree age [a]

Statistical indexes / uncertainties:

$r^2 = 0.9768$

$p < 0.0002$

Standard error of estimation = 0.5625 ≙ 8.44 %

The total uncertainty in the estimation of the mean stem diameter of apple trees as a function of tree age amounts to 23.59 % (half of the 95 % confidence interval).

Equation 20: Regression equation for estimating mean stem diameter [cm] of cherry and plum trees, as a function of tree age [a]

$$S_{mean\ cherry/plum} = 53.8165 * \left(1 - e^{(-0.0252x)}\right)$$

$S_{mean\_cherryplum}$: Mean stem diameter, cherry/plum tree [cm]

x: Tree age [a]

Statistical indexes:

$r^2 = 0.9486$

$n = 9$

$p < 0.0001$

Standard error of estimation = 1.2963 ≙ 11.14 %

The estimation of the stem diameter of cherry and plum trees as a function of tree age is subject to a total uncertainty of 25.68 % (half of the 95 % confidence interval).

Via destructive sampling, the masses, water content and carbon content of the fruit trees were separately determined for the compartments above-ground biomass (trunk and branches) and below-ground biomass (roots). The age of the so-tested apple trees was 6 and 9 years, while the age of the cherry and plum trees was 4, 12 and 14 years.

The trees' biomasses were adjusted by the water content measured during drying at 105°C and then, to determine the carbon stocks of the trees' parts / whole trees, were multiplied by the carbon-content percentage of the $biomass_{dry}$.

From the resulting data, highly significant relationships were derived between mean trunk diameter and carbon stocks of the entire plant [Equation23 (cherry/plum)] and between mean trunk diameter and carbon stocks of the above-ground biomass [Equation21 (apple); Equation24 (cherry/plum)]. The carbon stocks in the below-ground biomass of cherry and plum trees were determined by subtracting the above-ground biomass from the total stocks, while the relevant stocks for apple trees were determined via the equation of Mokany et al. (2006) (Equation22). In a survey, they derived root / shoot ratios for numerous types of vegetation, as a function of biomass, climatic parameters and local site parameters. Their results were then adopted as default values in the 2006 IPCC Guidelines (IPCC, 2006).

Equation21: Regression equation for estimating carbon stocks in the above-ground biomass of apple trees, as a function of mean stem diameter

$$\ln C_{above\ apple} = -2.7521 + 1.9533 * \ln x$$

ln C_{above_apple}: Logarithm for carbon stocks in above-ground plant parts [kg $plant^{-1}$]

ln x: Logarithm for mean stem diameter [cm]

Statistical indexes:

r^2 =0.8273

n = 90

p < 0.0001

Standard error of estimation = 0.044 ≙ 2.83 %

Equation22: Regression equation for estimation of the carbon stocks in below-ground biomass of apple trees as a function of above-ground biomass (MOKANY et al. (2006)):

$$C_{below\ apple} = 0.489 * x^{0.89}$$

C_{below_apple}: Soil organic carbon stocks in below-ground plant parts [kg $plant^{-1}$]

x: Soil organic carbon stocks in above-ground biomass [kg $plant^{-1}$]

Statistical indexes:

r^2 =0.93

n = 301

Standard error of the estimation = 13.6 % (derived from MOKANY et al. (2006))

Equation23: Regression equation for estimating carbon stocks of the entire biomass of cherry and plum trees, as a function of mean stem diameter

$$C_{totalcherry/plum} = 0.0369\ x^{2.2725}$$

$C_{total\_cherryplum}$: Soil organic carbon stocks of entire cherry/plum tree biomass [kg $plant^{-1}$]

x: Mean stem diameter, cherry/plum tree [cm]

Statistical indexes:

r^2 =0.9608

n = 9

p < 0.0001

Standard error of estimation = 1.7382 ≙ 14.04 %

Equation24: Regression equation for estimating carbon stocks in the above-ground biomass of cherry and plum trees, as a function of mean stem diameter

$$C_{above\ cherry/plum} = 0.0238\ x^{2.3586}$$

$C_{above\_cherryplum}$: Soil organic carbon stocks of above-ground cherry/plum tree biomass [kg $plant^{-1}$]

x: Mean stem diameter, cherry/plum tree [cm]

Statistical indexes:

r^2 =0.9442

n = 9

p < 0.0001

Standard error of estimation = 2.025 ≙ 18.76 %

The carbon stocks in roots of cherry / plum trees are obtained as the difference between the carbon stocks of the entire plant and the stocks of its above-ground parts (cf. Equation25).

Equation25: Estimation of the carbon stocks in the root mass of cherry/plum trees

$$C_{below} = C_{total} - C_{above}$$

C_{below}: Below-ground carbon stock [kg plant^{-1}]

C_{total}: Carbon stock of entire plant [kg plant^{-1}]

C_{above}: Above-ground carbon stock [kg plant^{-1}]

The absolute carbon stocks of all fruit trees in Germany were calculated on the basis of the results of the exhaustive statistical surveys for the fruit cultivation sector that were carried out in the years 2002, 2007 and 2012 (Statistisches Bundesamt, FS 3, R 3.2.1). On the basis of that survey's results, the Federal Statistical Office determined total numbers of apple, pear, sweet cherry / sour cherry, plum / prune, mirabelle and greengage trees, in different age classes, as well as the areas under cultivation with trees in the various age classes. Examples of the pertinent results, for the year 2007, are shown in Table 368.

Table 368: Results of the 2007 complete survey of fruit trees carried out by the Statistisches Bundesamt (FS 3, R 3.1.4)

Age class		Fruit trees, total	Apple	Pear	Sweet cherry	Sour cherry	Plum, prune	Mirabelle, greengage
<1	Area [ha]	6,337	2,610	558	1,669	569	561	89
	Number [n]	77,908,784	1,959,650	374,357	349,898	309,888	174,950	25,268
1-4	Area [ha]	1,314	1,283	30	125	9	142	8
	Number [n]	3,493,397	3,460,242	51,926	92,723	6,720	98,538	4,372
5-9	Area [ha]	7,403	5,159	252	859	330	713	90
	Number [n]	15,410,632	13,645,705	466,895	563,239	234,410	452,011	48,372
10-14	Area [ha]	10,606	7,275	350	783	866	1,186	146
	Number [n]	19,740,123	17,334,084	581,720	458,483	579,748	722,909	63,179
15-19	Area [ha]	10,321	7,603	454	763	372	1,057	71
	Number [n]	19,602,081	17,527,552	831,342	322,364	260,231	632,286	28,306
20-24	Area [ha]	8,599	5,995	338	764	791	621	91
	Number [n]	12,899,071	11,365,689	443,150	219,989	543,127	290,899	36,217
>25	Area [ha]	3,333	1,837	119	519	507	284	66
	Number [n]	3,348,345	2,569,271	126,438	143,442	351,826	130,916	26,452

To determine the total carbon stocks in fruit trees, the carbon stocks – either measured or determined via regression – in the above-ground and below-ground biomass of individual trees of each age class were multiplied by the relevant total numbers of trees. In the process, the values obtained for apple trees were also assigned to pear trees, while those obtained for cherry and plum trees were also assigned to prune, mirabelle and greengage trees.

The area-related emission factors for the various tree varieties were calculated, in each case, via division by the relevant area under cultivation. The results are shown in Table 369.

Table 369: Area-related carbon stocks [t C ha^{-1}] (± half of the 95 % confidence interval) in the biomass of fruit trees

Fruit tree	Fruit-tree survey, 2002 Soil organic carbon stocks [t C ha^{-1}]			Area [ha]
	Bio_{above}	Bio_{below}	Bio_{total}	
Apple	3.53 ± 0.85	1.55 ± 0.56	5.08 ± 2.20	32,406
Pear	2.93 ± 0.71	1.24 ± 0.45	4.18 ± 1.81	2,189
Sweet cherry	7.53 ± 1.39	1.33 ± 0.15	8.86 ± 1.25	5,505
Sour cherry	14.08 ± 2.74	2.67 ± 0.32	16.74 ± 2.5	4,230
Plum/prune	6.52 ± 1.36	1.28 ± 0.16	7.79 ± 1.25	4,562
Mirabelle/greengage	6.70 ± 1.26	1.25 ± 0.14	7.95 ± 1.14	473

Fruit tree	Fruit-tree survey, 2007 Soil organic carbon stocks [t C ha^{-1}]			Area [ha]
	Bio_{above}	Bio_{below}	Bio_{total}	
Apple	4.56 ± 1.10	1.97 ± 0.71	6.53 ± 2.83	31,762
Pear	3.95 ± 0.95	1.66 ± 0.60	5.61 ± 2.43	2,101
Sweet cherry	7.71 ± 1.50	1.39 ± 0.17	9.09 ± 1.36	5,482
Sour cherry	15.24 ± 2.98	2.83 ± 0.34	18.07 ± 2.71	3,444
Plum/prune	7.71 ± 1.59	1.53 ± 0.19	9.24 ± 1.47	4,565
Mirabelle/greengage	7.28 ± 1.41	1.38 ± 0.16	8.66 ± 1.29	561
Fruit tree	**Fruit-tree survey, 2012** **Soil organic carbon stocks [t C ha^{-1}]**			**Area [ha]**
	Bio_{above}	Bio_{below}	Bio_{total}	
Apple	5.31 ± 1.28	2.27 ± 0.82	7.58 ± 3.29	31,739
Pear	4.91 ± 1.19	2.04 ± 0.73	6.95 ± 3.02	1.933
Sweet cherry	8.44 ± 1.65	1.57 ± 0.19	10.01 ± 1.49	5,258
Sour cherry	17.31 ± 3.53	3.13 ± 0.39	20.45 ± 3.19	2,292
Plum/prune	9.60 ± 1.93	1.9 ± 0.24	11.51 ± 1.78	3,870
Mirabelle/greengage	8.25 ± 1.62	1.51 ± 0.18	9.76 ± 1.47	501

6.1.2.3.4.2 Wine (grapevines)

In the project "Development of methods for determining the biomass of perennial woody plants, outside of forests" ("Methodenentwicklung zur Erfassung der Biomasse mehrjährig verholzter Pflanzen außerhalb von Waldflächen") (Pöpken, 2011), a total of 74 grapevines were destructively sampled for the purpose of deriving a country-specific mean value for carbon stocks of grapevines. The ages of the vines were 15 and 25 years. In the analysis, the vines' weights, and the water and carbon content of the above-ground and below-ground plant parts, were determined (Pöpken, 2011). The carbon stocks of grapevines and of parts of vines are calculated via Equation58.

Equation 26: Calculation of the carbon stocks in grapevines

$$C_{vine} = C_{cont\ above} * M_{105\ bio\ above} + C_{cont\ below} * M_{105\ bio\ below}$$

C_{vine}: Soil organic carbon stocks of one grapevine [kg]

$C_{cont\ above}$: Carbon content of the above-ground vine [by weight]

$M_{105\ bio\ above}$: Dry biomass of the vine [kg]

$C_{cont\ below}$: Carbon content of below-ground biomass [by weight]

$M_{105\ bio\ below}$: Dry biomass of below-ground biomass [kg]

The annual quantity of cut wood was not taken into account in determination of the biomass of grapevines, since the annual growth is basically the same as the quantity cut, and thus a temporary equilibrium occurs.

Since vineyards in Germany contain an average of 4,000 grapevines per ha ((Pöpken, 2011)), the carbon stocks per area unit (ha) were calculated by multiplying the carbon stocks of individual plant compartments / total plants by 4,000. The absolute carbon stocks are calculated by multiplying the pertinent emission factors by the total vineyard area. This area was obtained from official German statistics (Statistisches Bundesamt, FS 3, R 3.1.5). The resulting values are shown in Table 370.

Table 370: Area-related carbon stocks [t C ha⁻¹ ± half of the 95 % confidence interval) in grapevine biomass

Trees and shrubs	Soil organic carbon stocks [t C ha^{-1}]			Area under cultivation, 2017 [ha]
	Bio_{above}	Bio_{below}	Bio_{total}	
Wine (grapevines)	1.12 ± 0.06	0.54 ± 0.04	1.66 ± 0.09	102,592

6.1.2.3.4.3 Christmas-tree plantations

In Germany in 2017, a total of 15,900 ha of agricultural land, outside of forests, was cultivated with Christmas trees (Statistisches Bundesamt, FS 3, R 3.1.7). With an average planting density of 6,000 plants per ha, about 50 t of $biomass_{dry}$ are produced per ha (Pöpken, 2011). Of that quantity, about 28 % is root mass. That value was derived via the regression of root biomass as a function of above-ground biomass (Equation22) pursuant to Mokany et al. (2006) (cf. Chapter 6.1.2.3.4.1). The area-based carbon stocks derived from these parameters are shown in Table 371.

Table 371: Area-related carbon stocks [t C ha^{-1}] (± half of the 95 % confidence interval) in Christmas tree biomass

Trees and shrubs	Soil organic carbon stocks [t C ha^{-1}]			Area [ha]
	Bio_{above}	Bio_{below}	Bio_{total}	
Christmas trees	8.10 ± 4.1	3.15 ± 1.6	11.25 ± 4.4	15,900

6.1.2.3.4.4 Tree nurseries

In 2017, the total area occupied by tree nurseries in Germany amounted to 19,400 ha (Statistisches Bundesamt, FS 3, R 3.1.7). An exhaustive tree-nursery survey carried out at 4-year intervals by Statistisches Bundesamt (FS 3, R 3.1.7) provides information about the tree species cultivated in tree nurseries. The 2012 survey showed that German tree nurseries cultivate primarily ornamental plants and other trees and shrubs (86.7 %); only 13.3 % of their area was used for cultivation of forest plants. The species composition of the cultivated trees and shrubs has varied widely over the years (Statistisches Bundesamt, FS 3, R 3.1.7). Unfortunately, no studies have been carried out of the average biomass stocks in trees and shrubs cultivated in tree nurseries in Germany. For this reason, the average carbon stocks per unit of tree-nursery area were derived from country-specific biomass-stock values for trees and shrubs. To this end, the following assumptions were made:

- Two-thirds of the trees and shrubs in tree nurseries are ornamental plants, and one-third are forest trees (this share was increased to 33 %, because although the recent survey showed that forest trees were being cultivated on only 13.3 % of the available area, that cultivation percentage has varied widely over the years (share of forest plants in 2004: 19.8 %, Statistisches Bundesamt (FS 3, R 3.1.7)), and ornamental-plant cultivation includes conifers (to a considerable extent) and forest trees such as oak and beech.
- The cultivation period for ornamental trees and shrubs is not more than 10 years, while that for forest plants is not more than 5 years.
- The age classes within the various tree/shrub groups are evenly distributed.

The carbon stocks determined via the project "Development of methods for determining the biomass of perennial woody plants, outside of forests" ((Pöpken, 2011)) were also applied to ornamental trees and shrubs, in a representative approach. For half of the larger trees and shrubs, the carbon stocks determined for cherry and plum trees were applied; for half of the smaller trees and shrubs, the stocks determined for apple trees were used (cf. Chapter 6.1.2.3.4.1).

For the calculation of the biomass of forest trees, the methods developed by Kändler and Bösch (2013) for calculating forest biomass were applied. Those methods are described in Chapter

6.4.2.2. For spruce, pine, beech and oak, the above-ground biomass stocks per individual tree, up to a tree age of 5 years, were determined using Equation28 and the coefficients shown in Table 390 in Chapter 6.4.2.2.4. The conversion factor 0.45 was used for the conversion of biomass into carbon stocks (t C ha^{-1}), and a total of 6,000 plants per ha was assumed (this corresponds to an average plant density, with a planting distance of about 120/130 cm). The below-ground biomass was estimated on the basis of the so-calculated shoot mass, using the equation of Mokany et al. (2006) (cf. Chapter 6.1.2.3.4.1), while the total biomass stocks were obtained by adding the above-ground and below-ground stocks.

This derivation approach then yields, via determination of average values, the mean, area-based carbon stocks shown in Table 372 for the various trees and shrubs concerned, as well as the resulting mean carbon stocks, which in this inventory represent the dynamic equilibrium of biomass in Germany's tree nurseries.

Table 372: Derivation of average area-based carbon stocks [mixed value$_{tree\ nurseries}$ in t C ha^{-1} ± half of the 95 % confidence interval] in the biomass of tree nurseries

Trees and shrubs	C stocks$_{total}$ [t C ha^{-1}]	C stocks$_{above}$ [t C ha^{-1}]	C stocks$_{below}$ [t C ha^{-1}]
Apple$_{10}$	6.69 ± 1.34	4.8 ± 1.16	1.89 ± 0.68
Cherry$_{10}$	21.52 ± 1.88	16.83 ± 1.92	4.69 ± 0.33
Forest trees$_{5}$	7.7 ± 0.82	5.54 ± 0.71	2.15 ± 0.42
Mixed value$_{tree\ nurseries}$	11.97 ± 0.82	9.06 ± 0.78	2.91 ± 0.29

6.1.2.3.4.5 Short-rotation plantations

In Germany, pursuant to Article 2 of the Federal Forest Act (BWaldG) (2015), short-rotation plantations are not considered forest land, and are therefore reported solely in the land-use category Cropland. Since short-rotation plantations are also listed as cropland in the framework of the National Forest Inventory, there is no risk of double-counting in this area. In 2017, the total area covered by short-rotation plantations in Germany amounted to 5,600 ha (Statistisches Bundesamt, FS 3, R 3.1.2). Since the biomass of short-rotation plantations in Germany is used exclusively for energy purposes (cf. category 1.A, Chapter 3.2), the emissions tied to such plantations are not reported under "harvested wood products" (HWP) (cf. Chapter 6.10.1).

To obtain country-specific, mean carbon stocks for the biomass of short-rotation plantations, data were derived from the relevant literature. Fundamental data were obtained especially from the overviews Walter et al. (2015), Horn (2013), Gurgel (2011), Kern et al. (2010), Biertümpfel et al. (2009), Boelcke (2007), Stolzenburg (2006) and Maier and Vetter (2004).

This work includes the results obtained on 23 experimental short-rotation plantation sites, which are distributed throughout Germany (Bavaria, Baden-Württemberg, Thuringia, Saxony, Brandenburg, Mecklenburg – West Pomerania and Lower Saxony). As a group, the sites cover all the country's relevant climate zones (precipitation: 550 – 1550 mm), average annual temperatures 6.8 – 10.1°C), soil types (light to heavy soils) and geographic regions (lowlands to mid-elevation mountains). Short-rotation plantations were established on a total of 62 test areas, with main species including poplars (58 %) and willow (34 %), although birch (3 %), alder, black locust (robinia) and foxglove tree (paulownia) (5%) were also planted. The rotation periods ranged from one to ten years, and averaged 4.2 years. Since these studies cover all relevant operational aspects of short-rotation plantations in Germany, including spatial distribution, site conditions, vegetation and management practices, they are representative.

From the results of these studies, an average annual dry yield of 9.05 (-6.0 % / +9.9 %) t ha^{-1} a^{-1} of above-ground biomass was derived for short-rotation plantations in Germany.

The average total yield of short-rotation plantations, as a function of plantation-operation duration, was obtained by multiplying the average annual dry yield by the number of years of plantation operation. An average plantation-operation duration of 20 years was assumed. In addition, it was assumed that the short-rotation plantations are evenly distributed in the various age classes (initialization class, and $class_{1\_a}$ – $class_{20\_a}$). For the initialization phase, it was assumed that 10,000 cuttings, each with 20 g of biomass, were planted per hectare (≙ 0.2 t biomass ha^{-1}). The below-ground biomass was determined on the basis of the average dry yield, as a function of the operational duration and the equation provided by Mokany et al. (2006). Via addition of above-ground and below-ground biomass, the total stocks in short-rotation plantations were determined for each different age class. Via multiplication by 0.45, those biomass stocks were then converted into carbon stocks. The average values of these carbon stocks, for all age classes, serve as the dynamic equilibrium values for the average, area-based carbon stocks in the biomass of short-rotation plantations, which values form the basis of the calculations of the pertinent inventory. These values are shown in Table 373.

Table 373: Average area-based carbon stocks [t C ha^{-1}] and 97.5 and 2.5% percentile values [%] in the biomass of short-rotation plantations

	Soil organic carbon stocks in the biomass of short-rotation plantations		
	Bio_{total}	Bio_{above}	Bio_{below}
Soil organic carbon stocks [t C ha^{-1}]	**53.71**	**40.75**	**12.96**
97.5 percentile [%]	10.30	9.93	29.13
2.5 percentile [%]	8.16	6.02	28.04

6.1.2.3.4.6 Mean carbon stocks in the biomass of perennial cultivates on Cropland

As Chapter 6.1.2.3.1 explains, the existing system for listing land-use changes does not allow listing of annual and perennial crops in a spatially explicit and complete manner. Consequently, in connection with land-use changes from and to Cropland, it is not known which woody crop is subject to land-use change. This fact is taken into account by deriving an emission factor, weighted by area in accordance with type and use, for the entire woody biomass of the relevant perennial cropland.

To this end, the absolute carbon stocks of the various crop types were calculated, by compartments, as follows: the cultivation areas were multiplied by the average crop-based carbon stocks, summed and then divided by the area sum. These calculations were carried out for the years 2002, 2007 and 2012 (Table 374). The intervals are tied to the survey dates for the fruit-tree census, which the Federal Statistical Office carries out only at five-year intervals. The census has been conducted in its current form only since 2002. The values between the individual surveys have been linearly interpolated. For the years 1990 – 2002, the data for the year 2002 have been used, while for the years 2013 through 2017 the data for 2012 have been used.

Table 374: Determination of area-weighted carbon stocks [t C ha^{-1}] for woody plants cultivated on Cropland in Germany, as of the years for the relevant statistical surveys (carbon stocks 2 ± half of the 95 % confidence interval)

Fruit trees	Soil organic carbon stocks [t C ha^{-1}]		
	Bio_{total}	Bio_{above}	Bio_{below}
2002	5.04 ± 0.41	3.72 ± 0.38	1.31 ± 0.17
2007	5.19 ± 0.43	3.83 ± 0.39	1.36 ± 0.18
2012	6.55 ± 0.48	4.85 ± 0.43	1.70 ± 0.21

Since woody plants cultivated on cropland in Germany are always mixed with grass, the total biomass carbon stocks per area unit for such areas are calculated via Equation27:

Equation27:

$$C\ stocks_{Biomass\_perennial\_crops} = C\ stocks_{perennial\_woody\ plants} + C\ stocks_{Grassland} * 0.75$$

The emission factor for grassland biomass takes into consideration that only the areas below woody plants are kept free of vegetative cover; in orchards and vineyards, grass is allowed to grow between the rows of trees/vines. The value for grassland in the strict sense is used as a basis for determining such biomass stocks. Table 375 shows the time series for the biomass carbon stocks of perennial woody plants cultivated on cropland in Germany. The large changes in the above-ground and below-ground biomass are due to the use of outdated stocks figures for Grassland (only in connection with this calculation). The changes with respect to total biomass are very small, however. For this reason, this error's impact on the mixed value for Cropland is virtually invisible (a difference of about 0.02 %).

Table 375: Area-weighted mixed value for biomass carbon stocks [t C ha^{-1}] of perennial woody plants cultivated on Cropland in Germany (carbon stocks of above-ground and below-ground biomass, and total carbon stocks ± half of the 95 % confidence interval)

Year	Cropland$_{perennial}$ Soil organic carbon stocks [t C ha^{-1}]		
	Phytomass$_{total}$	Phytomass$_{above-ground}$	Phytomass$_{below-ground}$
1990	10.15 ± 1.62	6.56 ± 1.08	3.59 ± 1.15
1995	10.15 ± 1.62	6.56 ± 1.08	3.59 ± 1.15
2000	10.15 ± 1.62	6.56 ± 1.08	3.59 ± 1.15
2005	10.24 ± 1.63	6.62 ± 1.09	3.62 ± 1.16
2010	11.12 ± 1.77	7.28 ± 1.20	3.84 ± 1.24
2011	11.39 ± 1.82	7.48 ± 1.23	3.91 ± 1.26
2012	11.66 ± 1.86	7.68 ± 1.27	3.98 ± 1.28
2013	11.66 ± 1.86	7.68 ± 1.27	3.98 ± 1.28
2014	11.66 ± 1.86	7.68 ± 1.27	3.98 ± 1.28
2015	11.66 ± 1.86	7.68 ± 1.27	3.98 ± 1.28
2016	11.66 ± 1.86	7.68 ± 1.27	3.98 ± 1.28
2017	11.66 ± 1.86	7.68 ± 1.27	3.98 ± 1.28

6.1.2.3.5 Derivation of the emission factors for hedges and field copses

In order to determine carbon stocks in hedges, PÖPKEN (2011) has studied 50 hedges to date, working in the framework of the research project "Methodenentwicklung zur Erfassung der Biomasse mehrjährig verholzter Pflanzen außerhalb von Waldflächen" ("Development of methods for determining the biomass of perennial woody plants, outside of forests") . The hedges studied to date vary widely in terms of:

1. **Age**
    - About 4 – 20 years old
2. **Size**
    - Height, about 2 - 9 m
    - Depth, about 1 – 6 m
    - Length, about 100 – 500 m
3. **Species composition**

- Typical hedge plants, such as dog rose (Rosa canina), blackthorn / sloe (Prunus spinosa), common hazel (Corylus avellana), elder (Sambuccus spec.), hawthorn (Crataegus spec.), honeysuckle (Lonicera spec.) and willow (Salix spec.)
- Trees, such as field maple (Acer campestre), common hornbeam (Carpinus betulus), willow (Salix spec.), beech (Fagus sylvatica), linden (Tilia spec.) and elm (Ulmus spec.)

As a result, the study has included a representative spectrum of relevant field trees and shrubs. Laboratory analysis of samples taken of the various species in question included measurement of weight, water content and carbon content. That, in turn, and in connection with relevant field sizes, made it possible to determine absolute and area-related carbon stocks (cf. Table 376). Via regression, carried out on the basis of these data, a highly significant correlation between the average carbon stocks of the above-ground biomass of hedges and the ages of hedges was found:

$$C_{above} = 1.5506 * X^{1.6015}$$

R^2 = 0.843; half of the 95 % confidence interval: ± 65.7 %

C_{above}: Average carbon stocks of above-ground biomass in hedges [t C ha^{-1}]

X: Hedge age [a]

With this equation, the average carbon stocks in the above-ground biomass of hedges was determined for each year of the rotation period (12 years). The study by Pöpken (2011) was able to survey only above-ground biomass, due to nature conservation constraints. For this reason, the below-ground biomass was estimated via the equation that Mokany et al. (2006) derived via regression, which made it possible, for each of the age classes in question, to determine below-ground biomass on the basis of above-ground biomass.

$$Bio_{below} = 0.489 * Bio_{above}^{0.890}$$ (Mokany et al., 2006)

R^2 = 0.93

Bio_{below}: Below-ground biomass in t C ha^{-1}

Bio_{above}: Above-ground biomass in t C ha^{-1}

The total stocks per age class are then obtained via

$$C_{total\_AK} = C_{above\_AK} + C_{below\_AK}$$

C_{total_AK}: Average carbon stocks in the total biomass of hedge plants of a single age class [t C ha^{-1}]

C_{above_AK}: Average carbon stocks in the above-ground biomass of hedge plants of a single age class [t C ha^{-1}]

C_{below_AK}: Average carbon stocks in the below-ground biomass of hedge plants of a single age class [t C ha^{-1}]

The average value for all age classes, for an assumed rotation period of 12 years, then yields the average equilibrium carbon stocks in Germany's hedges. That figure is then used as an emission factor and as a basis for the inventory calculations; cf. Table 376.

Table 376: Area-based carbon stocks [t ha^{-1} (95 % confidence interval)] in the biomass of Woody Grassland

Woody Grassland	Soil organic carbon stocks [t C ha^{-1}]		
	$Bio_{above-ground}$	$Bio_{below-ground}$	Bio_{total}
Woody Grassland	32.69 (10.46-55.27)	10.47 (3.16-18.11)	43.16 (19.77-67.00)

6.1.2.4 Carbon emissions from dead organic matter (4.A to 4.F)

Emissions from dead organic matter are reported only for the land-use category Forest Land and for land-use changes from Forest Land to one of the other land-use categories in 4.B – 4.E. For such reporting, dead organic matter is subdivided into the two pools dead wood and litter. Descriptions of the method used for this, and of the pertinent results, are presented in Chapter 6.4.2.3, for dead wood, and Chapter 6.4.2.4, for litter (in both cases, within the land-use category Forest Land).

In the land-use-change categories 4.B – 4.E, emissions from dead organic matter are included with emissions from living biomass, since estimates of emissions from living biomass are always based on entire plants. To prevent double-counting in these conversion categories, emissions from dead organic matter are marked IE (included elsewhere) in the CRF tables. In category 4.F, NO (not occurring) is used, since, by definition, the areas in this category have no vegetation cover.

6.1.2.5 Direct N_2O emissions from nitrogen fertilisation of forest land and other land areas (4(I))

No nitrogen fertilisation in Forest Land, Wetlands and Settlements is carried out in Germany. In CRF Table 4(I), therefore, NO (not occurring) is entered for all such activities.

6.1.2.6 Emissions from drainage of organic and mineral soils

Emissions from drainage or from other soil-management measures in Germany occur only on organic soils. No emissions occur on mineral soils. For this reason, NO (not occurring) is entered in CRF Table 4(II) for mineral soils, for all land-use categories.

Rewetting of organic soils was also not considered; accordingly, NO (not occurring) has been entered in the CRF Table. As a result, emissions occur solely through drainage of organic soils.

Carbon emissions from organic soils are included in CRF tables 4.A through 4.F. In CRF Table 4(II), and for organic soils, the values for N_2O and CH_4 are entered. IE (included elsewhere) has been entered for CO_2.

A description of the method for derivation of activity data and emission factors for organic soils is presented in Chapter 6.1.2.2 Emissions from organic soils.

6.1.2.7 Direct nitrous oxide (N_2O) emissions from nitrogen mineralisation 4(III)

The direct (CRF Table 4 (III)) N_2O emissions tied to losses of organic soil substance resulting from land-use changes and land cultivation have been determined in keeping with the 2006 IPCC Guidelines. To that end, the carbon-stock changes determined for the individual land-use-change areas were divided by the mean, area-weighted C/N ratios for the pertinent soils; this yielded the absolute changes in soil nitrogen stocks (Equation 11.8 in the 2006 IPCC Guidelines IPCC (2006)). The C/N ratios were derived from the estimated profile data of the Soil map for the Federal Republic of Germany 1:1,000,000 (BÜK 1000; n 2.3; (BGR 2011)).

For determination of the direct emissions, the absolute nitrogen-stock differences were multiplied by the IPCC default value of 0.01 kg N_2O-N (kg N)$^{-1}$, in keeping with Equation 11.1 in the 2006 IPCC Guidelines (IPCC, 2006). The so-determined N_2O emissions are listed in CRF Table 4 (III); the relevant emission factors are listed in Table 377; and the uncertainties are presented in the uncertainties chapters for the individual land-use categories (cf. Chapters 6.4.3, 6.5.3, 6.6.3, 6.7.3 and 6.8.3).

The nitrous oxide emissions are also subject to transition-time considerations; like the carbon-stock changes, they are distributed over 20 years. For Forest Land, the remarks made with regard to derivation of the implied emission factors for carbon also apply with regard to derivation of the implied emission factors for nitrogen (cf. Chapter 6.1.2.1.1).

Table 377: Implied emission factors for direct nitrous oxide emissions [kg N_2O ha^{-1} a^{-1}] caused by losses of organic matter from Germany's mineral soils, following land-use changes, for the year 2017

	Implied emission factors$_{mineral\ soils}$ [kg N_2O ha^{-1} a^{-1}] for the year 2017							
Initial\Final	Forest Land	Cropland	Grassland (in the strict sense)	Woody Grassland	Terrestrial Wetlands	Waters	Settlements	Other Land
Forest Land		*0.053*	*0*	*0*	*0*	0	*0.150*	0
Cropland	*0.021*		0	0	0	0	0.087	NO
Grassland (in the strict sense)	*0.889*	1.078		0.263	0.213	0	1.162	NO
Woody Grassland	*0.692*	0.845	0		0	0	0.932	NO
Terrestrial Wetlands	*0.650*	0.711	0	0.042		0	0.780	NO
Waters	0	0	0	0	0		0	NO
Settlements	*0.001*	0	0	0	0	0		NO
Other Land	*0*	0	0	0	0	0	0	

Values in italics: Changing from year to year

Positive: Nitrous oxide emissions

6.1.2.8 Indirect nitrous oxide (N_2O) emissions from cultivated soils 4(IV)

The indirect N_2O emissions tied to losses of organic soil substance resulting from land-use changes and land cultivation have been determined in keeping with the 2006 IPCC Guidelines (CRF Table 4 (IV)). To that end, the carbon-stock changes determined for the individual land-use-change areas were divided by the mean, area-weighted C/N ratios for the pertinent soils; this yielded the absolute changes in soil nitrogen stocks (Equation 11.8 in the 2006 IPCC Guidelines IPCC (2006)). The C/N ratios were derived from the estimated profile data of the Soil map for the Federal Republic of Germany 1:1,000,000 (BÜK 1000; n 2.3; (BGR 2011)).

For estimation of the indirect nitrous oxide emissions, the N-stocks differences pursuant to Equation 11.10 of the 2006 IPCC Guidelines were multiplied by the standard factors $Frac_{Leach-(H)}$ (0.3 kg N_2O-N (kg N)$^{-1}$) and EF_5 (0.0075 kg N_2O-N (kg N)$^{-1}$) (IPCC, 2006). The emission factors for the indirect nitrous oxide emissions, for the year 2017, are listed in Table 378. The pertinent uncertainties are listed in the uncertainties chapters for the respective land-use categories (cf. Chapters 6.4.3, 6.5.3, 6.6.3, 6.7.3 and 6.8.3). The results are entered in CRF Table 4(IV).

The nitrous oxide emissions are also subject to transition-time considerations; like the carbon-stock changes, they are distributed over 20 years. For Forest Land, the remarks made with regard to derivation of the implied emission factors for carbon also apply with regard to derivation of the implied emission factors for nitrogen (cf. Chapter 6.1.2.1.1).

Table 378: Implied emission factors for direct nitrous oxide emissions [kg N_2O ha^{-1} a^{-1}] caused by losses of organic matter from Germany's mineral soils, following land-use changes, for the year 2017

Implied emission factors$_{mineral\ soils}$ [kg N_2O ha^{-1} a^{-1}] for the year 2016								
Initial\Final	Forest Land	Cropland	Grassland (in the strict sense)	Woody Grassland	Terrestrial Wetlands	Waters	Settlements	Other Land
Forest Land		*0.012*	*0*	*0*	*0*	0	*0.034*	NO
Cropland	*0.005*		0	0	0	0	0.019	NO
Grassland (in the strict sense)	*0.200*	0.243		0.059	0.048	0	0.261	NO
Woody Grassland	*0.156*	0.190	0		0	0	0.210	NO
Terrestrial Wetlands	*0.146*	0.160	0	0.009		0	0.175	NO
Waters	0	0	0	0	0		0	NO
Settlements	*0.0002*	0	0	0	0	0		NO
Other Land	*0*	0	0	0	0	0	0	

Values in italics: Changing from year to year

Positive: Nitrous oxide emissions

6.1.2.9 Combustion of biomass

In Germany, combustion of biomass takes place solely via forest fires. The resulting emissions are entered in CRF Table 4(V). A description of the method used for estimating forest fire emissions is presented in Chapter 6.4.2.7 (forest fires) in the land-use category Forest Land.

No emissions from combustion of biomass occur in the land-use categories Cropland, Grassland, Wetlands, Settlements and Other Land. For all categories, a distinction is made between controlled burning and wildfires, however. Wildfires seldom occur in these land-use categories in Germany and thus are not recorded as such. The relevant greenhouse-gas emissions are negligible. In CRF Table 4(V), NO (not occurring) is entered for that category.

Controlled burning (on-site burning of biomass) is prohibited by law in Germany (Article 3 German Ordinance on direct payments (DirektZahlVerpflV); Federal Law Gazette (BGBl) 2004) and thus is assumed not to occur. This applies to all land-use categories. In CRF Table 4(V), NO (not occurring) is entered for that category.

6.1.2.10 Uncertainties

Uncertainties in the LULUCF section of the German GHG inventory are determined in accordance with the 2006 IPCC Guidelines and the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000). The uncertainty statistics commonly given for a normal distribution include the 95 % confidence interval, ± half of the 95 % confidence interval or 1.96 x the standard error, in % of the mean. In the case of non-symmetric distributions – such as log-normal distributions – the uncertainties are expressed as percentages of the position scale, and as upper and lower bounds. As a rule, they are determined via the quantiles (p = 0.025 and p = 0.975). In keeping with above guidelines, the propagation of uncertainties was calculated via a conservative estimation in which the distance between the extreme value of the sloping axis section and the position scale is defined as half of the 95 % confidence interval. Due to a lack of uncertainty estimates for the relevant emission factors, it was not possible to calculate uncertainties for harvested wood products (cf. also Chapter 11.3.1.5.3).

The total uncertainty of the LULUCF section of the German GHG inventory thus amounts to 23.29 % with respect to the level of emissions. CO_2 emissions account for the major part of this uncertainty (99.71 %), especially those from the biomass pool (68.12 %), followed by organic soils (21.35 %), mineral soils (9.53 %) and dead organic matter (0.89 %). Methane (0.22 %) and nitrous oxide emissions (0.07 %) have only a marginal effect on the total uncertainty – in fact, the effect is hardly noticeable.

With respect to the land-use categories, the largest uncertainties occur in the sub-category Forest Land remaining Forest Land. In it, the biomass pool, due to the emission factor's 56.37 % uncertainty and the absolute size of the pertinent sink (-41,098.77 kt CO_2-eq.), makes far and away the largest contribution (68.17 %) to the total uncertainty of the LULUCF inventory. In this land-use sub-category, mineral soils (9.12 %) and dead organic matter (0.89 %) rank next. Their contributions are determined primarily by the size of the relevant emission factors (litter: 294.00 %; dead wood: 106.88 %). Outside of the Forest Land category, CO_2 emissions from organic soils, in the sub-categories Grassland (in the strict sense) remaining Grassland (18.92 %) and Cropland remaining Cropland (1.60 %), contribute most to the total uncertainty of the LULUCF inventory, due to the absolute level of the CO_2 emissions (22,046.65 and 7,783.80 kt CO_2-eq.) and to the uncertainties of the relevant emission factors (56.28 % and 45.66 %). All other sub-categories and pools play only a marginal role in this regard; in sum, they contribute only about 1.25 % to the total uncertainty.

6.1.3 Quality assurance and control

General quality control (QC) and, additionally for 4.A to 4.G, category-specific quality control, and quality assurance (QA), have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity (SNE).

For QA, detailed checklists were used, and individual checks carried out, for review and documentation of the results in keeping with the quality management guidelines of the Thünen Institute (TI 2016). The Single National Entity archives the Thünen checklists, as well as other documents of importance for quality control. All these documents are thus also available for purposes of external review.

6.1.3.1 The Thünen Institute's quality management for emissions inventories

The Thünen Institute's quality management for emissions-inventory preparation has been developed in conformance with the IPCC Guidelines and the QSE manual (Chapter 1.3.3). The framework for the quality management, and the process for carrying it out, are described in detail in the relevant concept(BMELV, 2016) and in the provisions for the implementation of the concept (TI TI, 2016). All pertinent documents and data are added to the inventory description that is archived by the SNE. The requirements and procedures set forth by the provisions for implementation of the concept were fully complied with. The following section describes the special additional quality controls carried out for the present submission.

6.1.3.2 Input data, calculation procedures and emissions results

In a first step, the land-use matrix was checked for quality and then approved for emissions calculation. Quality checks covered the decision trees and the results of the annual land-use matrix and of the 20-year transition period. The following section lists key test criteria, for the land-use matrix, that were applied in this year's tests. These criteria exceed the requirements set forth by the provisions for implementation of the concept. They apply for the entire land-use matrix and for the two sub-matrixes for mineral and organic soils:

- The national area is constant.
- The national area is the same as that used in the previous year.
- The areas of the land-use categories are the same, or almost the same, as the corresponding areas used in the previous year; if there are any discrepancies, they can be explained.

- The areas and area trends are consistent with the relevant statistical data; if and where they are not consistent, the discrepancies can be explained.
- The sums of the total areas, consisting of remaining areas and areas with land-use changes, are correct.
- Other Land areas have remained the same or have decreased; no land-use changes to the category Other Land have occurred.
- Peat-extraction areas have been listed separately.
- Consistency between the Convention (LULUCF) and Kyoto-Protocol reporting (KP-LULUCF) is assured with regard to forest-land areas and afforestation/reforestation/deforestation (ARD) areas.

The emissions calculations have been carried out using the quality-assured land-use matrix. The calculations of emissions for annual land-use changes and the transition period were implemented step-by-step, in tabular form, on the basis of the area data and emission factors / implied emission factors (IEF). The tables have been reviewed with regard to:

1. Correctness of the calculations,
2. Consistency of the time series,
3. Consistency with the calculations of the previous year.

The following test criteria have also been applied:

Emission factors:

- The calculations of the emission factors and implied emission factors (IEF) are correct.
- The time series for the emission factors is consistent; any changes from year to year can be explained.
- The emission factors are the same as those of the previous year, except in cases in which data and methods have changed; any new emission factors are plausible. Any differences with respect to those of the previous year can be explained and have been completely documented.
- Uncertainties have been correctly reported and are consistent with those of the previous year.
- Data consistency between the Convention (LULUCF) and Kyoto-Protocol-reporting (KP-LULUCF) frameworks is assured.

Calculations:

- The basic calculations and the calculations for the annual land-use changes and the transition period are correct.
- The overview tables, which serve as the basis for the CRF tables and the text, are correct.
- The emissions results are consistent with those of the previous year; any discrepancies can be explained as the result of use of new data and methods.
- The consistency of the calculations, between the Convention (LULUCF) and Kyoto-Protocol-reporting (KP-LULUCF) frameworks, is assured.

Results of quality controls:

1. All calculations are correct.
2. The time series are consistent. Any major year-to-year changes result solely from the periodicity of data and from linear interpolation between pertinent periods.
3. No unexplainable outliers were found in the relative differences with regard to the emissions of the previous year. All changes with respect to the previous year have been correctly documented and are included in the National Inventory Report.

After the relevant activity data and implied emission factors (IEF) were entered into the Central System of Emissions (CSE) database, the emissions as calculated in the CSE were compared, for quality control purposes, with emissions results obtained via calculations made outside of the database environment. All quality control steps and their results are fully recorded in the inventory description that is also archived by the Single National Entity.

6.1.3.3 Verification

The inventory in the LULUCF sector is prepared primarily with data from inventories and surveys that are unique to Germany. This means that no comparable data are available that could be used to verify it. The inventories and surveys that are used include the National Forest Inventory (BWI), the Forest Soil Inventory and the Agricultural Soil Inventory (Soil Inventory – BZE), the data from the ATKIS® official topographic-cartographic information system, forest-fire statistics, etc. These sources serve as sources of primary statistics. In the interest of data quality, inventories such as the BWI and the BZE carry out their own extensive quality assurance and control programs (cf. also Chapter 6.4.4). All of the results used include error information that enters into the uncertainties calculation for the LULUCF inventory.

The results and implied emission factors (IEF), differentiated by carbon pools and land-use categories, have been compared with those of neighbouring countries. Details on such comparison are provided in the "Category-specific quality assurance / control and verification" chapters for the various land-use categories.

6.1.3.4 Reviews and reports

In September 2016, an In-Country Review was carried out by an expert panel of the UNFCCC Secretariat. The following recommendations have already been implemented, in the 2017 Submission (NIR 2017):

1. Estimation of the carbon-stock changes in (woody plant) phytomass in the land-use category Cropland remaining Cropland

- Inclusion of additional, more-detailed remarks designed to improve the transparency of the report, with regard to

    a. the mineral soils pool in the category Cropland remaining Cropland: proof that mineral soils are not a carbon source
    b. proof that the mean carbon stocks of mineral soils under Settlement areas are country-specific and conform with the available guidance, and that the method used is indeed a Tier 2 method
    c. emission factors in HWP CRF Table4.Gs2
    d. Forest Land: Stock-change method
    e. Proof with regard to land use, and preparation of the land-use matrix
    f. Additional descriptions of methods under KP-LULUCF (some remarks are redundant with those of UNFCCC)

6.1.4 Planned improvements

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

6.2 Land-use definitions and land-use classification systems, and their reflection in the LULUCF categories

With the introduction of the sample-point grid system, the various land-use definitions of the underlying data sources (B-DLM of ATKIS® and CORINE Land Cover and CIR data (cf. Chapter 6.3)) had to be correlated with the LULUCF reporting categories.

In the B-DLM, the catalogue of object types changed with the introduction of the new AAA model. For this reason, a new correlation table is being used for the submissions as of 2013. The six IPCC land-use categories are directly correlated with the object types used in the Basis-DLM (AAA levels) of ATKIS® (Table 379).

In preparation of the land-use matrix, the grid-point allocation is computerized; it is carried out fully automatically via dedicated programmes. In support of that purpose, the allocation keys for these classification systems are included in digital form, with the result that any given grid point can always be unambiguously allocated to an object type key number and, thus, to a specific land-use category, regardless of the data source being used. The scripts for these programmes are maintained in the inventory description.

Table 379: Allocation of main object type index numbers and attributes in ATKIS® to IPCC land-use categories

ATKIS Object-type catalog					CORINE LAND COVER
Object number, AAA levels	Attribute, AAA levels	Object number, levels	Object type	Description / attributes pursuant to ATKIS object-type catalog	Nomenclature code
IPCC category: Forest Land					
43002	VEG, all	4107	Forest Land	Deciduous, coniferous and mixed forest	311; 312; 313; 324
IPCC category: Cropland					
43001	VEG 1010	4101	Agriculture: Cropland	Area for cultivation of field crops (such as grain, legumes, root crops) and berries (such as strawberries) Cropland also includes rotational set-asides, permanent set-asides and areas set aside to achieve eligibility for EU compensation payments.	211; 212
43001	VEG 1012	4109	Agriculture: Hops	Hops	No allocation
43001	VEG 1030	4103	Agriculture: Horticultural land	Horticultural land is land for cultivation of vegetables, fruit and flowers, and for growing of cultivated plants	242
43001	VEG 1031	4109	Agriculture: Tree nursery	Tree nursery	No allocation
43001	VEG 1040	4109	Agriculture: Vineyard	Vineyard	221
43001	VEG 1050	4109	Agriculture: Fruit plantation	Fruit plantation	222

Object number, AAA levels	Attribute, AAA levels	Object number, levels	ATKIS Object-type catalog Object type		Description / attributes pursuant to ATKIS object-type catalog	CORINE LAND COVER Nomenclature code
IPCC category: Grassland						
43001	VEG 1020	4102	Agriculture: Grassland	Grassland (in the strict sense)	Grassland is a grassy area that is mowed or grazed.	231; 321;421
43004		4104	Heath		A heath area is a sandy area (typically) with certain typical shrubs and grasses, and with sparse, scrub tree cover.	322
43006		4106	Marsh		A marsh area is a waterlogged area that is covered with water for part of the year. Areas that are wet for brief periods, after rainfall, are not considered marsh areas.	411
43007	FKT 1300		Wasteland and vegetation-free areas: Semi-natural area		A semi-natural area is an area that is not used for crop cultivation and that is covered with grass, wild herbs and other plants.	No allocation
43003		4108	Trees and shrubs		Area covered with individual trees, groups of trees, bushes, hedges and shrubs.	243
43007	FKT 1200		Wasteland and vegetation-free areas: Succession area		A succession area is an area that has been permanently set aside from agricultural or other existing use and that is allowed to revert to its original condition – for example, as Woody Grassland, a peatland or a heath.	No allocation
IPCC category: Wetlands						
43005		4105	Peatland	Terrestrial Wetlands	Uncultivated area whose top layer consists of peaty or decomposed plant remains.	412
41005	AGT 4010	2301	Open-pit mine: Peat extraction			No allocation
44001 to 44007		5101 - 5203, 3402	Waters		For example, dammed reservoirs, rivers at least 12 m wide, canals, storage basins, shifting shorelines and banks. 3402 refers to harbour basins – and, thus, to Waters and not Settlements (in AAA 44005).	511; 512; 423; 521; 522; 523
IPCC category: Settlements						
41001 to 41010		2101-2352	Settlements		Settlements refer to areas, either with or without buildings and structures, that have been shaped by human occupation or that support human occupation.	111; 112; 121; 131; 132; 133; 141; 142
42001 to 42016		3101-3543	Transport		Transport areas consist of areas, either with or without buildings and structures, that serve and support transports.	122; 123; 124
43007	FKT 1100		Wasteland and vegetation-free areas: Area accompanying a water body		An area accompanying a water body is an area, either with or without buildings and structures, that is allocated to a watercourse.	122; 123; 124
IPCC category: Other Land						
43007	FKT 1000	4120	Wasteland and vegetation-free areas: Areas without vegetation		Areas without significant vegetation cover, as a result of special soil characteristics such as unprotruding rocks, sand or ice areas.	331; 332; 333; 334; 335
43008		4199	Area currently undefined		Areas whose characteristics cannot currently be determined, in terms of allocation to object types.	No allocation

6.2.1 Forests

The definition of forest used in the German inventory conforms with that given in the 2006 IPCC Guidelines (IPCC (2006): Vol. 4, Ch. 2.2). The manner in which national land-use systems are allocated to this IPCC category is shown in Table 379.

The basis for reporting consists of the definition of forest used by the National Forest Inventory (Bundeswaldinventur (BWI); (Polley, 2001):

"Forest" within the meaning of the BWI is any area of ground covered by forest vegetation, irrespective of the information in the relevant cadastral survey or similar records. The term "forest" also refers to clear-cut or thinned areas, forest tracks, firebreaks, openings and clearings, forest glades, feeding grounds for game, timber yards / lumberyards, forest aisles for conduction, further areas linked to and serving the forest including areas with recreation facilities, overgrown heaths and peatland, overgrown former pastures, alpine pastures and rough pastures, as well as areas of dwarf pines and green alders. Heaths, peatland, pastures, alpine pastures and rough pastures are considered to be overgrown if the naturally regenerated forest cover has reached an average age of five years and if at least 50 % of the area is covered by forest. Forested areas of less than 1,000 m^2 located in farmland or in developed regions, narrow thickets less than 10 m wide, Christmas tree and decorative brushwood cultivations and parkland belonging to residential areas do not constitute forest within the meaning of the BWI. Watercourses with widths of up to 5 m do not break the continuity of a forest area.

At the same time, in a departure from the BWI definition of forest, areas that the BWI counts as forest, but places in the forest category non-forest ground, i.e. because they are unstocked, are treated as "non-forest" in the BWI's calculation of carbon stocks and carbon-stock changes. While short-rotation plantations are recorded separately in the BWI, they are not forest within the meaning of the BWI, the Federal Forest Act and the present inventory. They are thus reported under Cropland.

Pursuant to the 2006 IPCC Guidelines, Land converted to Forest Land remains in that conversion category for at least 20 years and is only then included in Forest Land remaining Forest Land. For afforestation areas, data for the period as of 1970 are taken into account.

6.2.2 Cropland

The definition of Cropland used in the German inventory conforms with the 2006 IPCC Guidelines (IPCC (2006): Vol. 4, Ch. 3.2). The manner in which national land-use systems are allocated to this IPCC category is shown in Table 379.

For purposes of emissions calculations, such land-use systems are stratified by specific pools:

- Calculation of biomass stocks: Annually variable stratification by 65 annual crops (Chapter 6.1.2.3.3) and permanent crops. Permanent crops are grouped into the following categories: various fruit-tree categories (Chapter 6.1.2.3.4.1), wine grapes (Chapter 6.1.2.3.4.2), Christmas trees (Chapter 6.1.2.3.4.3), tree nurseries (Chapter 6.1.2.3.4.4) and short-rotation plantations (Chapter 6.1.2.3.4.5). Permanent crops accounted for 1.5 % of the total Cropland area in 2017. The stratification of this share, and the weighting applied to its various strata, are described in Chapter 6.5.2.2.2.
- Calculation of emissions from soils: Constant stratification over time; soils are broken down into organic soils and mineral soils. The mineral soils pool is subdivided by usage, soil type / soil-parent-rock groups and climate region (cf. Chapter 6.1.2.1).
- The total area of open drainage ditches is determined in addition to the area of organic soils under Cropland.
- Calculation of the emissions from land-use changes: Annually updated stratification by the categories Cropland remaining Cropland and Land converted to Cropland. The relevant data are taken annually from the pertinent land-use information (Chapter 6.2; Chapter 6.3).

6.2.3 Grassland

Grassland as defined in the German inventory is in keeping with the definition given in the 2006 IPCC Guidelines ((IPCC, 2006): Vol. 4, Chapter 3.2). The manner in which areas defined by national land-use systems are allocated to this category is shown in Table 379.

Grassland is divided into two sub-categories: a) areas covered with grasses and herbs (Grünland im engeren Sinn / Grassland in the strict sense) and b) areas that are covered with trees and shrubs (Gehölze / Woody Grassland) but do not fall under the forest definition. It also includes object type 4106 "swamp, reeds" from the Basic Digital Landscape Model (Digitales Basis-Landschaftsmodell; Basis-DLM) (Chapter 6.3.2.1), which consists of undrained organic soils under grassland. In the following, such areas are also referred to as wet grassland. In 2017, Grassland (in the strict sense) accounted for 88 % of the total grassland area (mineral soils: 73.8 %; organic soils: 14.4 %) while Woody Grassland accounted for 11.8 % of the total area (mineral soils: 9.4 %; organic soils: 2.4 %).

The sub-categories in this area include the following types of land use and plants:

- Meadows, pastures, alpine pastures, rough pastures, heath areas, natural-condition grassland, recreational areas and swamp/reeds are grouped under "Grassland (in the strict sense)".
- Hedges, field copses and shrubbery make up the sub-category "Woody Grassland".

Conversions and changes between these two sub-categories are treated like land-use changes.

For purposes of emissions calculation, the two grassland sub-categories have been stratified by pools. To that end, area-weighted mean carbon stocks are determined, and the resulting figures are used in the inventory:

- Calculation of biomass stocks: Stratification within the sub-categories, by crop types. For Grassland (in the strict sense), the stratifications include above-ground and below-ground biomass of grasses and herbaceous plants (Chapter 6.6.2.2). For Woody Grassland, mean carbon stocks have been determined for hedge plants and field copses, stratified by species combinations, age, growth density and growth height (Chapter 6.6.2.2). Those carbon stocks may be understood as representing long-term equilibrium (i.e. no changes).
- Calculation of the emissions from soils: Constant stratification over time; soils are broken down into organic soils and mineral soils.
    - The organic soils are subdivided into wet areas (depth to water table < 0.1 m) and drained areas (depth to water table > 0.1 m) (cf. Chapter 6.1.2.2). In addition, the total area of drainage ditches has been estimated.
    - The mineral soils are subdivided by usage, soil type / soil-parent-rock groups and climate region (cf. Chapter 6.1.2.1).
- Calculation of emissions from land-use changes: Annually updated stratification, by the categories Grassland (in the strict sense) remaining Grassland (i.t.s.s.), Woody Grassland remaining Woody Grassland and Land converted to Grassland. The relevant data are taken annually from the pertinent land-use information (Chapter 6.2; Chapter 6.3).

6.2.4 Wetlands

Pursuant to the 2006 IPCC Guidelines, the "Wetlands" land-use category must subsume all those land areas where soils are intermittently or constantly waterlogged, or covered with water, and that do not fall within the land-use categories 4.A, 4.B, 4.C and 4.E. In the German inventory, these areas are combined in the sub-categories Terrestrial Wetlands (IPCC: Other Wetlands) and Waters (IPCC: Flooded Land). In addition, all areas that are related to peat extraction are combined within an additional sub-category under the land-use category Wetlands (IPCC: Peat Extraction; cf. the 2006 IPCC Guidelines, IPCC (2006)).

The majority of Germany's former wetlands areas have been drained and are used mainly for agriculture and forestry (1,606 kha ≙ 88.1 % of the total area of organic soils, of which 1,499 kha ≙ 93.3 % are drained). Those areas are reported in the relevant land-use categories (4.A - 4.C) pursuant to the 2006 IPCC Guidelines. The sub-category Terrestrial Wetlands thus includes Germany's few remaining undrained, semi-natural (i.e. subject to very little anthropogenic influence) peatlands, along with certain other wetlands on mineral soils and peat-extraction areas. In the sub-category Waters, a distinction is also made in terms of the degree of anthropogenic influence – between a) flooded land[94] and b) natural water bodies, including non-regulated and regulated water bodies (which are not covered by reporting obligations). Table 380 shows how Germany's wetlands areas have been classified, for the year 2017, in accordance with these provisions.

Table 380: Breakdown of the land-use category Wetlands pursuant to the 2006 IPCC Guidelines, and allocation of water-body and terrestrial-wetlands areas [ha] to the relevant sub-categories for 2017

<table>
<tr><th colspan="7">4.D Wetlands
[731,985 ha]</th></tr>
<tr><th colspan="4">Terrestrial Wetlands
[113.399 ha]</th><th>Peat extraction
[19,857 ha]</th><th colspan="2">Waters
[598,913 ha]</th></tr>
<tr><td colspan="2">Mineral soils
[13,399 ha]</td><td colspan="2">Organic soils
[99,816 ha]</td><td>Organic soils
[19,857 ha]</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td colspan="2">not drained
[13,399 ha]</td><td colspan="2">drained [76,429 ha] /
undrained [23,387 ha]</td><td>drained
[19,857 ha]</td></tr>
<tr><td>Remaining,
[7,249 ha]</td><td>Converted
[6,150 ha]</td><td>Remaining, including all undrained
[77,893 ha]</td><td>Converted (drained)
[21,923 ha]</td><td>Remaining,
[19,857 ha]</td><td>Remaining,
[537,695 ha]</td><td>Converted
[60,795 ha]</td></tr>
<tr><td colspan="2">Natural and semi-natural wetlands (such as swamps, rivers and streams)</td><td>Natural and semi-natural peatlands (such as peat areas, fens)</td><td>Semi-natural peatlands</td><td>Peat-extraction areas</td><td></td><td></td></tr>
<tr><td>No emissions</td><td>Emissions from mineral soils, biomass</td><td>Emissions from organic soils, biomass</td><td>Emissions from organic soils, biomass</td><td>Emissions from on-site, off-site</td><td>No emissions</td><td>Emissions from biomass</td></tr>
</table>

The sub-categories "Peat extraction", "Terrestrial Wetlands" and "Waters" differ in terms of their emissions behaviour. For this reason, they are listed as separate sub-categories and reported separately in the CRF tables (4.D and 4.(II)) (for details, cf. Chapter 6.3). In the land-use category Wetlands, land areas are calculated with the help of annually updated stratification by Terrestrial Wetlands and Waters remaining as such, as well as by Land converted into Waters or Terrestrial Wetlands. The relevant data are taken annually from the pertinent land-use information (Chapter 6.3). With regard to the peat-extraction area, a constant value of 19,857 ha is assumed (cf. Chapter 6.7.2); that area is reported only in the remaining category. Conversions of Waters into Terrestrial Wetlands and vice versa are treated like land-use changes from other land-use categories.

For purposes of emissions calculation, the sub-categories Peat extraction, Terrestrial Wetlands and Waters are stratified by pools. To that end, area-weighted mean carbon stocks are determined, and the resulting figures are used in the inventory:

Remaining category:

[94] Water bodies that are regulated via human activities and that exhibit wide fluctuations in water level and/or changes in the area they cover (dammed reservoirs, etc.) (2006 IPCC Guidelines)

- Calculation of biomass stocks: No biomass occurs in the sub-category Waters. The biomass of the sub-category Terrestrial Wetlands has been derived from the relevant figures for Grassland (in the strict sense) and Woody Grassland (Chapter 6.7.2.2).
- Calculation of emissions from mineral soils: No anthropogenic emissions occur in any of the sub-categories, since the areas are undrained. In the tables, the emissions are listed as not occurring (NO).
- Calculation of emissions from organic soils: For peat-extraction areas, both on-site and off-site emissions are calculated (Chapter 6.7.2), in keeping with the 2006 IPCC Guidelines and the 2013 IPCC Supplement on Wetlands. The sub-category Terrestrial Wetlands is divided into wet (depth to water table < 0.1 m) and drained areas (depth to water table > 0.1 m) (cf. Chapter 6.1.2.2); on-site emissions are reported, but no emissions are reported for the sub-category Waters.

Conversion categories:

- Calculation of biomass stocks: In the case of land-use changes to Waters, the biomass stocks are set to zero. The biomass of the sub-category Terrestrial Wetlands has been derived from the relevant figures for Grassland (in the strict sense) and Woody Grassland (Chapter 6.7.2.2; cf. Chapter 6.1.2.3).
- Calculation of emissions from soils: No emissions occur in the sub-category Waters. The sub-category Terrestrial Wetlands is divided, in a constant manner over time, into "organic soils" and "mineral soils." For organic soils, on-site emissions are reported, following subdivision of such soils into wet (depth to water table < 0.1 m) and drained areas (depth to water table > 0.1 m) (Chapter 6.1.2.2). The mineral soils pool is subdivided by usage, soil type / soil-parent-rock groups and climate region (cf. Chapter 6.1.2.1).

6.2.5 Settlements

The description of the categories used by national land-use systems in connection with settlements and transport, and the manner in which the are allocated to the IPCC category Settlements, are shown in Table 379. The definition of settlements used in the German inventory conforms with the 2006 IPCC Guidelines (IPCC (2006): Vol. 4, Ch. 2.2). All settlement areas have been combined within a single category.

- For purposes of emissions calculations, the land-use category is stratified by specific pools. To that end, area-weighted mean carbon stocks are determined, and the resulting figures are used in the inventory:
- Calculation of biomass stocks: The biomass of the category Settlements has been derived from the relevant figures for Grassland (in the strict sense) and Woody Grassland (Chapter 6.8.2.2; cf. Chapter 6.6.2.2).
- Calculation of the emissions from soils: Constant differentiation over time by organic soils and mineral soils. The mineral soils are subdivided by usage, soil type / soil-parent-rock groups and climate region (cf. Chapter 6.1.2.1). For organic soils, the values for Grassland (in the strict sense) are used as proxies (Chapter 6.1.2.26.1.2.2).
- Calculation of emissions from land-use changes: Annually updated stratification by the categories Settlements remaining Settlements and Land converted to Settlements. The relevant data are taken annually from the pertinent land-use information (Chapter 6.2; Chapter 6.3).

6.2.6 Other Land

The following object types defined in ATKIS® are assigned to the category Other Land within the German reporting system, in keeping with the 2006 IPCC Guidelines: "area currently not classifiable" (object number 4199), and "vegetation-free areas" (object number 4120). The relevant areas are described and allocated in keeping with Table 379 in Chapter 6.2 and the algorithms described in that section.

6.3 Information on approaches used for determining relevant land areas and on the sources of land-use data used

6.3.1 Introduction

The method for determining land-use changes in the LULUCF sector takes account of all land uses and land-use changes in a spatially consistent manner over time. A sample-based system is used. The method used is based on spatially explicit observations, and thus can be considered a Tier 3 approach according to the 2006 IPCC. The reasons why this sample-based system was chosen are listed in Freibauer et al. (2017) .

The sampling system is based on a regular grid of sample points laid over the entire surface area of Germany. The grid, which is randomly distributed, is based on the grid for the 2012 National Forest Inventory (BWI 2012), which assigns points an average area of 1.4 km^2. The number of samples provided by the BWI grid proved to be too small for spatially precise, reliable identification of land uses and land-use changes on areas with organic soils, however. To address this issue, the entire area of Germany was divided into two systems: a "mineral soils system" covering areas of mineral soils and an "organic soils system" covering areas of organic soils (cf. also Table 381). The stratification basis for the organic soils system consists of the map of Germany's organic soils ("Karte organischer Böden Deutschlands"), which has a scale of 1:25,000 (Roßkopf et al., 2015). The area of the mineral soils system is obtained as the difference between the total area of Germany and the area taken up by organic soils. In the mineral soils system, the standard point density of the BWI, which has 243,454 sample points, is used. The resolution of the point grid in the organic soils system was increased, to take improved account of the small areas and great spatial diversity of wetlands in the landscape, to an average area of 6.4 ha per point (284,769 sample points). The relevant land areas are calculated separately, for the two systems, using the same methods and algorithms (Chapter 6.3.2 ff.), and then the results are combined to produce a unified land-use matrix. This procedure considerably improves precision in the identification and demarcation of land uses and land-use changes on organic and mineral soils, in all land-use categories.

Table 381: Comparison of the strata mineral soils and organic soils

Land area	Sampling network	Number of sample points	Area [ha]	Average area per sample point
Mineral soils	BWI grid	243,454	33,955,711	139.5 ha (≙1.395 km^2)
Organic soils	BWI grid (with partly increased resolution)	284,769	1,823,922	6.4 ha (≙0.064 km^2)
Germany	BWI grid (with resolution partly increased)	528,223	35,779,633	67.7 ha (≙0.677 km^2)

6.3.2 Database and data processing

The land-use matrix (LUM) is derived on the basis of all available geographically explicit data sets. For a data source to be usable, its land-use classes – as assigned via interpretation or modelling – must lend themselves to translation into the IPCC land-use categories. Not every data set has to show all land-use classes; it suffices if at least one of the six main land-use categories can be identified. The land-use information in the various data sets is correlated with the sample points, via geographic location. With this, information is then available for each sample point – information that is distributed over time, and that can differ in terms of amount of data items and in terms of quality with regard to errors of location, preparation and interpretation.

The aim of this flexible survey system is not to record land-use changes as often as possible, but rather

- to identify the most reliable land-use information, from the overall available information,
- to filter out and detect land-use changes, and
- to eliminate any possible uncertainties and sources of error.

The quality of the available data sets differs in terms of usefulness for classification of land-use categories. For this reason, a clear hierarchy was introduced for sorting (ranking) the data sets, from the most precise data – the 1st quality level – to the poorest quality level. A land use is recorded in the year in which the pertinent data source is surveyed. If, for a given year and a given sample point, several different land-use data items are available, from different data sources, then the information with the highest quality level (QL) is used to define the pertinent land-use category. Where data sets with the same quality level show different land-use categories, additional rules for applicable decision-making have been defined and documented. Such rules can be oriented to references such as verification data – for example, trends shown in agricultural statistics – that are not available in georeferenced form.

6.3.2.1 Data sources

The following data sources / sets have been used:

- Information on the forest-related categories from the National Forest Inventory (Bundeswaldinventur, BWI) 1987 and 2002, for the period 1987 to 2002 for the old German Länder; data of the BWI 2002 and the Inventory Study (Inventurstudie) 2008 (Oehmichen, 2011), for 2002 to 2008 nationwide, and data of the Inventory Study 2008 and the BWI 2012 for the period 2008 through the present submission,
- Maps, derived from Color-InfraRed (CIR) aerial photos, from the mapping of biotopes and land-use classes carried out for 1990,
- The Basic Digital Landscape Model (Basis-Digitales Landschaftsmodell; Basis-DLM) for the years 2000, 2005, 2008, 2012 and 2014,
- The digital land cover model (Digitales Landbedeckungsmodell; LBM-DE) for the year 2009,
- Corine Land Cover (CLC) 1990, 2000, 2006,
- 1990 GSE data for the new German Länder.

A total of 99.97 % of all land-use information is obtained from the BWI, the CIR data or the Basis-DLM (for 1990, from the Corine Land Cover). Land-use information from the "LBM-DE digital land-cover model for 2009" (LBM-DE) and the 1990 GSE data accounts for very little – only 0.03 % – of the data used in land-use determination.

1st quality level: BWI data

Details relative to the BWI are described in Chapter 6.4.2.1.1. The BWI is a permanent, systematic cluster sample that is collected periodically. At present, BWI data are available referenced to 1987, 2002 and 2012 and, in a sub-sample, to 2008 (Inventory Study 2008). The data of the BWI 2012 provide precise information, as of the end of the first Kyoto-Protocol commitment period in 2012 and as of the beginning of the second Kyoto-Protocol commitment period in 2013, relative to land use (Forest Land remaining Forest Land) and land-use changes to Forest Land (afforestation) or from Forest Land (deforestation). Land uses, and afforestation / deforestation, are determined for each sample point, with the help of aerial photographs, country-specific maps and in situ inspections. The basis for relevant reporting, pursuant to the UNFCCC, is the forest definition used by the BWI (BMVEL, 2001); cf. Chapter 6.2.1.

The first German report under the Kyoto Protocol uses the following forest definition, which accords with the relevant definition of the UN Food and Agriculture Organization (FAO):

- Land with tree crown cover of more than 10% of the area;
- The smallest land area to be taken into consideration is 0.1 ha; and
- The potential tree height is at least 5 meters.

Within the limits defined by the Marrakesh Accords[95], that definition is the one that comes closest to the definition used in the BWI. Studies (Tomter et al., 2010) comparing activity-data calculations using the aforementioned definitions have found that the resulting discrepancies are negligible. For that reason, the same area-estimation algorithms have been used for purposes of both UNFCCC and KP reporting. At the same time, in a departure from the BWI forest definition, areas that the BWI counts as forest, but places in the forest category non-woodland, because they are permanently unstocked, were not taken into account in the LULUCF sector in calculation of carbon stocks and carbon-stock changes.

For the new German Länder, forest / non-forest information was not available for the year 1987 at the relevant BWI points. In the interest of obtaining a maximally consistent database for the new German Länder, the individual-tree data of the BWI 2002 were used in the following manner: for 1987, the sample points were retro-actively assigned to the land-use class Forest Land for those cases in which the BWI 2002 listed trees that were more than 15 years old at the pertinent forest cluster points.

2nd quality level: CIR data

The CIR data are thematic maps prepared from color-infrared aerial photos. The aerial photos have a resolution of about 40 cm and thus provide a considerably better data basis than the CORINE Land Cover data. The thematic-map data, in terms of time precision (the data include precise records of when the photographs were taken) and degree of detail, are superior even to those of the B-DLM. The measures called for in the action plan for addressing the problems identified in the 2010 In Country Review included using the CIR data for improving the 1990 land-use data. In the years 1989 through 1992, the German Länder Schleswig-Holstein, Saxony, Saxony-Anhalt, Brandenburg, Mecklenburg – West Pomerania and Thuringia used legally mandated biotope-type-mapping programmes as an opportunity to map their entire territories. As of the reporting year 2014, all CIR data are being used in the 1990 base year. Each such data set has been converted, with the help of an individualised conversion table, into the B-DLM format applied.

3rd quality level: Basis-DLM data

The Basic Digital Landscape Model (Basis Digitale Landschaftsmodell; B-DLM) is the basis for Germany's Official Topographical-Cartographical Infomation System (Amtliches Topographisch-Kartographischen Informationssystem; ATKIS®), which is managed by the Working Committee of the Surveying Authorities of the Länder of the Federal Republic of Germany (AdV). The ATKIS® system describes Germany's topography in terms of digital landscape and terrain models. "The Basis-DLM uses a vector format to describe topographic objects of the landscapes and the relief of the earth's surface. Each object is assigned to a specific object type and defined in terms of its spatial position, geometric type, descriptive attributes and relations to other objects. Each object

[95] A set of rules and guidelines pertaining to specific aspects of the Kyoto Protocol.

has an identification number (identifier) that is unique throughout all objects for Germany. In the Basis-DLM, spatial position is given true to scale, and independently of any representations, within the coordinate system used for land surveying. The object types contained in the DLM, and the manner in which the objects are to be formed, are defined in the ATKIS® object-type catalogue (ATKIS®-OK)" (AdV). The informational spectrum of the Basis-DLM is oriented to the contents of standard 1:25,000 topographic maps. At the same time, the Basis-DLM features greater precision of position (± 3m) for the most important point-shaped and line-shaped objects. Data of the Basis-DLM systems of the Länder are adopted by the Federal Agency for Cartography and Geodesy (BKG) and then checked, harmonised, georeferenced and processed, without any overlapping, for use within a nationally standardised Basis-DLM. The BKG also manages the data, within a special database, for purposes of provision to federal authorities and other agencies.

The purpose of ATKIS® is to provide a landscape model (land-cover model that is maximally up-to-date and has the highest resolution possible) of Germany, with regularly updated and expanded geometries and content. The surveying administrations of the Länder collect the pertinent data on an ongoing basis, and not on a national basis as of a given key date. As a result, new surveying results are continuously transmitted to the Federal Agency for Cartography and Geodesy (BKG) and integrated within ATKIS®. While five years is given as time period within which a complete revision should be accomplished, that specification is applied very differently from state to state (states = German Länder). In practice, the data for areas with vegetation cover are between one and seven years old. For areas of very high current interest, especially with regard to area changes – such as settlement and transport areas – a period of three to twelve months is prescribed for transfer into ATKIS®. The Basis-DLM version maintained and managed by the BKG is always the latest version. No pertinent history data are recorded, nor are old versions archived.

For the reporting by the Thünen Institute, this means:

- Basis-DLMs are obtained on an annual basis; the Basis-DLM for a given reporting year is obtained in September of that year;
- In each case, the version for the current year is archived within the institute.

Basis-DLM data sets have been available on an annual basis to the Thünen Institute only since 2005. One data set is available for the year 2000. No ATKIS® data exist for years prior to 2000. Due to the multi-year revision cycles involved, multi-year intervals in the Basis-DLM data sets are used, however, to prevent regional artifacts that can occur via seemingly sudden massing of land-use changes in updating years.

As of 2009, the Basis-DLM is being converted to a new data model, referred to in the following as "AAA levels", to distinguish it from the "levels" referred to under the old model. In the years 2009 through 2012, some German Länder provided data in the old model and some provided data in the new model. As of 2013, the Basis-DLM (AAA levels) is being used for all of Germany.

Each data set in the Basis-DLM (levels) comprises some 800 individual layers of differing degrees of detail. For example, polygons with relatively low resolution (such as those showing settlement areas) are found on the lowest level, while polygons with very high resolution and rich detail (such as those showing residential areas) are found on the highest level. A single record thus will contain numerous super-imposed polygons that, in terms of content, can be assigned to the same LULUCF categories. All such related content, with all overlays, is put into the calculation system as a whole. As a result, data gaps occur only where the entire pertinent Basis-DLM data record contains no data. In a subsequent step, the areas so defined are merged with the points of the BWI grid. Where a point touches several stacked areas, only a single value is chosen, with the help of a priority list. Where the same priorities overlap (for example, vegetation with vegetation), then that area with the lower ATKIS® identification value is selected. The procedure was carried out for the Basis-

DLM (levels) from the years 2000, 2005, 2008 and 2012. The Basis-DLM categories (levels) are assigned to the LULUCF categories with the help of a translation table (cf. also Table 379).

The new data model (Basis-DLM AAA levels) includes a layer designated "actual use" ("Tatsächliche Nutzung"). "All object types of this object-type area participate in seamless, non-overlapping and complete-coverage description of the earth's surface (land areas)". Additional attributes emerge in additional layers. The Basis-DLM categories (AAA levels) are assigned to the LULUCF categories with the help of a translation table (cf. also Table 379).

4th quality level: CORINE Land Cover (CLC) data

CORINE Land Cover (CLC) is a European remote-sensing project for standardising classification of land use and land-use changes. It was initiated by the EU Commission in the mid-1980s. In the CLC framework, digital satellite images of European countries are collected, via standardised procedures, and analysed with regard to land-use changes. Image data recorded in three different years, 1990, 2000 and 2006, are currently available. These data have been entered into the database with the help of a script. The CORINE classes have been allocated to the LULUCF categories with the help of a translation table (cf. also Table 379).

5th quality level: GSE data

The GSE Forest Monitoring project is part of the Global Monitoring for Environment and Security (GMES) programme, which was established in 1998 by the European Commission and the European Space Agency (ESA). In the framework of the GSE Forest Monitoring project, the service "Forest Monitoring: Inputs for national greenhouse-gas reporting (GSE FM-INT; "Wald Monitoring: Inputs für die Nationale Treibhausgasberichterstattung") has been implemented for the Federal Ministry of Food and Agriculture (BMEL). The products of that service have included maps of forest cover, land use and land-use changes, for 1990 and for pertinent changes through 2002 and 2005/06; area statistics; and error analyses for the new German Länder (GSE (2003), GSE (2006), GSE (2007), GSE (2009)). Further information about the GSE FM-INT project is provided in Oehmichen et al. (2011) Oehmichen et al. (2011).

6.3.2.2 Derivation of LULUCF information

Each sample point is assigned information, based on the available data sets, with regard to annual land use. Then, classification in keeping with the LULUCF categories can begin. This is achieved via retrospective and prospective comparison – with reference to the year under consideration – to determine, for each point, the time at which land-use information on the highest quality level is available (QL-MAX retrospective and QL-MAX prospective). This means, for example, that for a sample point to which a land-use class is to be assigned for 2001, data on the 1st quality level are available – the BWI information. Retrospectively, the point's first survey-time point, 1987, lies in forest land. Prospectively, the next survey-time point, 2002, also lies in forest land. From the two land-use classes, the classes as seen at the times 1987 and 2002, the relevant land-use category is then derived. In the above-mentioned case, the resulting land-use category would be "Forest Land remaining Forest Land."

Sample points at which BWI information on land use (Forest Land remaining Forest Land), and on categories of land-use change to Forest Land (afforestation) or from Forest Land (deforestation), are available were validated via on-site inspections during the forest inventories and may be considered correct. A similar status may be assumed for the CIR data (which contain information about all land uses), since those maps were prepared to a very large scale and were validated via field surveys. The Basis-DLM data for the period as of 2013 (complete-coverage AAA model) are also considered current and quality-assured, since that project used a strictly hierarchical nomenclature (and was the first to do so). All other records have been reviewed for plausibility of the assigned land-use categories, for a given year, on the basis of additional data, and in keeping with the following criteria:

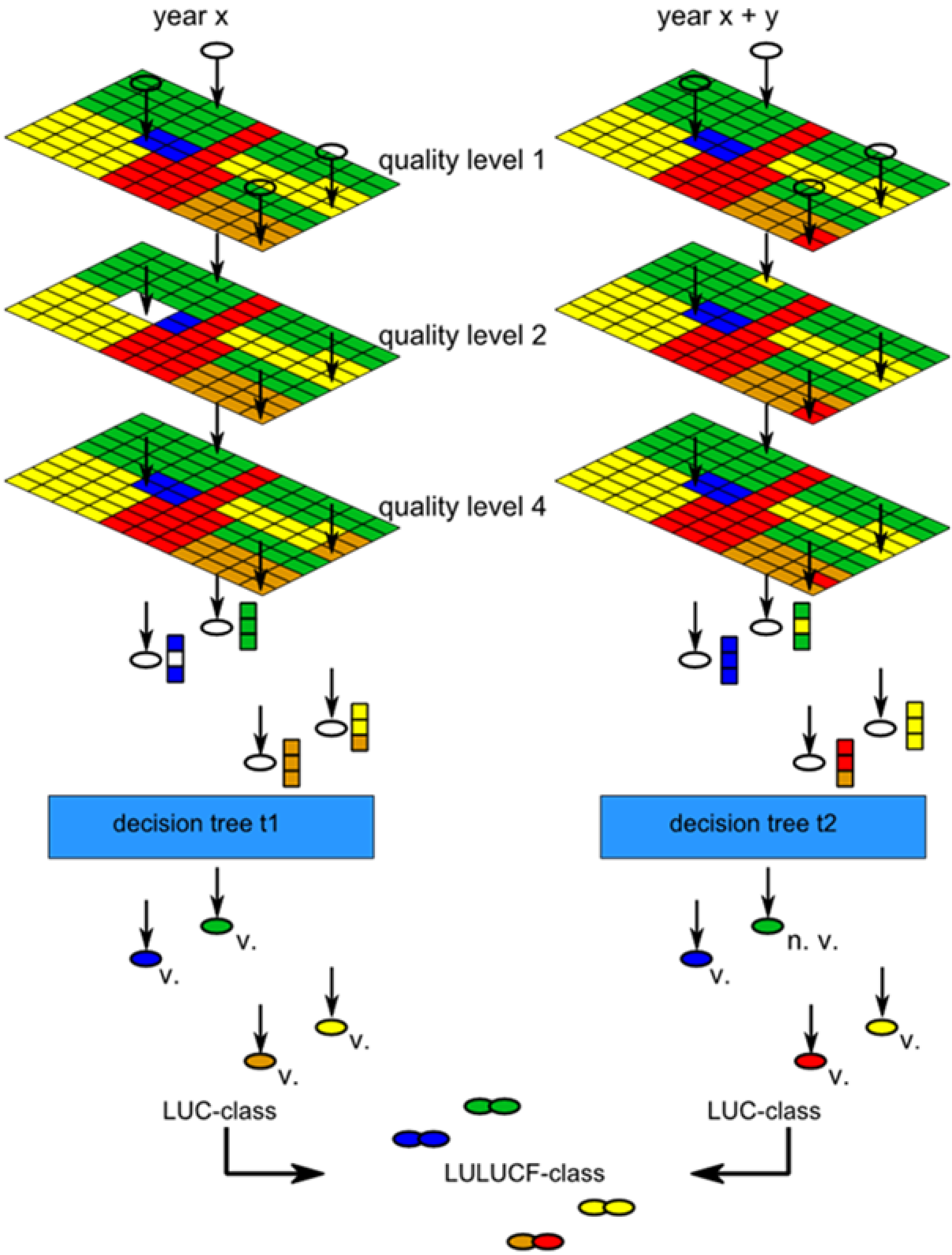
- Can the classification into a specific land-use category be substantiated with pertinent data from a lower quality level?
- Following placement in a land-use category, cases involving land-use changes were reviewed to determine whether data of lower quality levels could be used to narrow down the time period in which the change must have occurred.
- To provide an additional criterion, the national trend in land-use changes (except for those changes to and from Forest Land) was compared with the national net land-use-change rates obtained via the periodic land inventories and agricultural-structural inventories of the Federal Statistical Office. Howevear, those inventories use land-use-category definitions that differ – widely, in some cases – from those used in the present system.

The following example illustrates the manner in which the time period in which a land-use change may have happened is narrowed down: Assuming that, on the basis of BWI data, a sample point was classified as Forest Land in 1987 and as Settlements in 2002. If no additional data were available, the land-use change would be linearly interpolated between those two years, meaning that 1/15 of the represented area would change from forest land to Settlements each year. If Basis-DLM data are available for the point, and those data also show the category Forest Land for 2000 and also show the category Settlements for 2005, then placement in the land-use-change category Forest Land converted to Settlements would be logical and justified, and the change period could be narrowed down to two years (2000 = Forest Land in the Basis-DLM and 2002 = Settlements pursuant to BWI) (cf. also Figure 53).

For each sample point and time, the process of selecting a land-use category – i.e. of conducting relevant review and decision-making – has been carried out transparently, on the basis of a decision tree (cf. Chapter 6.3.4.1).

In keeping with the provisions of the 2006 IPCC Guidelines, reporting under the UNFCCC takes account of land-use changes that took place as early as 1970. As a result, the conversion categories are already being filled with areas in a manner that enables them, as of 1990, to reach a stable dynamic state comprising additions of new change areas and transfers of areas into relevant final-use categories. At present, the earliest georeferenced data available for Germany date from the BWI 1987; and, in general, no complete and – more importantly – internally consistent national data sets are available for the period prior to 1990. Consequently, the changes in all land-use categories in the period 1990 – 2000 were extrapolated retroactively to 1970. That approach is in keeping with that used, for example, by the Czech Republic and by Austria for the land-use matrix.

Figure 53: Schematic representation of allocation of sample plots to a land-use category



6.3.3 Validation and error assessment

With the sampling method used, various sources of error can be quantified, such as

- additional sampling errors,
- differences in definitions, and
- discrepancies between Minimum Mapping Units,

- The task of detecting errors in the georeferencing of data sets is more difficult.
- Still, this flexible, sample-based system is able to eliminate the three error sources a) differences in definitions, b) discrepancies between Minimum Mapping Units and c) imprecise georeferencing, for the following reasons: Pursuant to the decision tree that has been introduced, placement within a land-use category is assumed correct only if such placement can be derived from suitably precise data sets on the 1st quality level, or if data from a lower quality level confirm the placement. In every other case – i.e. whenever different data sources disagree about land use at a given time – the relevant sample point has to be evaluated with the help of aerial photos (whenever such photos are available). Such evaluation was carried out for several German Länder for the year 1990. For the few points where aerial photos are not available, or would not support a decision, an on-site inspection is conducted, as far as is possible.

6.3.4 Step-by-step implementation

Complete implementation over time of this above-described new system for determining land uses and land-use changes throughout Germany necessitates extensive preliminary work and continuous supporting efforts. This includes the following:

- The various data sets, for different points in time, have to be acquired,
- Geometric corrections (of erroneous geometries, etc.) and checks have to be carried out,
- Conversion functions have to be written for converting the original classifications into the categorisation used here,
- The sample points have to be merged with the maps,
- The decision tree has to be programmed and adjusted as necessary, in keeping with data quality and availability, and
- The transition-time procedures have to be programmed and adjusted as necessary, in keeping with data quality and availability.

The decision to use this flexible, sample-based system was made in spring 2011, in consultation with the Single National Entity (Federal Environment Agency – UBA) and the Federal Ministry of Food and Agriculture (BMEL), which is responsible for the forest inventories.

The decision trees for the classification years (one per year), and the "transition-time" procedures, were programmed in keeping with the current data structure.

6.3.4.1 Derivation of land uses

Each sample point can be assigned to a land-use category for the years in question (1990, 2000, 2005, 2008, 2012 and 2014), on the basis of the available data (cf. Chapter 6.3.2), and in keeping with the relevant quality levels. The basic table (cf. Table 382) is structured as follows (here with the example of a sampling point):

Table 382: Basic table for derivation of land uses

Cluster	Cluster point	BWI 1987	BWI 2002	BWI 2008	DLM 2000	DLM 2005	DLM 2008	DLM 2012	DLM 2014	CORINE 1990	CORINE 2000	CORINE 2006	GSE 1990	GSE 2005
xya	1	forl	sett	sett	forl	sett	sett	sett	sett	forl	gra1	sett	gse0	gse0

The following codes are used for the land-use categories in the data sets:

Table 383: Codes in the basic table

Code	Category	Sub-category
crop	Cropland	Cropland
gra1	Grassland	Grassland (in the strict sense)
gra2	Grassland	Woody Grassland
forl	Forest Land	Forest Land
wet1	Wetlands	Terrestrial wetland
wet2	Wetlands	Waters
sett	Settlements	Settlements
othl	Other Land	Other Land
nofo	Non-forest land[96]	
bwi0	No information[97]	
dlm0	No information[98]	
clc0	No information[99]	
gse0	No information[100]	

The decision trees were applied to this basic table for the respective years, 1990, 2000, 2005, 2008, 2012 and 2014. Figure 54 shows, by way of example, the decision tree for 2012. In reading the decision trees, it must be noted that all lines consist of "IF - ELSE IF - ELSE" structures, rather than simple "IF - THEN - ELSE" structures. In other words, when a condition applies, it is implemented. All subsequent conditions are then irrelevant. This structure considerably simplifies the query logic.

[96] The information stems from BWI data, needs to be further specified with the help of other data sources and must be non-forest land.

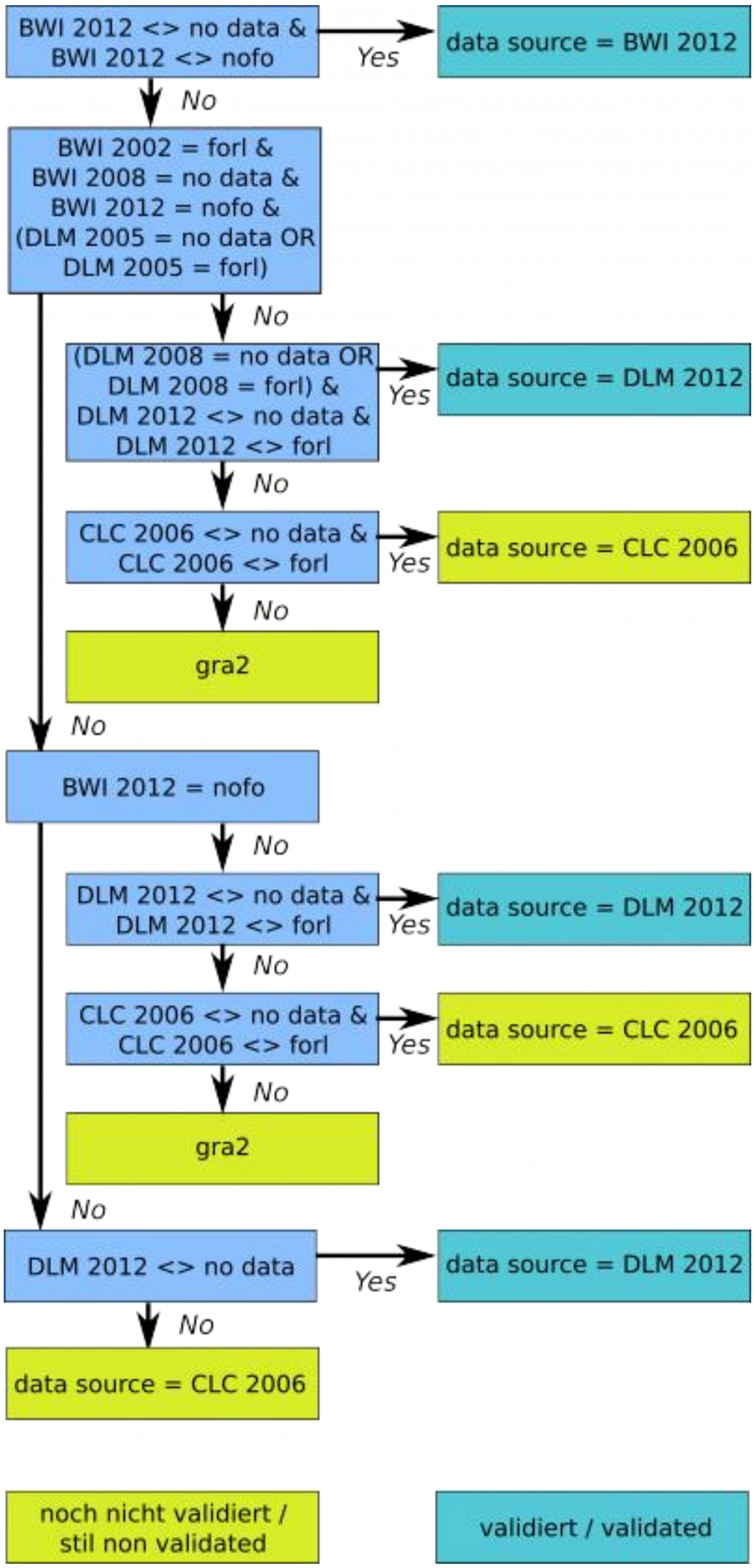
[97] No land-use information at this point in the BWI data

[98] No land-use information at this point in the Basis-DLM data

[99] No land-use information at this point in the CORINE data

[100] No land-use information at this point in the GSE data

Figure 54: Decision tree for the year 2012, presented as an example (for abbreviations, cf. Table 383)



Use of the decision trees yields a further table (cf. Table 384), with the most likely land uses per sample point and year (1990, 2000, 2005, 2008, 2012 and 2014) and the best data source in each case. The BWI data are cited only for actual forest areas. Where the BWI shows "non-forest", other data sources are always used to define the land use, which has to be a use other than Forest Land:

Table 384: Most probable land use (LU) and pertinent data sources (DB)

Cluster	Cluster point	LU 1990	LU 2000	LU 2005	LU 2008	LU 2012	LU 2014	DB 1990	DB 2000	DB 2005	DB 2008	DB 2012	DB 2015
xya	1	forl	forl	sett	sett	sett	sett	bwi	dlm	dlm	dlm	dlm	dlm

(For abbreviations, see Table 383)

6.3.4.2 Derivation of annual land-use changes

Subsequently, the relevant land-use-change categories were derived for each change period (1990-2000, 2001-2005, 2006-2008, 2009-2012 and 2013-2016) and each sample point. To that end, an SQL script was programmed; it is documented in the inventory description.

The process of developing a land-use matrix that takes account of the required 20-year transition period following a land-use change takes place in several sub-steps:

- For all land-use changes that occur within a transition period covered by the included observations (1990-2016), processing is first carried out on a point-oriented basis. At the same time, the land-use changes are spatially correlated with the individual observation points.
- Land-use changes that occurred prior to that period (1970-1990) are extrapolated retroactively from observations carried out during the first measurement period (1990-2000). In those cases, spatial correlation with the observation points is not possible, but it is no longer required. As a result, for those cases a change is made from point-based processing to calculation on the basis of area sums.
- The observation period is divided into transition periods of different lengths (1990-2000, 2001-2005, 2006-2008, 2009-2012, 2013-2016), and the annual changes in those change periods are calculated on a proportional basis, via linear interpolation.

6.3.5 Land-use changes pursuant to the Convention and the KP

The method described here for determining land-use changes, and the resulting land-use matrix (cf. Table 385), including a 20-year "transition time" beginning in 1970, are compliant with reporting requirements pursuant to the UNFCCC and to the 2006 IPCC Guidelines. Table 386 shows the complete detailed land-use matrix for 2017, by way of example.

For determination of land-use changes pursuant to the Kyoto Protocol, the same set of annual data is used (cf. Table 387), but only land-use changes since 1990 are taken into account and, in the conversion categories of afforestation and deforestation, they are accumulated for more than 20 years (cf. Table 488 in Chapter 11.2.2).

Table 385: Land-use categories (LUC), including 20-year transition time, pursuant to reporting under the UNFCCC

Source category	4.A.1 Forest Land remaining Forest Land	4.A.2 … LUC to Forest Land	4.B.1 Cropland remaining Cropland	4.A.2 … LUC to Cropland	4.C.1 Grassland remaining Grassland	4.A.2 … LUC to Grassland	4.D.1 Wetlands remaining Wetlands	4.A.2 … LUC to Wetlands	4.E.1 Settlements remaining Settlements	4.A.2 … LUC to Settlements	4.F.1 Other Land remaining Other Land	4.F.2 … LUC to Other Land
Units	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha
1990	10,376,246	552,374	12,587,710	1,045,088	6,378,432	966,821	616,711	92,953	2,396,776	684,463	82,060	0
1991	10,391,325	552,374	12,575,987	1,045,088	6,357,592	966,821	615,772	92,953	2,417,618	684,463	79,640	0
1992	10,406,405	552,374	12,564,265	1,045,088	6,336,752	966,821	614,833	92,953	2,438,460	684,463	77,220	0
1993	10,421,485	552,374	12,552,543	1,045,088	6,315,912	966,821	613,894	92,953	2,459,302	684,463	74,799	0
1994	10,436,564	552,374	12,540,820	1,045,088	6,295,072	966,821	612,955	92,953	2,480,144	684,463	72,379	0
1995	10,451,644	552,374	12,529,098	1,045,088	6,274,232	966,821	612,016	92,953	2,500,987	684,463	69,959	0
1996	10,466,723	552,374	12,517,375	1,045,088	6,253,392	966,821	611,077	92,953	2,521,829	684,463	67,538	0
1997	10,481,803	552,374	12,505,653	1,045,088	6,232,552	966,821	610,138	92,953	2,542,671	684,463	65,118	0
1998	10,496,882	552,374	12,493,931	1,045,088	6,211,712	966,821	609,199	92,953	2,563,513	684,463	62,698	0
1999	10,511,962	552,374	12,482,208	1,045,088	6,190,872	966,821	608,259	92,953	2,584,355	684,463	60,277	0
2000	10,527,042	552,374	12,470,486	1,045,088	6,170,032	966,821	607,320	92,953	2,605,198	684,463	57,857	0
2001	10,545,240	540,106	12,452,601	1,014,809	6,178,155	961,206	607,819	94,832	2,627,600	705,025	52,239	0
2002	10,563,438	527,838	12,434,717	984,530	6,186,278	955,592	608,317	96,712	2,650,003	725,587	46,622	0
2003	10,581,636	515,569	12,416,832	954,252	6,194,402	949,977	608,816	98,591	2,672,405	746,149	41,004	0
2004	10,599,835	503,301	12,398,948	923,973	6,202,525	944,363	609,314	100,470	2,694,808	766,711	35,386	0
2005	10,618,033	491,033	12,381,063	893,694	6,210,648	938,749	609,812	102,349	2,717,210	787,273	29,769	0
2006	10,634,337	478,462	12,382,137	924,047	6,155,508	924,577	612,675	102,695	2,738,447	798,784	27,965	0
2007	10,650,641	465,890	12,383,211	954,399	6,100,368	910,405	615,538	103,041	2,759,683	810,296	26,161	0
2008	10,666,944	453,319	12,384,285	984,752	6,045,228	896,232	618,401	103,387	2,780,919	821,807	24,357	0
2009	10,683,558	442,258	12,384,373	1,015,414	5,987,639	875,696	621,387	101,574	2,806,860	837,544	23,330	0
2010	10,700,171	431,196	12,384,461	1,046,075	5,930,050	855,160	624,373	99,760	2,832,801	853,282	22,303	0
2011	10,716,784	420,135	12,384,549	1,076,737	5,872,461	834,624	627,359	97,946	2,858,742	869,019	21,277	0
2012	10,733,397	409,074	12,384,637	1,107,398	5,814,873	814,088	630,345	96,133	2,884,683	884,756	20,250	0
2013	10,753,207	395,526	12,384,320	1,107,278	5,787,141	794,231	633,577	94,002	2,912,638	897,563	20,151	0
2014	10,773,017	381,978	12,384,003	1,107,157	5,759,409	774,373	636,810	91,871	2,940,593	910,370	20,052	0
2015	10,792,827	368,430	12,383,686	1,107,037	5,731,677	754,515	640,042	89,740	2,968,549	923,177	19,953	0
2016	10,812,637	354,882	12,383,369	1,106,916	5,703,945	734,658	643,275	87,609	2,996,504	935,984	19,854	0
2017	10,832,447	341,335	12,383,052	1,106,796	5,676,213	714,800	646,507	85,478	3,024,459	948,791	19,755	0

Table 386: Land-use matrix for 2017. In each case, the boldface number on the diagonal shows the area remaining in the same category for the column in question. The other table cells show the relevant land-use changes (including 20-year transition times)

	Land-use matrix for 2016: Areas [ha]										
Initial*Final* land use	*Forest Land*	*Cropland*	*Grassland (in the strict sense)*	*Woody Grassland*	*Terrestrial Wetlands*	*Waters*	*Peat extraction*	*Settlements*	*Other Land*	**Σ reductions**	**Σ additions - Σ reductions**
Forest Land	**10,832,447**	25,991	52,592	17,591	5,707	5,548	0	94,300	0	**201,730**	**139,605**
Cropland	102,146	**12,383,052**	433,122	63,345	1,046	14,376	0	558,293	0	**1,167,689**	**-60,894**
Grassland (in the strict sense)	160,773	1,024,382	**5,048,323**	79,342	18,597	19,606	0	249,148	0	**1,560,142**	**- 936,073**
Woody Grassland	23,439	8,337	22,121	**555,963**	444	998	0	13,413	0	**68,753**	**127,714**
Terrestrial Wetlands	5,742	757	5,348	1,274	**85,142**	335	0	6,477	0	**19,932**	**8,140**
Waters	6,946	2,396	21,565	1,486	377	**540,796**	0	4,594	0	**37,363**	**20,754**
Peat extraction	0	0	0	0	0	0	**19,857**	0	0	**0**	**0**
Settlements	34,355	40,166	87,751	27,279	1,410	11,714	0	**3,024,459**	0	**202,675**	**746,117**
Other Land	7,935	4,767	14,102	2,949	0	7,306	0	8,304	**19,755**	**45,363**	**-45,363**
Σ additions	**341,335**	**1,106,796**	**624,069**	**196,467**	**28,073**	**58,117**	**0**	**948,791**	**0**		
Σ Land-use category	**11,173,782**	**13,489,847**	**5,638,584**	**752,430**	**113,215**	**598,913**	**19,857**	**3,973,251**	**19,755**		
Total area of Germany				**35,779,633**							

Table 387: Annual areas for land-use changes used as a basis for inventory calculations for reporting under the UNFCCC (20-year transition period) and the Kyoto Protocol (cumulative area changes)

Land-use change [hectares per year]	**1990-2000**	**2001-2005**	**2006-2008**	**2009-2012**	**2013-2017**
… to Forest Land					
Cropland to Forest Land	9,715	4,843	5,648	4,274	2,949
Grassland (in the strict sense) to Forest Land	11,189	6,454	4,454	8,645	9,398
Woody Grassland to Forest Land	1,874	922	1,006	1,371	941
Terrestrial Wetlands to Forest Land	258	610	260	224	48
Wetlands to Forest Land	1,050	209	276	441	31
Settlements to Forest Land	2,467	1,805	3,035	1,327	703
Other Land to Forest Land	1,066	506	368	276	0
… to Cropland					
Forest Land to Cropland	3,369	1,543	784	872	466
Grassland (in the strict sense) to Cropland	42,871	17,004	78,703	80,929	50,185
Woody Grassland to Cropland	1,552	153	199	78	401
Terrestrial Wetlands to Forest Land	223	11	6	3	0
Waters to Cropland	612	68	35	25	3
Settlements to Cropland	3,517	2,350	2,813	1,008	1,078
Other Land to Cropland	111	847	67	0	0
… to Grassland (in the strict sense)					
Forest Land to Grassland (in the strict sense)	2,863	3,394	2,826	2,487	1,721
Cropland to Grassland (in the strict sense)	31,127	24,005	17,276	15,596	18,594
Woody Grassland to Grassland (in the strict sense)	3,015	1,670	743	228	317
Terrestrial Wetlands to Grassland (in the strict sense)	194	382	20	120	464
Waters to Grassland (in the strict sense)	2,227	1,338	920	503	684
Settlements to Grassland (in the strict sense)	5,258	4,330	5,026	4,819	3,194
Other Land to Grassland (in the strict sense)	613	1,771	668	351	0
… to Woody Grassland					
Forest Land to Woody Grassland	1,008	409	1,709	778	857
Cropland to Woody Grassland	3,288	4,102	3,891	2,285	2,217
Grassland (in the strict sense) to Woody Grassland	1,114	5,145	5,620	2,688	5,387
Terrestrial Wetlands to Woody Grassland	61	161	26	48	3
Waters to Woody Grassland	197	63	103	7	49
Settlements to Woody Grassland	1,385	2,454	1,638	612	699
Other Land to Woody Grassland	119	319	66	200	0

Land-use change [hectares per year]	**1990-2000**	**2001-2005**	**2006-2008**	**2009-2012**	**2013-2017**
... to Terrestrial Wetlands					
Forest Land to Terrestrial Wetlands	92	698	443	78	60
Cropland to Terrestrial Wetlands	127	55	10	2	56
Grassland (in the strict sense) to Terrestrial Wetlands	358	1,532	1,210	548	920
Woody Grassland to Terrestrial Wetlands	72	40	2	2	3
Waters to Terrestrial Wetlands	60	19	2	4	16
Settlements to Terrestrial Wetlands	32	52	35	10	181
Other Land to Terrestrial Wetlands	0	0	0	0	0
... to Waters					
Forest Land to Waters	484	132	572	340	72
Cropland to Waters	1,317	817	643	465	309
Grassland (in the strict sense) to Waters	1,160	1,489	1,096	656	401
Woody Grassland to Waters	184	20	75	27	3
Terrestrial Wetlands to Waters	21	30	6	10	13
Settlements to Waters	722	829	439	506	412
Other Land to Waters	99	862	468	200	99
... to Settlements					
Forest Land to Settlements	4,723	3,245	4,981	6,450	4,632
Cropland to Settlements	18,402	36,317	23,712	29,544	28,446
Grassland (in the strict sense) to Settlements	8,595	12,299	16,269	13,304	12,813
Woody Grassland to Settlements	1,327	304	467	370	1,006
Terrestrial Wetlands to Settlements	96	1,111	71	68	30
Waters to Settlements	668	195	68	225	103
Other Land to Settlements	412	1,314	167	0	0

6.3.6 Verification

The land-use categories were selected so as to be in accordance with the relevant definitions pursuant to the UNFCCC, the Kyoto Protocol and the IPCC. Germany uses a range of different definitions for important land-use categories – in particular, agricultural land (Cropland, Grassland) and Settlements. The data on area sizes can vary as a result of differences in definitions and in data-collection methods. While such inconsistencies, on the order of over 10%, or 2 million hectares, per land-use category, are well-known, they have been retained with a view to achieving consistent time series in all data sets.

The three most important data sources in Germany, for data on agricultural areas, are (cf. Table 388) as follows:

1. The main soil use survey (Bodennutzungshaupterhebung) of the Federal Statistical Office: It determines land use by surveying agricultural facilities (2010 and 2016: exhaustive survey). Cropland excludes a number of permanent crops, while Grassland excludes extensive, non-commercial forms of use, such as nature-conservation and recreational uses. The Federal Statistical Office reports the Cropland and Grassland data that result from the main soil use survey also to Eurostat. In the inventory, the net area changes, between the Cropland and grassland categories, are used for validation of land-use changes.
2. AKTIS® Basis-DLM: It derives land use from the official land-cover cadastre. The land-use polygons come from topographical maps with scales ranging from 1:5,000 to 1:25,000, and they are corrected and validated via aerial photos. Its content (object types) is determined solely through aerial photos. Grassland includes all forms of herbaceous vegetation. Roads are depicted as lines, and thus roadside vegetation is classified as Grassland, and not as infrastructure. As a result, up to 0.7 million hectares of roadside vegetation are additionally classified as Grassland. The Basis-DLM is one of the inventory's central data sets. For reasons of transparency, it is used without any post-processing or reclassification.
3. The area survey (Flächenerhebung) of the Federal Statistical Office: It derives land use from the official real estate cadastre and from the AKTIS® Basis-DLM. Grassland excludes recreational areas. Because it does not always differentiate between Cropland and Grassland, Cropland and Grassland data are published only as aggregated information for "Cropland + Grassland". The reference date for the latest survey, and thus for the value in Table 388, is 31 December 2015 (Statistisches Bundesamt, FS 3, R 5.1). While the area survey makes use of data that are largely consistent with the ATKIS® Basis-DLM, it converts roads from lines to areas (in a post-processing step). While the area survey represents Germany completely, and consistently over time, it does not show a constant national area for the country. The area survey is consistent with the inventory.

Table 388: Cropland and Grassland, and agricultural areas, by data sources, for the year 2015 [kha]

Land-use category	Main soil use survey (Bodennutzungshaupterhebung)	Inventory	Area survey (Flächenerhebung)
Cropland	11,846	13,491	Not published
Grassland	4,677	6,486	Not published
Total	**16,731**	**19,977**	**18,433**

6.4 Forest Land (4.A)

6.4.1 Category description (4.A)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
-/-	4.A. Forest Land	0	N_2O	265.70	0.02%	150.06	0.02%	-43.5%
-/-	4.A. Forest Land	0	CH_4	20.08	0.00%	19.48	0.00%	-3.0%
L/T	**4.A Forest Land**	**0**	**CO_2**	**-75,542.09**	**-6.17%**	**-57,760.15**	**-6.48%**	**-23.5%**

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS/Tier 2	RS/NS	CS
CH_4	Tier 2	RS/NS	D/CS
N_2O	Tier 2	RS/NS	D/CS

The categories Forest Land remaining Forest Land (4.A.1) und *Land converted to Forest Land* (4.A.2) are key sources for CO_2 emissions and removals in terms of emissions level, trend and Tier 2 analysis.

In the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006), and in the official Common Reporting Format (CRF) tables for GHG inventories submitted to the UNFCCC Secretariat, the category "Forest Land" is subdivided into "Forest Land remaining Forest Land" and "Land converted to Forest Land". Land converted to Forest Land occurs as a result of succession, reforestation and afforestation, on land previously used for other purposes. Pursuant to the 2006 IPCC Guidelines, when such land-use changes occur, calculations must take a 20-year transition period into account, on the basis of data as of the year 1970 (cf. Chapter 6.3). Consequently, before it can be placed in the category Forest Land remaining Forest Land, Land converted to Forest Land has to remain in the relevant conversion category for 20 years. Forest Land remaining Forest Land refers to a) areas that, in the year for which the inventory is being prepared, remain Forest Land, and b) areas that, at the end of a 20-year transition period, are removed from the relevant conversion category (Land converted to Forest Land (4.A.2)) and added to the category Forest Land remaining Forest Land.

Reporting in the category *Forest Land* covers CO_2 emissions / removals from mineral and organic soils, above-ground and below-ground biomass, litter, dead wood and wildfires. It also covers nitrous oxide emissions from wildfires, from drainage of organic soils and from mineralisation in mineral soils, and it covers methane emissions from wildfires and from drainage of organic soils.

In 2017, the total emissions from forests amounted to -57,591 kt CO_2 equivalents. Table 389 lists the emissions for the category Forest Land, by pools and GHG, and with the pertinent uncertainties included.

Table 389: Emissions in the category Forest Land, for the year 2017

Source category	Gas	Emissions from Forest Land, 2017 Emission	2.5 % percentile [kt CO_2-eq.]	97.5 % percentile	2.5 % percentile %	97.5 % percentile
Forest Land$_{total}$ [101]		**-57,590.6**	-36,039.4	-79,143.2	37.4	37.4
Mineral soils	CO_2 [102]	-15,749.0	-7,695.5	-23,803.3	51.1	51.1
	$N_2O_{indirect}$ [103]	9.5	-1.2	34.2	112.9	259.6
	N_2O_{direct} [104]	42.3	8.7	120.8	79.5	185.8
Organic soils	CO_2 [102]	1,221.0	1,016.8	1,459.7	16.7	19.5
	CH_4 [105]	17.2	4.2	155.1	75.4	800.7
	N_2O [105]	96.8	24.9	250.6	74.3	158.9
Biomass	CO_2 [102]	-45,164.5	-21,992.5	-68,336.6	51.3	51.3
Litter	CO_2 [102]	87.4	30.7	205.6	135.1	135.1
Dead wood	CO_2 [102]	2,019.83	-94.8	4,134.3	104.7	104.7
Wildfires	CO_2 [106]	IE	-	-	-	-
	CH_4 [106]	2.2	1.4	3.1	38.1	38.1
	N_2O [106]	1.5	0.9	2.0	38.1	38.1

As the time series for emissions from forests (cf. Figure 55 and Figure 56) show, the sum of GHG removals decreased abruptly in 2002 and then increased again in 2008. The reason for these jumps is that relevant surveys in the framework of the National Forest Inventory (BWI) are carried out periodically. Additional details about this aspect are provided in Chapter 6.4.2.2.1.

In the category Forest Land, the most important factors for CO_2 removals are the pools biomass (70.12 %), mineral soils (24.45 %) and litter (0.14 %). Sources occur via dead wood, drainage, mineralisation and wildfires. Such sources account for only a very small share – 5.29 % – of the greenhouse-gas balance for forests, however.

[101] Sum of the emissions from CRF tables 4.A, 4.(II).A, 4.(III).A, 4.(IV).2, 4.(V).A

[102] CRF table 4.A

[103] The category-specific indirect N_2O emissions are not included and shown as such in the CRF tables; they are included, however, in the sum, for all sub-categories, presented in CRF Table 4.(IV).2.

[104] CRF table 4.(III).A

[105] CRF table 4.(II).A

[106] CRF table 4.(V).A

Figure 55: Greenhouse-gas emissions (total of CO_2, CH_4 and N_2O) [kt CO_2-eq.] as a result of land use and land-use changes in forests, 1990 – 2017, by sub-categories

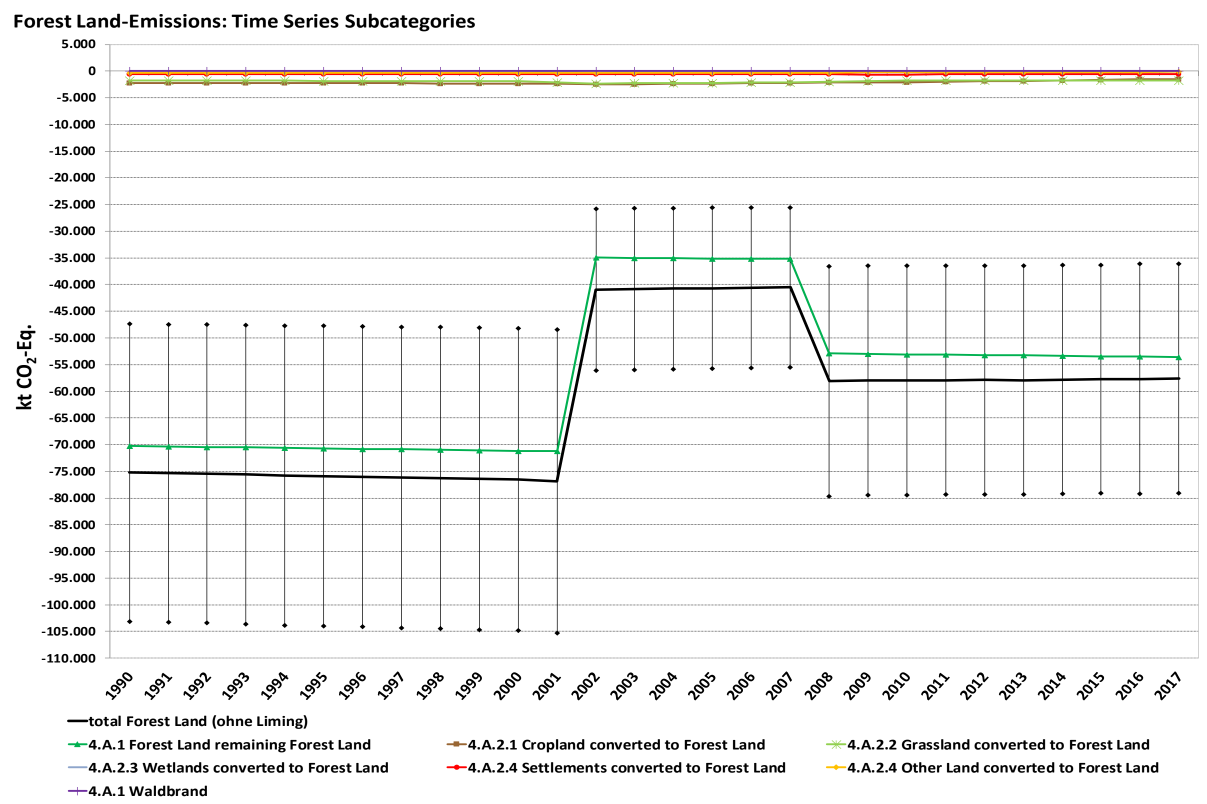
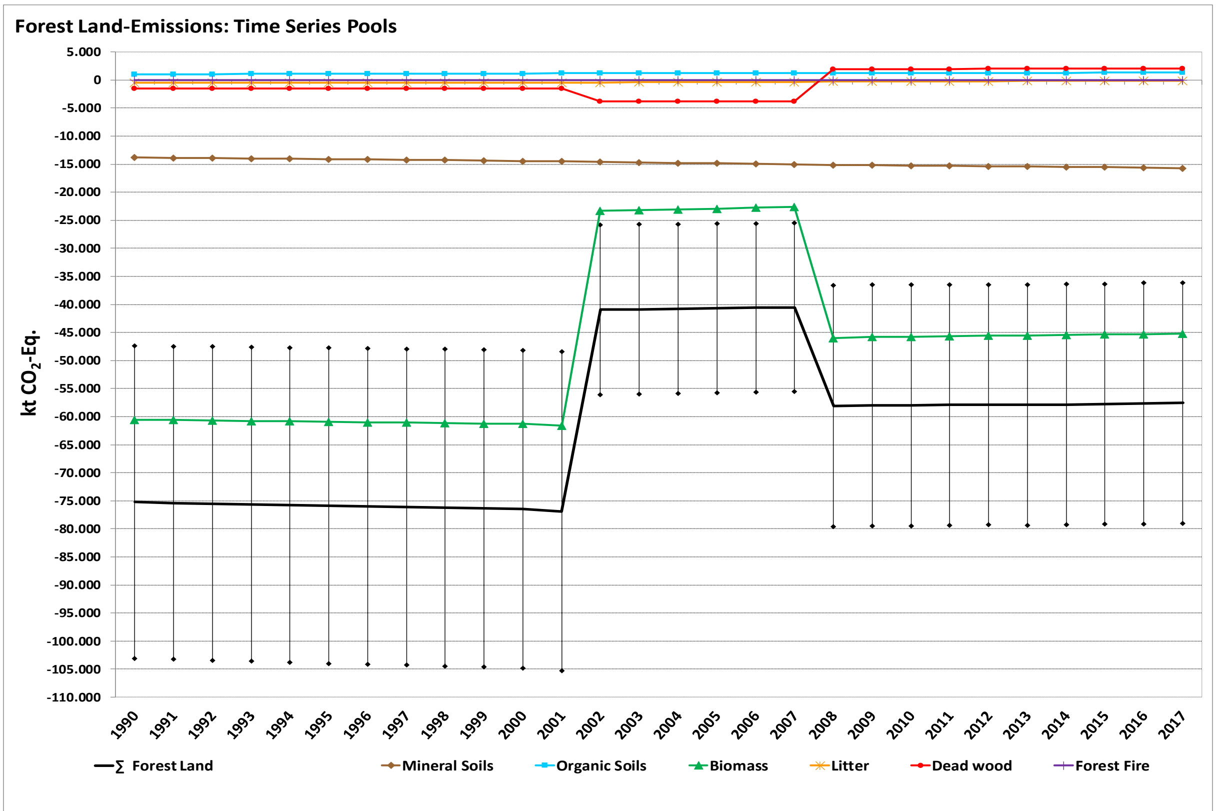


Figure 56: Greenhouse-gas emissions (total of CO_2, CH_4 and N_2O) [kt CO_2-eq.] as a result of land use and land-use changes in forests, 1990 – 2017, by pools



6.4.2 Methodological issues (4.A)

6.4.2.1 Data sources

The following data sources were used for determination of forest areas and of land-use changes that have occurred; for estimation of the relevant emission factors for soil, biomass, litter and dead wood; for calculation of carbon stocks and stock changes at various times and over various periods; and for calculation of emissions from wildfires, drainage and mineralisation:

- National Forest Inventory 1987 (Bundeswaldinventur; BWI 1987)
- National Forest Inventory 2002 (Bundeswaldinventur; BWI 2002)
- National Forest Inventory 2012 (Bundeswaldinventur; BWI 2012)
- Inventory Study 2008 (Inventurstudie; IS08)
- Datenspeicher Waldfonds (DSW)
- Forest Soil Inventory I (Bodenzustandserhebung im Wald I; BZE I)
- Forest Soil Inventory II (Bodenzustandserhebung im Wald II; BZE II)
- Maps, derived from CIR data, from the mapping of biotopes and use types carried out for 1990,
- Official topographic-cartographic information system (Topographisch-Kartographisches Informationssystem; ATKIS®)
- CORINE Land Cover (CLC)
- Soil map for Germany 1:1,000,000 (Bodenübersichtskarte der Bundesrepublik Deutschland; BÜK 1000)
- Map of Germany's organic soils (Roßkopf et al., 2015)
- Forest-fire statistics of the Federal Republic of Germany

6.4.2.1.1 National Forest Inventory, Inventory Study 2008 and Datenspeicher Waldfonds

The National Forest Inventory surveys the state of forests, and of forest production potential, on a large scale throughout Germany, using a standardised sampling procedure. The National Forest Inventory is a terrestrial sampling inventory that uses permanently marked sample points in a 4 km x 4 km basic grid whose resolution, at the request of the Länder, has been increased on a regional basis[107]. The first National Forest Inventory (BWI 1987) covered only the territory of the Federal Republic of Germany, in its pre-1990 borders, and West Berlin. It was carried out in the period 1986 to 1989 (sample year 1987). The second National Forest Inventory (BWI 2002) was carried out in the period 2001 to 2003 (sample year 2002), as a repeat inventory in the old German Länder and as a first inventory in the new German Länder (BMVEL, 2001; BMELV, 2005). The data of the third National Forest Inventory (BWI 2012) are now available. That inventory was carried out from 2011 through 2012 (sample year 2012), as a repeat inventory, throughout the entire national territory. The BWI 2012 provides current data, as of the beginning of the Kyoto Protocol's second commitment period, on the condition of forests and the ways they are changing.

In 2008, data on the state of forests were collected on a sub-sample of the BWI that consisted of an 8 by 8 km grid. In general, the methods used for that so-called "2008 Inventory Study" (Inventurstudie 2008; IS08) are the same as those used for the BWI (Schwitzgebel et al., 2008; BMELV 2010).

The Datenspeicher Waldfonds (DSWF) database contains complete-coverage forestry-management data for the territory of the former GDR through 1993. Those data were collected at periodic intervals, annually revised in connection with growth models and updated in keeping with completion and change reports of that country's forest operations (BMELF, 1994).

[107] Other information http://www.bundeswaldinventur.de

6.4.2.1.2 Forest Soil Inventory (Bodenzustandserhebung im Wald – BZE)

Carbon emissions from forest soils have been estimated via the stock-difference method (2006 IPCC Guidelines). To that end, data from the soil surveys BZE I and BZE II were used. The Forest Soil Inventory I (BZE I) was carried out from 1987 to 1992, while the Forest Soil Inventory II (BZE II) was carried out from 2006 to 2008. In both inventories, samples were taken of the total organic layer, hereafter "litter", pursuant to the 2006 IPCC Guidelines, as well as of mineral soils. The data for the inventories were collected by the German Länder.

In the BZE I (WOLFF & RIEK, 1996) and BZE II (WELLBROCK et al., 2006), forest soils throughout Germany were sampled within an 8 by 8 km grid. In the sampling procedure, at each grid point, eight satellite samples were taken, within a 10 m radius around a central excavation with an exposed soil profile. For the BZE I, there were 1800 grid points; for the BZE II, there were 2000. The primary reason for the increase in the number of grid sample points, from one inventory to the next, is that for the second it became possible to access areas which had been closed for the first (for which no access permits were available; for example, various former military exercise grounds were opened up).

For the most part, corresponding grid points for the two inventories lay within a 30-m radius. For some 400 points, a systematic grid shift with respect to the BZE I occurred.

For the BZE I, a database is available that contains about 1,800 points for which carbon stocks in litter and mineral soils (0-30 cm depth) have been calculated (Wolff & Riek, 1996). For the BZE II, the German Länder transmitted some 2,000 points to a common national database. Carbon-stocks data are available for about 1,800 of the 2,000 sample points available from the BZE II[108].

6.4.2.2 Biomass (CRF Table 4.A)

6.4.2.2.1 Forest Land remaining Forest Land

The changes in biomass carbon stocks are calculated with the stock-difference method, following a Tier 2 approach (Equation 2.8, 2006 IPCC Guidelines). With that method, one obtains an average country-specific implied emission factor (IEF) for the time periods between different relevant years for which data sets are available. This leads to an IEF for the period prior to 2002, expressing the average biomass change between the BWI 1987 and the BWI 2002 in the old German Länder, and between the DWSF and the BWI 2002 in the new German Länder; an IEF for the period 2002 through 2008, expressing the average biomass change between the BWI 2002 and the IS08 (2008); and an IEF for the period 2008 through 2012, expressing the average biomass change between the IS08 and the BWI 2012 nationwide. As a result, the relevant biomass changes are adjusted between the years 2001/2002 and 2007/2008, which leads to the "jumps" referred to above (cf. Chapter 6.4.1, and Figure 55 & Figure 56). The changes between the periods are due to changes in wood use, which increased in the inventory period 2002 through 2008 and decreased in the period 2008 through 2012.

For the old German Länder, and for the period until 2002, relevant data are available from two national forest inventories (referenced to the dates 1 October 1987 and 1 October 2002). Between the BWI 1987 and the BWI 2002, carbon stocks in biomass increased by 1.26 t C ha^{-1} a^{-1} in the forests of the old German Länder. The increase in stocks is a result of low use, in comparison to biomass increments. For the new German Länder, data from the BWI 2002 were compared with data from the Datenspeicher Waldfonds (DSWF) database, given the lack of an initial inventory comparable to the 1987 BWI. The comparison showed a net carbon-stock increase of 1.83 t C ha^{-1} a^{-1}. The emission factor for Germany as a whole, for this period, is 1.43 t C ha^{-1} a^{-1}. For the period from 2002 through 2008, data for stock-change calculations are available from the BWI 2002 and

[108] cf.: https://www.thuenen.de/de/wo/arbeitsbereiche/waldmonitoring/bodenzustandserhebung/

the Inventory Study 2008 (IS08) (in each case, for Germany as a whole). On the basis of that data, a carbon-stock increase of 0.44 t C ha^{-1} a^{-1} was calculated for Germany. For the period 2008 through 2012, new data of the BWI 2012 have been used for an updated calculation of the carbon-stock change, based on the IS08 and BWI 2012 data. The change amounts to 1.03 t C $ha^{-1}a^{-1}$. That value is being updated as of 2013.

Nonetheless, the sink effect of managed forests decreased significantly in 2002. One reason is a near doubling of the annual harvest. In the first inventory period (1987 – -2002), for example, an average of about 47.9 million m^3 (cubic meters of standing timber) were harvested per year in the old German Länder, while some 89.0 million m^3 were harvested in the 2002 – 2008 inventory period. Despite the higher annual harvest, and the resulting higher CO_2 emissions, the sum total of the emissions is less than the CO_2 removals from increments. With the data of the BWI 2012, it has been possible to show that forests regained a substantial sink function as of 2008. This is due to decreases in annual harvests (cf. Figure 57) in this period.

Figure 57: Comparison of raw-timber production with the development of forest biomass

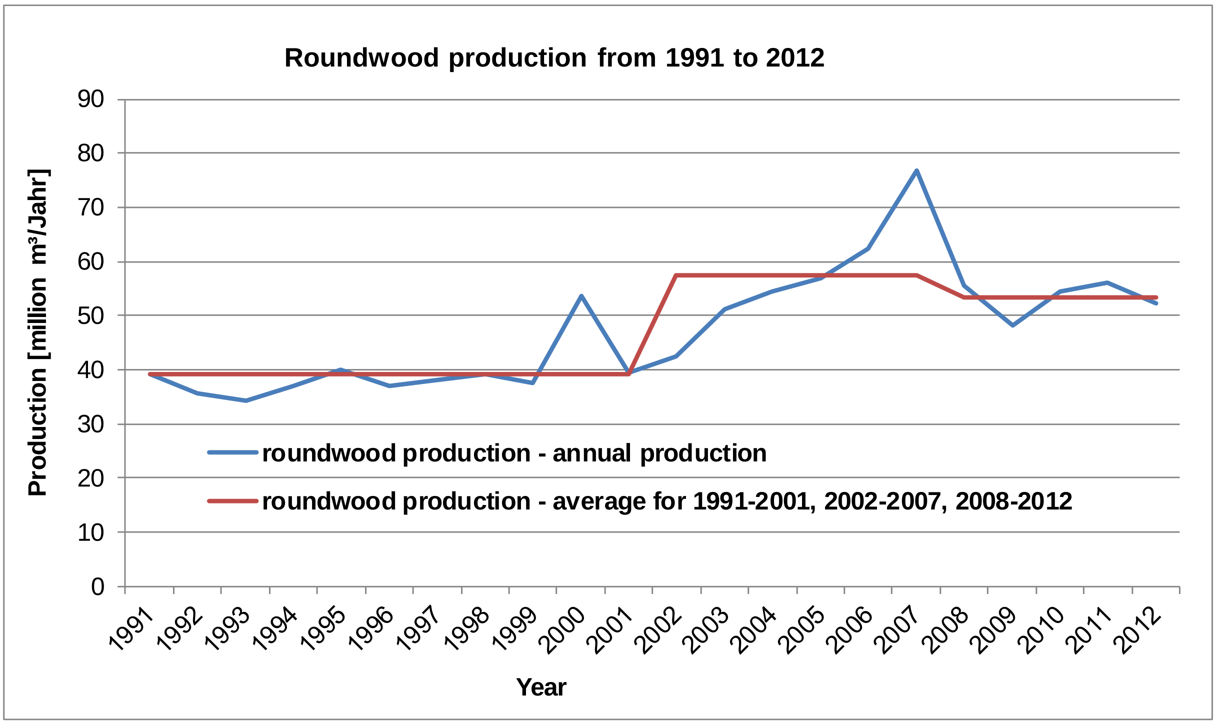
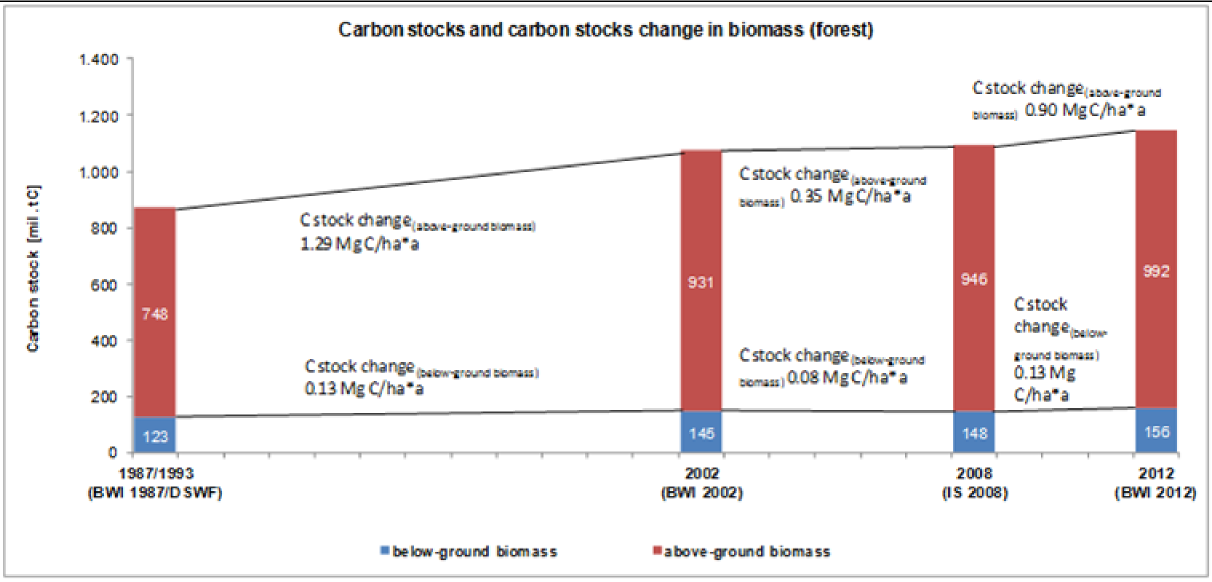


Figure 58 shows the carbon stocks for the four inventory dates. The data for 1987 and 1993 have been derived from the BWI 1987 and the DSWF; data for 2002 have been taken from the BWI 2002; data for 2008 have been derived from the IS08; and data for 2012 have been derived from the BWI 2012. These values highlight the increase in forest biomass carbon stocks as well, even though they include only carbon stocks in the category Forest Land remaining Forest Land (and not the conversion category).

Overall, the forests of the Federal Republic of Germany thus act as a net sink of carbon.

Figure 58: Soil organic carbon stocks and carbon-stock changes in below-ground and above-ground biomass, in forests, for the years 1987/1993, 2002, 2008 and 2012



6.4.2.2.2 Land converted to Forest Land

The changes in biomass carbon stocks on Land converted to Forest Land are calculated following the Tier 2 method given by Equation 2.16 of the *2006 IPCC Guidelines*. In that method, the stock changes are determined as the difference between the biomass stocks prior to the conversion and after the conversion (cf. also Chapter 6.1.2.3). In each case in the CRF tables, the biomass stocks from the previous use that are lost are entered under "losses," while the biomass increase on Land converted to Forest Land is entered under "gains."

To obtain emission factors for the category converted to Forest Land, an individual-tree calculation was carried out on the basis of the BWI 1987, BWI 2002 and BWI 2012 inventories. For the period through 2002, only trees in the old German Länder were taken into account, since the BWI 1987 inventory was carried out only there. As of the year 2002, calculations were carried out on a nationwide basis. The biomass carbon stocks were calculated for each area on which conversion from a given land use to Forest Land took place, and then all the resulting stocks were aggregated within the category "Land converted to Forest Land". The stocks of initial land-use categories were deducted – and thus taken into account.

For the new German Länder in the period 1990 through 2002, it was not possible to derive timber stocks for Land converted to Forest Land directly from comparison of two inventories. Thus, the relevant values for the old German Länder were used for that period.

The biomass stocks at the end of the vegetation period in 2002 and in 2012 represent the increase in biomass stocks throughout the entire period under consideration since 1987. That stock increase has been linearly interpolated in the periods 1990 through 2002 and 2002 through 2012. The data of the IS08 are unsuitable for calculation of biomass in the category Land converted to Forest Land, since that survey did not cover this category. For each year of the period 1990 through 2002, the carbon-stock increase is 3.40 t C ha^{-1} a^{-1}; as of 2002, the annual increase amounts to 3.64 t C ha^{-1} a^{-1}. It must be remembered that afforested areas remain in this land-use category for 20 years. On the areas added each year, the carbon-stock losses from initial land uses must be taken into account in the year in which conversion takes place; those losses are immediately accounted for as emissions.

6.4.2.2.3 Derivation of individual-tree biomass

The above-ground biomass is estimated by means of biomass allometric equations derived from the data of the BWI. Additional information is presented in Kändler and Bösch (2013) and in Chapter 6.4.2.2.4. The below-ground biomass is also derived via allometric equations. The equations being used for this purpose are representative of national circumstances (cf. Chapter 6.4.2.2.5).

Soil organic carbon stocks in the old German Länder as of 1987 were calculated on the basis of data from the BWI 1987 (some 230,000 measured trees). For the new German Länder, data on forest-management plans through 1993 are available in an aggregated form, in the Datenspeicher Waldfonds database, which can be used for calculations of carbon stocks. The BWI 2002 survey, in which some 377,000 trees were measured, provides the database for the 2002 sampling year. The BWI data have been supplemented with repeat-survey data for some 83,000 trees, from the Inventory Study 2008. The data of the BWI 2012, covering some 537,000 trees, are now also available. These data sets provide a good basis for calculation of the estimated carbon-stock changes. Thus it was possible to use the stock-difference method (2006 IPCC Guidelines) instead of the gain-loss method (2006 IPCC Guidelines).

6.4.2.2.4 Conversion into above-ground individual-tree biomass

The some 1,600 trees covered by the study of Kändler and Bösch (2013) included only the species spruce, pine, beech and oak. All other tree species, except for soft hardwoods species, were included in those four species groups. If the study had also included the soft hardwoods in the beech group, and then applied the pertinent functions and coefficients, it would have considerably overestimated the biomass of that group. For this reason, for soft hardwoods a more suitable allometric equation of the same type was used that was adapted with the help of "pseudo-observations" based on the tables in Grundner and Schwappach (1952).

The biomass allometric equations based on the tree-species groups are divided into three parts:

- Trees >= 10 cm diameter at breast height (DBH)
- Trees >= 1.3 m height and < 10 cm DBH, and
- Trees < 1.3 m height

Trees that are less than 1.3 m in height (and for which no DBH can be measured) cannot be reasonably differentiated in accordance with the five aforementioned tree-species groups. For this reason, such trees are differentiated only in terms of whether they are coniferous or broadleaf trees. In conversion areas, the functions have been smoothed with the help of statistical procedures. This prevented any jumps between the functions that might otherwise have occurred.

The following section presents the equations used for deriving above-ground biomass from the BWI data, as well as the equations' coefficients, broken down by tree-species groups.

Trees with at least 10 cm DBH

Equation28:

$$Y_{BIOM_0} = b_0 e^{b_1 \frac{BHD}{BHD+k_1}} e^{b_2 \frac{D03}{D03+k_2}} H^{b_3}$$

Where Y_{BIOM_0} = Above-ground biomass in kg per individual tree,

$b_{0,1,2,3}$ and $k_{1,2}$ = Coefficients of the Marklund function,

DBH = Diameter at breast height in cm,

D03 = Diameter in cm at 30% of tree height,

H = Tree height in m.

Table 390: Coefficients of biomass function for trees >= 10 cm DBH

Tree species	b_0	b_1	b_2	b_3	k_1	k_2	RMSE%
Spruce	0.75285	2.84985	6.03036	0.62188	42.0	24.0	11.2
Pine	0.33778	2.84055	6.34964	0.62755	18.0	23.0	15.6
Beech	0.16787	6.25452	6.64752	0.80745	11.0	135.0	18.8
Oak	0.09428	10.26998	8.13894	0.55845	400.0	8.0	12.1
Soft hardwoods	0.27278	4.19240	5.96298	0.81031	13.7	66.8	50.0[109]

Trees > 1.3 m height and < 10 cm DBH

Equation 29:

$$Y_{BIOM_0} = b_0 + \left(\frac{b_s - b_0}{d_s^2} + b_3(BHD - d_s)\right) BHD^2$$

Y_{BIOM_0} = Above-ground biomass in kg per individual tree,

$b_{0,s,3}$ = Coefficients of the function,

DBH = Diameter at breast height in cm,

d_s = Diameter-validity boundary for this function = 10 cm.

Table 391: Coefficients of biomass function for trees >= 1.3 m height and < 10 cm DBH

Tree species	b_0	b_s	b_3
Spruce	0.41080	26.63122	0.01370
Pine	0.41080	19.99943	0.00916
Beech	0.09644	33.22328	0.01162
Oak	0.09644	28.94782	0.01501
Soft hardwoods	0.09644	16.86101	-0.00551

Trees < 1.3 m height

Equation 30:

$$Y_{BIOM_0} = b_0 \, H_1^b$$

Y_{BIOM_0} = Above-ground biomass in kg per individual tree,

$b_{0,1}$ = Coefficients of the function,

H = Tree height in m.

In the BWI, heights of trees smaller than 1.3 m are recorded only in terms of two basic classes: 20 – 50 cm and 50 – 130 cm, and thus the mid-range values of these classes, 35 cm and 90 cm, have been used in the function as standard values.

Table 392: Coefficients of biomass function for trees < 1.3 m height

Tree species	b_0	b_1
Spruce	0.23059	2.20101
Beech	0.04940	2.54946

No inventory data were available for the new German Länder for the year 1990. The only available data source is the Datenspeicher Waldfonds of 1993, which surveyed the stocks and the forested areas in the new German Länder via a consistent method. For this reason, raw-wood stocks have been converted into biomass, using the methods described in BURSCHEL et. al (1993). In a first step of the relevant process, the raw-wood volume is multiplied by the applicable root percentage; this yields the pertinent below-ground volume. Then the raw-wood volume and the below-ground volume are multiplied by a volume-expansion factor. The product of that multiplication is then the

[109] For this function, no figure for RMSE% is available. Therefore, the IPCC default value of 50% has been used.

applicable total tree-wood volume. The branch volume is obtained by subtracting the raw-wood volume and the below-ground volume from the tree-wood volume. Then, the various volumes are multiplied by the bulk density, using specific-bulk-density figures pursuant to PISTORIUS et. al (2006). All relevant values are listed in the following tables.

Table 393: Root percentages and bulk densities for conversion of Datenspeicher Waldfonds data

Tree species	Root percentage (up to 20 years old)	Root percentage (> 20 years)	RMSE%	Bulk density (roundwood and roots)	Bulk density (branch wood)	RMSE%
Spruce	100	30	50	0.38	0.49	18.8
Fir	100	25	50	0.36	0.49	22.7
Douglas fir	100	25	50	0.41	0.49	20.7
Pine	100	25	50	0.43	0.49	27.2
Larch	100	25	50	0.49	0.49	18.2
Beech	100	25	50	0.56	0.54	13.7
Oak	100	25	50	0.57	0.57	19.8
Hard hardwoods	100	25	50	0.56	0.57	15.0
Soft hardwoods	100	25	50	0.46	0.54	8.7

Table 394: Volume-expansion factors for conversion of raw-wood volume and below-ground volume into the tree-wood volumes of the Datenspeicher Waldfonds data

Tree species	0 through 20 years	21 through 40 years	41 through 60 years	61 through 80 years	81 through 100 years	101 through 120 years	121 through 140 years	141 through 160 years	> 160 years	RMSE%
Spruce	4	1.65	1.51	1.45	1.45	1.45	1.46	1.47	1.48	50
Fir	4	1.52	1.44	1.44	1.38	1.41	1.41	1.42	1.41	50
Douglas fir	4	1.65	1.51	1.45	1.45	1.45	1.46	1.47	1.48	50
Pine	4	1.51	1.42	1.40	1.36	1.34	1.34	1.34	1.33	50
Larch	4	1.51	1.42	1.40	1.36	1.34	1.34	1.34	1.33	50
Beech	4	1.69	1.47	1.41	1.38	1.39	1.39	1.38	1.39	50
Oak	4	1.58	1.41	1.39	1.37	1.35	1.34	1.35	1.34	50
Hard hardwoods	4	1.69	1.47	1.41	1.38	1.39	1.39	1.38	1.39	50
Soft hardwoods	4	1.69	1.47	1.41	1.38	1.39	1.39	1.38	1.39	50

No uncertainties are known for the root percentage and for the volume-expansion factor. For this reason, the IPCC default value of 50 % has been used.

6.4.2.2.5 Conversion into below-ground biomass

As of the 2015 Submission, allometric equations based on peer-reviewed articles are used. This addresses the need for consistency between the method used to derive above-ground biomass and that used to derive below-ground biomass, as well as the need for overall clarity and transparency. The Thünen Institut has developed a separate biomass function for derivation of below-ground biomass for pine. All biomass functions chosen are of the form of Equation31.

Equation31:

$$Y_{BIOM_u} = b_0\ BHD^{b1}$$

Y_{BIOM_u} = Below-ground biomass, in kg per individual tree

$b_{0,1}$ = Coefficients of the below-ground biomass function.

DBH = Diameter at breast height in cm

Table 395: Coefficients, parameters, uncertainties and sources for the biomass functions used, by tree species

Tree species	b_0	Parameter	b_1	RMSE%	Region	Source
Spruce	0.003720	DBH [cm]	2.792465	34.6	Solling	(Bolte et al., 2003)
Pine	0.006089	DBH [cm]	2.739073	26.3	Barnim	(Neubauer & Demant)
Beech	0.018256	DBH [cm]	2.321997	49.0	Solling	(Bolte et al., 2003)
Oak	0.028000	DBH [cm]	2.440000	50.0[110]	Northeast France	(Drexhage & Colin, 2001) in (Bolte et al., 2003)
Soft hardwoods (root biomass)	0.000010	DBH [mm]	2.529000	9.6	South Sweden	(Johansson & Hjelm, 2012)
Soft hardwoods (root-stump biomass)[111]	0.000116	DBH [mm]	2.290300	15.9	South Sweden	(Johansson & Hjelm, 2012)

The log functions available in the literature (cf. Figure 59) were intentionally not used. "Back transformation" of log error values, for further use in the error budget, either was unfeasible or, in cases in which the original measurements were available, yielded values as high as they were in the original scale units.

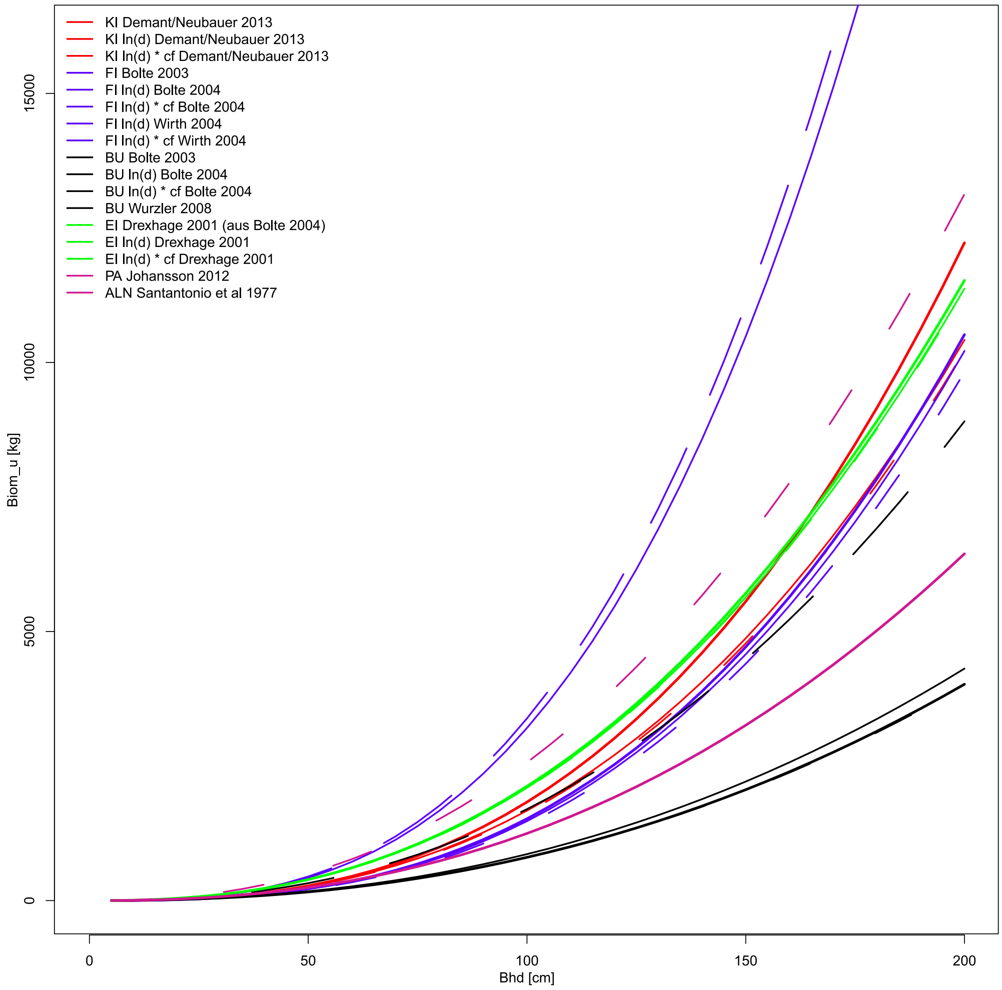
Both the Thünen institute's own pine function (Neubauer & Demant, 2016) and the oak function of Drexhage and Colin (2001), in Bolte et al. (2003), are unique in Europe. The selected functions for beech and spruce cover a considerably broader area of DBH distribution, especially for larger diameters, than do the comparable studies of Wutzler et al. (2008) and Wirth et al. (2004a). The functions thus have a considerably smaller extrapolation region, which prevents upward "drifting" of biomass values (cf. Figure 59).

At the same time, the chosen functions for spruce and beech were derived from data of a small region, the "Solling" region. On the other hand, the functions of Wutzler et al. (2008) and Wirth et al. (2004a) make use of data from various, and geographically different, studies.

This comparison of the chosen functions for spruce, beech and soft hardwoods (in each case, the unbroken line in Figure 59) with functions from other publications shows that the chosen functions always produce conservative estimates of biomass stocks. The rates of change between two states are thus also small compared to the corresponding figures produced by other functions. Since carbon accumulates in the category of below-ground biomass, throughout the entire period covered by the report, the estimates of the sequestration rate may be considered conservative.

110 For this function, no figure for RMSE% is available. Therefore, the IPCC default value of 50% has been used.
111 The mean RMSE% for both functions (root-stump biomass + root biomass) is 24.2%.

Figure 59: Comparison of different functions for derivation of below-ground biomass



6.4.2.2.6 Conversion of individual-tree biomass to carbon

A value of 0.5 has been applied for conversion of biomass to carbon stocks. Wirth et al. (2004a) report that the differences between compartments within a given tree species are larger than the differences between tree species. They obtain a range of 0.50 to 0.56 g C g^{-1} in conifers. The relative standard error for carbon content in wood is given by Burschel et al. (1993) as 1 to 2 %; Weiss et al. (2000) use 2 %. Overall, therefore, 0.5 g C g^{-1}, with a relative standard error of ±2 %, seems appropriate as a good assumption for mean carbon content.

6.4.2.2.7 State estimator for 1987, 2002, 2008 and 2012

Some German Länder use sampling grids smaller than 4 by 4 km. In addition, some Länder have increased the density of their sampling grids between the inventories. For this reason, extrapolation to the level of the national territory must be done in a stratified manner, using sampling strata with grids of homogeneous densities. This section presents the procedures for scaling up the values "raw-wood stocks", "biomass" and "carbon", in the framework of the stratified sampling plan, for given time periods. The relevant states for the years 1987, 2002, 2008 and 2012 were calculated. The up-scaling procedures for different domains (all of Germany, various regions (old/new Länder) and different LULUCF/ARD categories) are identical.

The BWI is designed as a cluster sample. The cluster, with four cluster points (sample points), is the smallest sampling unit. Along the boundaries of the inventory area, or of sampling strata, incomplete clusters, of varying sizes, will be found, i.e. the number of sample points (cluster points in forest and non-forest) within such clusters can vary between 1 and 4. For each cluster c located within a stratum *l*, the local sampling density (*Y*) must be calculated first:

Equation32:

$$Y_{lc} = \frac{\sum_{m=1}^{M} I_{l,c,m} Y_{l,c,m}}{M_{l,c}}$$

Y = local sampling density

l = stratum

c =cluster

m =sample point

M = number of sample points

The estimator of means for stratum *l*, with respect to the sampling density for both Forest Land and non- Forest Land, is thus obtained as follows:

Equation33:

$$\hat{\bar{Y}}_l = \frac{\sum_{c_l=1}^{C_l} M_{l,c} Y_{lc}}{\sum_{c_l=1}^{C_l} M_l}$$

$\hat{\bar{Y}}$ = Weighted average of the local sampling density

l = stratum
c = cluster
C = number of clusters
M = number of sample points
Y = local sampling density

The estimator of means for a given value, throughout all sampling strata, is the mean of the individual stratum estimators, weighted with the area proportions for the various strata:

Equation34:

$$\hat{\bar{Y}}_{st} = \sum_{l=1}^{L} \hat{\bar{Y}}_l \frac{\lambda(U_l)}{\lambda(U)}$$

$(\hat{\bar{Y}}_{st})$ = estimator of the total

l = stratum
U = area
λ= estimated value

The estimator of the total is obtained by multiplying the estimator of means throughout all strata by the total area *λ(U)*.

Equation35:

$$\hat{Y}_{st} = \hat{\bar{Y}}_{st}\lambda(U)$$

$\widehat{Y}_{st}$ = estimator of the total

st = state
U = area
λ = estimated value

The (forest-) area-related mean value is defined as the quotient or ratio estimator; it is obtained as follows:

Equation36:

$$\hat{R}_{st} = \frac{\hat{Y}_{st}}{\lambda(U_{Wald})}$$

6.4.2.2.8 Estimator for stock changes pursuant to the stock-difference method

For calculation of the changes between two time points (the periods 1987-2002, 2002-2008 and 2008-2012), the "continuous forest inventory" (CFI) method was used, i.e. for up-scaling only those cluster points were used that were included at both times. The change estimate is thus based on the difference between the two estimators of the total. At the stratum level, the total change is estimated as follows:

Equation 37:

$$\hat{G}_l = \hat{Y}_l^{(t_2)} - \hat{Y}_l^{(t_1)}$$

$\widehat{G}_l$ = total change in stratum
l = stratum
t = time
$\widehat{Y}$ = estimator of the total

The total change throughout all strata for a given domain is estimated in the manner described in Equation34. The estimated total change is calculated by means of Equation35. The change in the area-related mean estimator is determined via:

Equation38:

$$\hat{G}_{Rst} = \hat{R}_{st}^{(t_2)} - \hat{R}_{st}^{(t_1)}$$

$\widehat{G}_{R_{st}}$ = total change over all strata
t = time
$\left(\widehat{R}_{st}\right)$ = estimator of ratio

6.4.2.2.9 Interpolation of time periods, to obtain annual-change estimates

The BWI is carried out periodically. Consequently, annual rates of change – emission factors – have to be obtained via interpolation between two points in time. For the time periods between the inventories BWI 1987, BWI 2002, the IS 2008 and BWI 2012, linear interpolation was carried out at the level of the LULUCF and ARD classes. The emission factor EF for a LULUCF class is thus defined as the quotient of the area-related mean estimator and the number of years *a* within the relevant inventory interval:

Equation 39:

$$EF = \frac{\hat{G}_{R\,st}}{a}$$

EF = emission factor
a = number of years
$\widehat{G}_{R_{st}}$ = total change

Consequently, Equation 27 is equivalent to Equation 2.5 of the 2006 IPCC Guidelines (IPCC, 2006):

Equation 2.5, 2006 IPCC Guidelines

$$\Delta C = \frac{(C_{t_2} - C_{t_1})}{(t_2 - t_1)}$$

A linear trend was also chosen in cases in which change estimates had to be extrapolated into the future, beyond an inventory period.

6.4.2.3 Dead wood (CRF Table 4.A)

6.4.2.3.1 Forest Land remaining Forest Land

The changes in dead-wood carbon stocks are calculated with the stock-difference method, a Tier 2 approach (Equation 2.19, IPCC (2006)).

The carbon stocks in dead wood were calculated with data of the BWI 2002 (Schmitz et al., 2005), the 2008 Inventory Study and the BWI 2012. The BWI 1987 did not include any surveys of dead wood, and thus no dead-wood data for that time are available. The terrestrial survey used for the BWI 2002 included only fallen dead wood with a thicker-end diameter of at least 20 cm, standing dead wood with a diameter of at least 20 cm at breast height (DBH), and trunks with either a height of at least 50 cm or a cut-surface diameter of at least 60 cm (Polley, 2001). In keeping with requirements for climate reporting, in the 2008 Inventory Study and the BWI 2012 the survey threshold for dead-wood objects was reduced to a diameter of at least 10 cm at the thicker end (BMELF, 2010). In all three forest inventories, trees were sub-divided into three main tree-species groups: conifers, deciduous trees (except for oaks) and oaks. The degree of decomposition of dead wood was divided into four classes (BMELF, 2010) (Polley, 2001).

For purposes of reporting pursuant to the 2006 IPCC Guidelines, the applicable dead-wood-stock relationship between the 10 cm and 20 cm survey limits was determined from the data collected in the Inventory Study 2008. Under the assumption that this relationship was the same at the time of the BWI 2002, the dead-wood stocks from the 10 cm survey limit upward were estimated for the year 2002. The biomass of the dead-wood stocks from the BWI 2002, the Inventory Study 2008 and the BWI 2012, for the various relevant decomposition classes, was determined with the wood density figures pursuant to Fraver et al. (2002) for conifers, and pursuant to Müller-Using and

Bartsch (2009) for deciduous trees. To calculate the bulk density of deciduous wood, the dead-wood objects in the deciduous (other than oak) and oak tree-species groups were combined. An overview of the biomass-expansion factors and their errors, by tree-species classes and degrees of decomposition, is presented in Table 396.

Table 396: Biomass-expansion factors (BEF) and their errors (RMSE%) for the various tree-species classes and degrees of decomposition (NDH = conifers (Nadelbäume), LBH = deciduous trees (Laubbäume), EI = oak (Eiche))

Type of dead wood	Degree of decomposition		BEF	RMSE%	Source
NDH	1	Just died	0,372	17.2	FRAVER (2002)
NDH	2	Onset of decomposition	0,308	27.9	FRAVER (2002)
NDH	3	Advanced decomposition	0,141	35.5	FRAVER (2002)
NDH	4	Heavily rotted	0,123	25.2	FRAVER (2002)
LBH	1	Just died	0.58	12.1	MÜLLER-USING (2009)
LBH	2	Onset of decomposition	0.37	43.2	MÜLLER-USING (2009)
LBH	3	Advanced decomposition	0.21	33.3	MÜLLER-USING (2009)
LBH	4	Heavily rotted	0.26	65.4	MÜLLER-USING (2009)
EI	1	Just died	0.58	12.1	MÜLLER-USING (2009)
EI	2	Onset of decomposition	0.37	43.2	MÜLLER-USING (2009)
EI	3	Advanced decomposition	0.21	33.3	MÜLLER-USING (2009)
EI	4	Heavily rotted	0.26	65.4	MÜLLER-USING (2009)

The annual carbon stock change in dead wood was calculated using Equation 40 (Equation 2.19, IPCC (2006)). For the period 2002 through 2007, the change amounts to 0.0967 t C ha^{-1} a^{-1}, and for 2008 through 2016 it amounts to 0.0519 t C ha^{-1} a^{-1}. For all years in the period 1990 through 2001, the average change in dead-wood C stocks in the periods 2002-2007 and 2008-2012 was used, without change. It amounts to 0.0368 t C ha^{-1} a^{-1}.

Equation 40:

$$\Delta C_{FF_{DW}} = \frac{A * (B_{t_2} - B_{t_1})}{T} CF$$

Where:

ΔC_{FFDW} =	Annual change in carbon stocks in dead wood, on Forest Land remaining Forest Land [t C ha^{-1}]
A =	Area of Forest Land remaining Forest Land [ha]
B_{t1} =	Dead-wood stocks at time t_1 (beginning of the period) for Forest Land remaining Forest Land
B_{t2} =	Dead-wood stocks at time t_2 (end of the period) for Forest Land remaining Forest Land [t C ha^{-1}]
$T=(t_2-t_1)$ =	Time period between the two estimates [a]
CF =	Carbon conversion factor (IPCC default value = 0.5)

6.4.2.3.2 Land converted to Forest Land

The annual changes in carbon stocks in dead wood on Land converted to Forest Land were calculated using Equation 2.19 of the 2006 IPCC Guidelines (IPCC, 2006). That equation is identical with the equation for calculating changes in dead-wood carbon stocks on Forest Land remaining Forest Land (cf. Equation 40). The dead-wood carbon stocks in the category Land converted to Forest Land in 2012 (t2) are identified in the BWI 2012. The areas that were non- Forest Land at the time of the BWI 1987 were identified as Land converted to Forest Land areas. Consequently, the dead-wood carbon stocks in 1987 (t1) are assumed to be zero. The interval between the two time points is 25 years, which leads to underestimation of the change in dead-wood carbon stocks, for purposes of reporting under both UNFCCC and the Kyoto Protocol. The method being applied is thus a conservative one. On Land converted to Forest Land, the annual carbon-stocks change in dead wood amounts to 0.0344 t C ha^{-1} a^{-1}.

Only the data of the BWI 2012 were available for determination of dead-wood carbon stocks on Land converted to Forest Land. The Inventory Study 2008 did not survey Land converted to Forest Land. With regard to dead wood, the BWI 2002 only included dead wood with a diameter of at least 20 cm at its thicker end (fallen dead wood) or with a DBH of at least 20 cm (standing dead wood), and the BWI 1987 did not survey dead wood at all.

6.4.2.4 Litter (CRF Table 4.A)

6.4.2.4.1 Forest Land remaining Forest Land

The changes in carbon stocks in litter are calculated with the stock-difference method, following the Tier 2 approach (Equation 2.19, 2006 IPCC Guidelines).

The calculation of carbon-stocks changes in the soil and in litter is based on data from national forest-soil inventories (BZE I and BZE II; cf. Chapter 6.4.2.1.2 and Grüneberg et al. (2014)). A slight decrease in carbon stocks in litter, amounting to a source of -0.02 t C ha^{-1} a^{-1}, occurred in the period from 1990 (BZE I) to 2006 (BZE II) (Grüneberg et al., 2014). That trend is assumed to be valid as well for the period 2007 to 2016. A detailed description of the method used to determine the carbon-stock change in litter is presented in Chapter 6.4.2.4.4.

6.4.2.4.2 Land converted to Forest Land

The carbon-stock changes were calculated in keeping with the Tier 2 methodology (Equation 2.23, 2006 IPCC Guidelines). This methodology requires derivation of the annual rate of carbon-stock change. That rate is calculated from the average litter stocks in forests, under equilibrium conditions, and the transition period that is required for litter stocks to develop following afforestation.

Calculations relative to the litter ground cover were carried out with the status data of the BZE I and BZE II Forest Soil Inventories. According to those calculations, the mean carbon stocks in litter, referenced to 1990 (BZE I), were 19.0 t C ha^{-1}, and, referenced to 2006 (BZE II), 18.8 t C ha^{-1}. This shows that the average carbon stocks in litter in forests also exhibited a slight trend. The average litter carbon stocks are being adjusted in keeping with that trend. For the period 1991 to 2005, the mean carbon stocks in litter are obtained via interpolation; for the period as of 2007 they are obtained via extrapolation and used as a basis for calculating afforestation areas (cf. Table 397). A description of the method used to derive carbon stocks in litter is presented in Chapter 6.4.2.4.3.

Table 397: Implied emission factors (IEF) (carbon) for litter in the land-use categories Land converted to Forest Land

Year	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012
IEF [t C ha^{-1}]	0.4750	0.4734	0.4719	0.4703	0.4700	0.4697	0.4694	0.4691	0.4688	0.4684	0.4681
Year	**2013**	**2014**	**2015**	**2016**	**2017**						
IEF [t C ha^{-1}]	0.4678	0.4675	0.4672	0.4669	0.4666						

Regarding the transition period, it was assumed that the resulting average carbon stocks take 40 years to form in litter. That value is confirmed by default values for carbon accumulation in litter, and by default values for the time periods required for a new equilibrium to form pursuant to Paul et al. (2009) and the 2003 IPCC Good Practice Guidance, Table 3.2.1 (IPCC, 2003). In IPCC Table 3.2.1, the warm, temperate climate zone is assumed to be moist in Germany, and an applicable average is obtained from the values for deciduous and coniferous forests. The annual carbon-stock increase in litter is obtained by dividing the mean carbon stocks for the year in question by the number of years required for those mean carbon stocks to accumulate.

The afforestation areas were not further subdivided into the classes "natural regeneration" and "human induced" (cf. Chapter 11.4.1).

6.4.2.4.3 Derivation of carbon stocks in litter

Litter was sampled at the BZE sample points. This was accomplished by taking mixed samples at satellite plots, using sampling frames of various sizes (Grüneberg et al., 2014). In keeping with the 2006 IPCC Guidelines, litter was considered to include the entire dead organic top soil layer, including the L, Of and Oh horizons (IPCC, 2006). Organic carbon concentrations in the litter were measured via similar methods. It is assumed that total carbon (C_{ges}) is equal to organic carbon (C_{org}) ([C_{ges}]=[C_{org}]). In each case, the carbon stocks in litter are calculated from the area of the sampling frame, and from the weight and organic carbon concentration in the litter. A description of the methods used for sampling and analysis is presented in Wellbrock et al. (2006) and König et al. (2005).

All points available from the BZEI and BZE II surveys, along with information on the respective forest types, entered into calculation of litter carbon stocks. All values that were either smaller or larger than twice the standard deviation ($x \pm 2\sigma$) were considered to be outliers and were deleted. The values of the remaining sample points for the BZE I (n = 1629) and BZE II (n = 1542) enabled the calculation of carbon stocks separately for deciduous, coniferous and mixed forest (cf. Table 398). The mean carbon stocks given by the two inventories were calculated as a weighted mean from the carbon stocks for the three forest types concerned. The applicable weights were obtained from the forest types' area shares of the total forest area, as given by CORINE Land-Cover data for 1990 and 2006, and from the regional densities of the sample grid. The mean carbon stocks in the samples were 19.0 ± 0.3 t C ha^{-1}, for BZE I, and 18.8 ± 0.3 t C ha^{-1}, for BZE II (Grüneberg et al., 2014). These values serve as the basis for calculating CO_2 emissions from litter in connection with deforestation (cf. Chapter 11.3.1.4) and carbon sequestration in litter in connection with afforestation (cf. Chapter 6.4.2.4.2).

Table 398: Soil organic carbon stocks in litter in German forests, as determined in the BZE I and BZE II inventories, along with the pertinent standard error (Grüneberg et al., 2014)

Forest type	Soil organic carbon stocks (BZE I) [t C ha^{-1}]	Carbon stocks (BZE II) [t C ha^{-1}]
Deciduous forest	8.35 ± 0.37	6.78 ± 0.30
Mixed forest	17.94 ± 0.63	14.99 ± 0.70
Coniferous forest	23.75 ± 0.44	25.23 ± 0.49
Total forest	**19.04 ± 0.30**	**18.83 ± 0.32**

6.4.2.4.4 Derivation of carbon-stock changes in litter in the period from 1990 (BZE I) to 2006 (BZE II)

The sample points included in the calculation of carbon stocks were analysed as unpaired samples. With a two-sided t-test for unpaired samples, it was tested whether the carbon stocks (which had been logarithmised) at the two inventory times differed. Each sample plot was assigned a weight consisting of the area percentage for the relevant stratum and the regional sample grid density. The average difference was -0.02 ± 0.02 MgC ha^{-1} a^{-1} (Grüneberg et al., 2014). The value does not deviate significantly from zero.

For Land converted to Forest Land, annually decreasing factors for litter accumulation were calculated from the carbon stocks given by BZE I / BZE II and the average difference (cf. Chapter 6.4.2.4.2 and Table 397).

6.4.2.5 Mineral soils (CRF-Table 4.A)

6.4.2.5.1 Forest Land remaining Forest Land

The changes in carbon stocks in mineral soils are calculated following the Tier 2 methodology of the 2006 IPCC Guidelines (Equation 2.25, IPCC (2006)).

Carbon stocks, and carbon-stock changes, in mineral soils were up-scaled on the basis of the BZE I and BZE II (cf. Chapter 6.4.2.1.2), in accordance with Grüneberg et al. (2014). With the available data, the changes in mineral soils were calculated, with respect to both inventories. The relevant methods are described in detail in the following Chapter 6.4.2.5.3 and Chapter 6.4.2.5.4. The resulting extrapolation for the entire national territory yielded a mean annual increase in carbon stocks in mineral soils of 0.41 ± 0.11 t C ha^{-1}. It has been assumed that this trend also continued in the period 2007 to 2017.

The third Forest Soil Inventory (BZE III) is currently being prepared. It will be carried out beginning in 2020. When the results of BZE III become available, recalculations will be carried out for the period as of 2007.

6.4.2.5.2 Land converted to Forest Land

For Land converted to Forest Land, as for Forest Land remaining Forest Land, the carbon-stock change in mineral soils is calculated following the Tier 2 methodology (Equation 2.25, IPCC (2006)).

For Land converted to Forest Land, the carbon-stock changes in mineral soils were calculated in keeping with the procedure in Chapter 6.1.2.1. The calculated mean emission factors (implied emission factors) for the year 2017, which are summarised in Table 350 in Chapter 6.1.2.1.1, are oriented to annual carbon-stock changes in mineral soils in connection with land-use conversions to Forest Land (Land converted to Forest Land), over a change period of 20 years.

6.4.2.5.3 Derivation of carbon stocks and carbon-stock changes

The carbon stocks and their changes were derived on the basis of inventory data (cf. Chapter 6.4.2.1.2 and Grüneberg et al. (2014)). Mineral soil was sampled at depths of relevance for the national inventory report; at most BZE plots, this involved depth ranges of 0-5 cm, 5-10 cm and 10-30 cm. In a few cases, samples were taken on a horizon basis.

As part of sampling, the fine-soil bulk density (TRD_{fb}), the coarse-fragment content (GBA) and the organic-carbon concentration (C_{org}) were determined using similar methods (König et al., 2005). The fine-soil bulk density was determined via volume-adapted sampling, for different depth ranges; to some extent, values estimated on the basis of soil profiles were used (Wolff and Riek (1997), Wellbrock et al. (2006)). Where fine-soil bulk-density data is lacking, existing relevant values from other inventories have been used. That procedure has also been applied to obtain coarse-fragment-content values, which are needed for calculation of the TRD_{fb} and fine-soil stocks.

In carbonate-containing soils, the organic-carbon concentration (C_{org}) in fine soils was measured with respect to the inorganic-carbon concentration (C_{inorg}) ($[C_{org}] = [C_{total}] - [C_{inorg}]$). In non-carbonate-containing soils, the relationship $[C_{org}] = [C_{total}]$ applies.

The total carbon stocks per plot were calculated from the stocks of the individual depth layers. To that end, it was necessary first to translate horizon-based data into depth-layer sections. This was accomplished, in each case, by calculating the carbon stocks in a given depth layer, with stocks weighted in accordance with the thicknesses of overlapping sections and their carbon stocks.

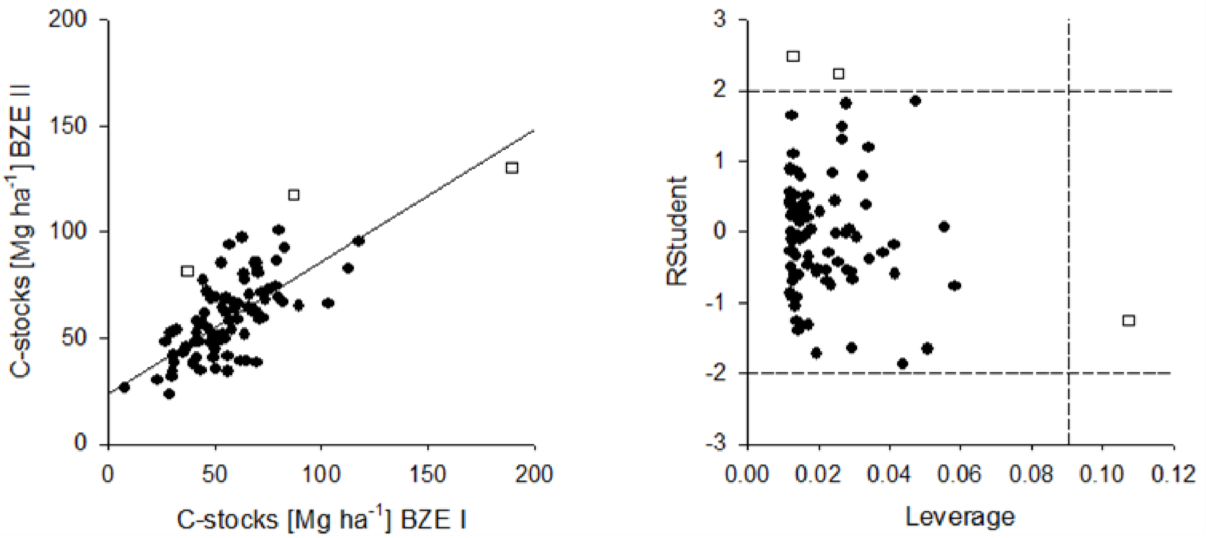
An area-referenced approach, with strata formation, was used for calculation of carbon stocks and of their changes between the two inventory time points. The basis for formation of area-relevant strata consisted of the 72 legend units used in the soil map for Germany "Bodenübersichtskarte der Bundesrepublik Deutschland 1:1.000.000" (BÜK 1000). That source describes the dominant soil types, and parent material for soil formation, pursuant to the German soil system (Arbeitsgruppe Boden, 1994) and FAO (International Soil Reference Information Centre, 1990). Since the classes concerned differed in the number of sample points they contained, the various dominant soil units were aggregated into new dominant soil units. This increased the population size for each class, thereby increasing the pertinent statistical significance. The groups formed were oriented to similar soil types, to substrate type and parent material and to texture and lime content. Overall, 16 new dominant soil units, with their pertinent parent material, were then available for area-referenced evaluation (cf. Table 399). The sample points were allocated to the dominant soil units on the basis of data, collected in the inventories, relative to the parent material and any layering of that material, to soil type, to horizon sequences and to soil texture.

Table 399: Combined legend units on the basis of the BÜK 1000 soil map

Abb.	Dominant soil groups, by substrate type, soil type and lime content
1	Nutrient-poor soils from dry, nutrient-poor sands
2	Various soils from sandy to loamy terrace or riverine deposits
3	Various soils from partly calcareous, loamy-clayey terrace or riverine deposits
4	Pseudo-gleyed soils from sandy to loamy sediments overlying boulder clay
5	Various soils from sandy sediments overlying boulder clay
6	Brown earths from nutrient-rich sands
7	Soils of loess areas
8	Various soils from scree overlying calcareous, marl and dolomite rock, alternating with terra fusca from silty-clayey redeposited products of limestone weathering
9	Brown earth and terra fusca from redeposited products of weathering of calcareous, marl and dolomite rock, and rendzina from limestone
10	Pelosol – brown earth / pelosol-pseudogley from weathering products of marl and clay rocks and calcareous layers
11	Brown earth from alkiline and intermediary magmatic rock
12	Brown earth from acidic magmatic and metamorphic rock
13	Brown-earth / podzolic soils from hard clayey and silty slates with fractions of greywacke, sandstone, siltstone, quarzite and phyllite
14	Podzols / brown earths from low-alkilinity quarzites, sandstones and conglomerates
15	Various soils alternating tightly with greywacke, clay slate, limestone, sandy, silty and clayey stones and loess-loam overlying various rocks
16	High-mountain soils from limestone, dolomite rock and silicate rock

For purposes of analysis, carbon-stocks data was available from a total of 1,865 plots from the BZE I inventory, and from 1,813 plots from the BZE II inventory Grüneberg et al. (2014). Except for the data from two German Länder, the data were available mainly as paired samples, i.e. samples in which it was possible to correlate each BZE I plot with exactly one BZE II plot. The number of points that entered into the final calculation was lower than the number suggested by the above figures, however. This was because some organic-soil areas were excluded, because a) it proved impossible to assign the relevant points to a dominant soil unit or b) because their stocks were seen to be implausible, on the basis of outlier analysis, and thus were rejected. For the analysis, the total sample, broken down by German Länder, was divided into a paired sample subset and an unpaired sample subset. In the paired sample subset, it proved possible to identify outliers via residual analysis. To that end, the carbon stocks for each dominant soil unit, at the various inventory time points, were compared through plotting a linear regression. A relevant example is presented in Figure 60 (on the left). Studentised residuals were used to eliminate outliers that seemed inconsistent with the rest of the data (cf. Figure 60 (on the right)). In addition, a "hat matrix" was generated, for identification of "leverage" points[112] that represent outliers within the independent variable (cf. Figure 60 (right); (Weisberg, 2005)).

Figure 60: Regression between carbon stocks (0-30cm) as shown by BZE II data and the BZE I data (left), and outliers identified via residuals analysis with studentised residuals (middle) and "high-leverage" points (right), illustrated with the example of a dominant soil group



Since two Länder have shifted the grid between the BZE I and BZE II inventories, the points for which assignment to a dominant soil group was possible are available as unpaired samples. Soil organic carbon stocks for those plots were calculated via formation of mean values for each dominant soil group. Outliers for each class were detected via double standard deviation (x ± 2 σ) and then removed. In addition, organic soils were excluded. Then, the mean carbon stocks for each dominant soil group were correlated with the relevant annual differences. After elimination of the outliers, via outlier analysis, a total of 1577 points from the BZE I inventory, and 1539 points from the BZE II inventory, remained. Of those, a total of 1075 points were available as paired samples.

To permit area-weighted calculation of carbon-stock changes, the forest areas in the dominant soil units were determined as percentage shares of Germany's total forest area. To that end, the CORINE Land Cover data were combined with the BÜK 1000, within a Geographic Information System (GIS). In each case, it proved possible to correlate a forest area with the mean carbon-stock change for a dominant soil group. That, in turn, enabled the calculation of the average annual change in organic carbon for Germany, taking account of the selected dominant soil units' shares of the total area.

6.4.2.5.4 Results of derivation of carbon stocks and carbon-stock changes

Based on the area-weighted approach, the carbon stocks in Germany's mineral soil, to a depth of 30 cm, amounted to 55.6 ± 3.4 t C ha^{-1} at the time of the BZE I inventory, and to 61.8 ± 3.7 t C ha^{-1} at the time of the BZE II inventories. Those figures translated into annual increases of 0.41 ± 0.11 t C ha^{-1} (Grüneberg et al., 2014). A variance analysis (type III - ANOVA) showed that the differences between the two inventories were significant ($p<0.001$). Both the rate of change and the total stocks lie within a range that other authors have already estimated for central Europe. Estimates of annual carbon sequestration in the root zone range from 0.1 t C ha^{-1} a^{-1} (Nabuurs & Schelhaas,

[112] Leverage is a dimensionless statistical indicator that shows how strongly a given individual value is influencing a given statistical regression model.

2002) to 0.9 t C ha^{-1} a^{-1} (Schulze et al., 2000). Most of the values given in the literature are based on model-based up-scaling, and they take the soil's entire root zone into account (Liski et al. (2002); De Vries et al. (2006)). In comparison to those studies, the present effort was able to draw on considerably more measurement plots, arrayed within a finer grid. Those data represent a more valid sample, one that supports conclusions for Germany that are more reliable and that have a nationwide focus.

For nearly all dominant soil units, carbon stocks, broken down by classes, were estimated to be higher at the time of the BZE II inventory than they were at the time of the BZE I inventory (cf. Table 400). In addition, carbon stocks were higher in soils with high clay content than they were in soils with high sand content. Reasons for this are discussed in Six et al. (2002) and Baritz et al. (2010), for example. An assessment of the time series between the BZE I and BZE II shows greater annual changes in carbon stocks especially in sandy dominant soil units of the North German lowlands. For example, the annual relevant rate of change for the dominant soil units 1, 5 and 6 was greater than 0.6 MgC ha^{-1} a^{-1} (Grüneberg et al., 2014). On the other hand, Prietzel et al. (2006) put carbon sequestration, in the upper 30 cm, at 0.2 t C ha^{-1} a^{-1} on sandy sites and at 0.4 t C ha^{-1} a^{-1} on loamy sites. Smaller positive changes in carbon stocks, ranging between 0.1 and 0.6 t C ha^{-1} a^{-1}, were found in over half of all classes formed. A marked decrease in carbon stocks, between the two inventory times, was seen in class 9.

Table 400: Carbon stocks at the time of the BZE I, and at the time of the BZE II, in the newly formed dominant soil units (Grüneberg et al., 2014)

		Carbon stocks (BZE I) [t C ha^{-1}]			Carbon stocks (BZE II) [t C ha^{-1}]	
DSU	n	MV	SE	n	MV	SE
1	201	52.8	1.6	187	65.5	6.8
2	56	60.5	2.6	62	65.0	4.9
3	20	67.3	3.2	25	68.1	2.4
4	105	66.4	1.8	87	64.1	4.5
5	77	33.4	1.6	75	52.8	2.2
6	34	24.6	1.6	34	43.7	1.8
7	126	55.8	1.5	109	63.0	2.2
8	110	76.3	2.4	106	79.1	0.8
9	36	77.1	4.9	43	68.3	1.0
10	55	56.7	2.1	63	60.8	0.8
11	39	51.3	3.2	39	54.6	0.9
12	187	59.5	1.7	163	62.5	2.2
13	222	54.7	1.4	233	60.1	4.1
14	245	50.5	1.2	257	55.3	3.2
15	30	51.8	2.9	30	49.0	0.9
16	34	84.4	6.2	26	104.5	0.5

(DSU = dominant soil units, n = number of soil samples, MV = mean value, SE = standard error)

6.4.2.6 Organic soils (CRF Table 4.A)

This chapter solely discusses CO_2 emissions from organic soils. Those emissions are entered in CRF Table 4.A, under "organic soils." The methods applied for N_2O and CH_4 emissions are described in Chapter 6.1.2.2. Those emissions are reported in CRF Table 4(II).

6.4.2.6.1 Forest Land remaining Forest Land

The areas covered by organic soils were determined via a georeferencing procedure, with overlaying of the map of organic soils ("Karte organischer Böden") and ATKIS® data. In the process, drained and non-drained organic soils are differentiated. For Forest Land remaining

Forest Land, the organic soils area for the year 2017 is 115,379 ha, and 77.4 % of that area is drained. A detailed description of the method used to derive organic-soil areas is presented in Chapter 6.1.2.2.1.

A description of the method used for derivation of the emission factor is presented in Chapter 6.1.2.2.2, while a description of the method used for derivation of the implied emission factor (IEF) is presented in Chapter 6.1.2.2.3. Table 401 summarizes the implied emission factors for organic forest soils.

Table 401: Implied emission factors (IEF) (carbon) for organic soils

Year	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012
IEF [t C ha^{-1}]	-2.1034	-2.1442	-2.1811	-2.2099	-2.2112	-2.2124	-2.2136	-2.2144	-2.2151	-2.2158	-2.2166
Year	**2013**	**2014**	**2015**	**2016**	**2017**						
IEF [t C ha^{-1}]	-2.2222	-2.2277	-2.2331	-2.2384	-2.2436						

6.4.2.6.2 Land converted to Forest Land

In the category Land converted to Forest Land, the organic soils area for the year 2017 is 33,045 ha, of which 77.4 % – as in the case of the Forest Land remaining Forest Land areas – are drained (cf. Chapter 6.1.2.2.1). The emission factors presented in Table 401 are also used for organic soils on Land converted to Forest Land. Those annual emissions are being reported for all years since the relevant conversions. The manner in which GHG emissions from organic soils are derived, for all land-use categories, is described in Chapter 6.1.2.2.

6.4.2.7 Other GHG emissions from forests

6.4.2.7.1 Nitrous oxide emissions from nitrogen fertilisation (CRF Table 4(I))

No nitrogen fertilisation in forests takes place in Germany. Therefore, CRF Table 4(I) reports this activity as NO (not occurring; cf. also Chapter 6.1.2.5).

6.4.2.7.2 Drainage and rewetting of organic and mineral soils (CRF Table 4(II))

The derivation of GHG emissions, from organic and mineral soils, related to drainage and rewetting is described, for all land-use categories, in Chapter 6.1.2.6. The CO_2 emissions for forests are entered in CRF Table 4.A and, in CRF Table 4(II), are marked IE (included elsewhere; cf. also Chapter 6.4.2.6). The pertinent CH_4 and N_2O emissions, on the other hand, are presented in CRF Table 4(II). Table 402 summarizes the implied emission factors for organic forest soils.

No rewetting of mineral soils in forests occurs; in CRF Table 4(II), that source is marked NO (not occurring).

Table 402: Implied emission factors (IEF) (methane and nitrogen) for organic soils

Year	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
Methane [kg CH_4 ha^{-1}]	4.3519	4.4363	4.5125	4.5722	4.583	4.5845	4.586	4.5976	4.6089	4.6201	4.6311	4.6419
Nitrogen [kg N_2O-N ha^{-1}]	2.0516	2.0914	2.1273	2.1555	2.1605	2.1613	2.1620	2.1674	2.1728	2.1781	2.1832	2.1883

6.4.2.7.3 Direct nitrous oxide emissions related to nitrogen mineralisation and immobilisation (CRF Table 4(III))

The manner in which direct N_2O emissions from mineralisation and immobilisation of mineral soils are determined is described in Chapter 6.1.2.7. The pertinent N_2O emissions are listed in CRF Table 4(III).

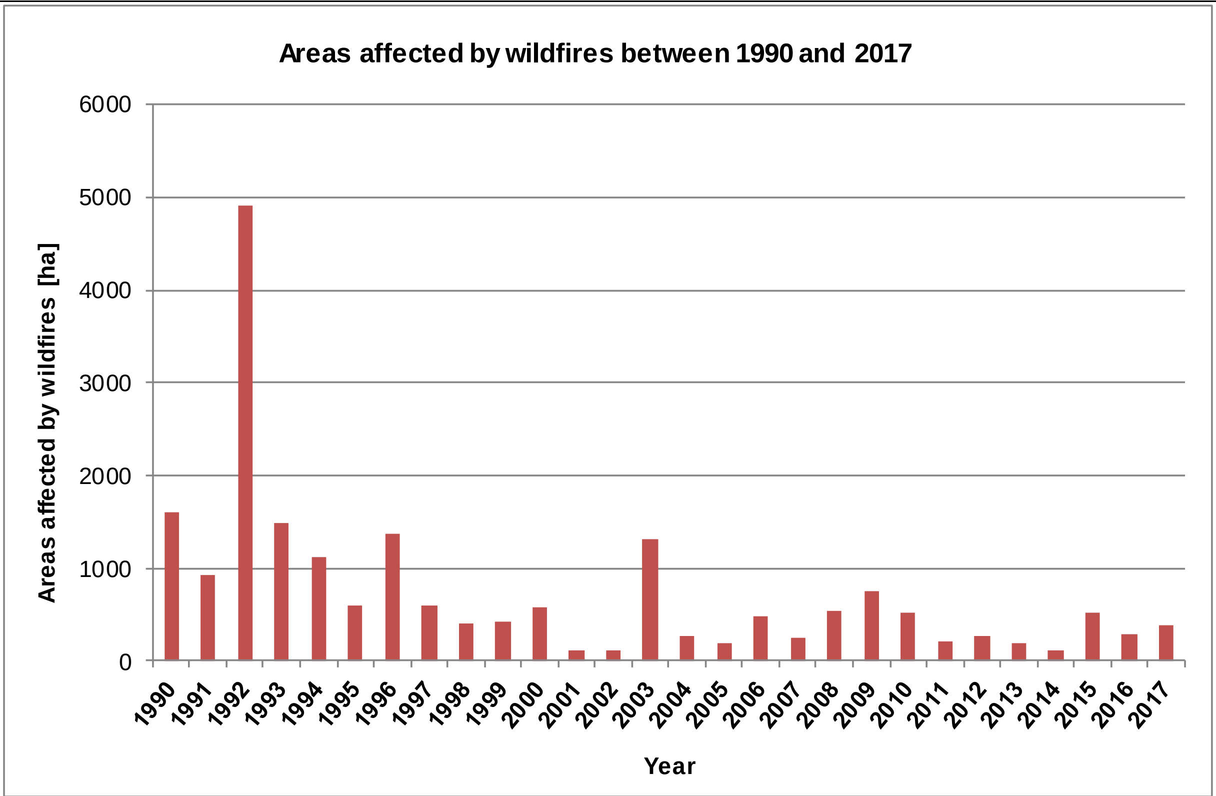
6.4.2.7.4 Indirect nitrous oxide emissions from cultivated soils (CRF Table 4(IV))

The manner in which indirect N_2O emissions related to losses of organic soil substance resulting from land-use changes and cultivation measures are determined is described, in summary form for all land-use categories, in Chapter 6.1.2.8. The pertinent N_2O emissions are listed in CRF Table 4(IV).

6.4.2.7.5 Wildfires (CRF Table 4(V))

While in other countries "prescribed burning" is an accepted method for clearing land or for managing ecosystems, no prescribed/controlled burning of biomass is carried out in Germany's managed forests. In CRF-Table 4 (V), therefore, NO is entered in the category "Controlled Burning." Due to the climatic conditions prevailing in Germany, and the measures taken to prevent wildfires, such fires tend to be rather seldom. This assumption is confirmed by relevant wildfire statistics (BLE, 2002-2017) and their data on areas affected by wildfires (cf. Figure 61). The mean area affected annually by wildfires, in the period 1990-2016, was 735 ha. In some years, unseasonably high summer temperatures have resulted in larger burned areas. This was the case, for example, in 1996 and 2003. An unusually large burned area, about 4,908 ha, was measured in 1992, which had an extremely warm summer.

Figure 61: Areas affected by wildfires between 1990 and 2017 (pursuant to BLE, 2002-2018)



Along with CO_2, wildfires release a range of other greenhouse gases (CO, CH_4, N_2O, NO_x and NMVOC). The CO_2 emissions resulting from biomass combustion have already been taken into account as part of changes of biomass stocks (CRF Sector 4.A.1 Forest Land remaining Forest Land), via the stock-difference method. For this reason, they are listed as IE (included elsewhere). The emissions of other greenhouse gases were calculated using Equation41 (Equation 2.27, IPCC (2006)).

Equation41:

$$L_{fire} = A * B * C * D * 10^{-6}$$

L_{fire} = Quantity of GHG [t] released via fire

A = Wildfire burned area [ha]

B = Mass of fuel present on the relevant site (biomass) [$kg_{dry\ matter}\ ha^{-1}$]

C = Combustion efficiency

D = Emission factor [$g(kg_{drymatter})^{-1}$]

The NMVOC emissions were calculated with the pertinent equation pursuant to the 2013 EMEP/EEA Emission Inventory Guidebook (EMEP, 2013).

Equation 42:

$$M(C) = 0.45 * A * B * \alpha * \beta$$

0.45 = Average fraction of carbon in fuel wood

A = *Area burnt [m^2];*

B = Average total biomass of fuel material per unit area [kg m^2] *$^{-2}$];*

α = *Fraction of average above-ground biomass, relative to the total average biomass B;*

β = *Burning efficiency (fraction burnt) of the above-ground biomass.*

The data on areas affected by wildfires in the period 1990 to 2017 have been taken from the wildfire statistics maintained by the Federal Agency for Agriculture and Food (BLE; "Waldbrandstatistik" – BLE 2002-2018). In determination of the relevant areas, no distinction is made between Land converted to Forest Land and Forest Land remaining Forest Land. For this reason, the emissions from Land converted to Forest Land are reported within the section for the category Forest Land remaining Forest Land and listed as IE in CRF Table 4(V). The data available for determination of biomass include the data for 1990 from the BWI 1987 and DSWF; the data for 2002 from the BWI 2002; the data for 2008 from the IS08; and the data for 2012 from the BWI 2012. The mean above-ground biomass for each year was derived via linear interpolation between 1990, 2002, 2008 and 2012, and via extrapolation for the years as of 2013. Pursuant to the expert judgement carried out by König (2007), 80 % of the wildfires in Germany remain on the ground surface and 20 % rise into tree crowns. In accordance with Table 2.6 (IPCC, 2006), a combustion efficiency (mass loss via direct combustion) of 0.15 was used for fires remaining on the surface, and an efficiency of 0.45 was used for fires rising to tree crowns. The emission factors for CH_4, N_2O, CO and NO_X were taken from Table 2.5 (IPCC, 2006). The emission factor for NMVOC was taken from the 2013 EMEP/EEA Emission Inventory Guidebook.

Germany suffers relatively little wildfire damage in terms of burned area, and thus the relevant CH_4, N_2O, CO, NO_X and NMVOC gas emissions are low. The complete time series for greenhouse gases resulting from wildfires is shown in Table 403.

Table 403: Greenhouse gases emitted by wildfires

Year	Above-ground biomass [t ha⁻¹]	Wildfire burned area [ha]	Emitted GHG [t]				
			CH_4	N_2O	CO	NO_X	NMVOC
1990	171	1,606	271	15.0	6,165	173	545
1991	174	920	158	8.7	3,594	101	317
1992	177	4,908	857	47.4	19,502	547	1,722
1993	180	1,493	265	14.7	6,033	169	533
1994	183	1,114	201	11.1	4,576	128	404
1995	186	592	109	6.0	2,472	69	218
1996	189	1,381	257	14.2	5,859	164	517
1997	192	599	113	6.3	2,582	72	228
1998	195	397	76	4.2	1,738	49	153
1999	198	415	81	4.5	1,844	52	163
2000	201	581	115	6.4	2,621	73	232
2001	204	122	24	1.4	559	16	49
2002	207	122	25	1.4	567	16	50
2003	208	1,315	270	15.0	6,137	172	542
2004	209	274	56	3.1	1,286	36	113
2005	210	183	38	2.1	863	24	76
2006	210	482	100	5.5	2,280	64	201
2007	211	256	53	2.9	1,214	34	107
2008	212	539	113	6.2	2,569	72	227
2009	214	757	160	8.9	3,646	102	322
2010	216	522	111	6.2	2,538	71	224
2011	218	214	46	2.6	1,051	29	93
2012	221	269	58	3.2	1,331	37	118
2013	223	199	44	2.4	994	28	88
2014	225	120	27	1.5	606	17	54
2015	227	526	118	6.5	2,678	75	236
2016	229	283	64	3.5	1,455	41	129
2017	231	395	90	5.0	2,048	57	181

6.4.3 Uncertainties and time-series consistency (4.A)

Various uncertainties have to be taken into account in calculation of carbon stocks. The actual uncertainties, however, can only be approximated, with the help of pragmatic approaches.

The uncertainties described in the following chapters are included in a total-error budget for the LULUCF sector that is presented in Chapter 6.1.2.10.

With regard to the uncertainties in the carbon-conversion factor, we call attention to Chapter 6.4.2.2.6.

When aggregated, error estimates (U) for values (1, ..., *i*, ..., *I*) propagate themselves in two different ways. When two values are added or subtracted, the error propagation is additive (cf. Equation 43).

Equation 43:

$$U = \frac{\sqrt{\sum_i (U_i x_i)^2}}{\sum_i x_i}$$

U	= Total uncertainty
U_i	= Uncertainty for target value
x_i	= Quantity of target value

On the other hand, when two values are multiplied or divided, the errors for the two values propagate themselves multiplicatively (cf.).

Equation 44:

$$U = \sqrt{\sum_i (U_i)^2}$$

U = Total uncertainty

U_i = Uncertainty for value sought

6.4.3.1 Uncertainties in estimation of areas affected by land-use changes

The land-use changes are determined via a sample-based system, and thus it was possible to calculate the sampling errors for each LULUCF category. The sampling error is calculated in keeping with the formulae in Chapter 6.4.3.2. Once validation has been completed, all other error sources can be ruled out (cf. also Chapter 6.3.3). All areas have been recorded significantly.

6.4.3.2 Uncertainties in estimation of emission factors of living and dead biomass

Because biomass cannot be directly measured, a number of error sources enter the processes of deriving forest biomass and carbon stocks and of deriving changes in forest biomass and carbon stocks. The errors in the biomass functions and in the carbon-conversion factor are listed and discussed in Chapter 6.4.2.2.4, 6.4.2.2.5 and 6.4.2.2.6. The errors in biomass-conversion factors for dead wood, broken down by tree species and degrees of decomposition, are given in Section 6.4.2.3.

The specific errors for the tree-species groups are added to the uncertainties for the above-ground and below-ground biomass and then aggregated to yield an error figure for the total biomass. Because the biomass stocks at the first time point are subtracted from the stocks at the second time point, the uncertainty for the biomass change is obtained via addition. The error for the total biomass change is multiplied by the error for the carbon-conversion factor and by the sampling error. The sampling error is derived from the variance in the sample.

The following tables show the uncertainties for the individual error sources and for the resulting emission factor.

Table 404: Uncertainties in emission factors for living biomass on Forest Land remaining Forest Land, for various periods

FM 1987 – 2002	Error % (biomass conversion)						Error % (C)	SE %	RMSE%
Old German Länder	**Spruce**	**Pine**	**Beech**	**Oak**	**Softwood$_{Foliage}$**	**All**			
Biomass$_{above-ground}$	7.96	11.06	13.41	8.61	35.95	6.82	2.00	2.43	7.51
Biomass$_{below-ground}$	24.54	18.63	34.91	35.55	17.33	13.95	2.00	2.36	14.29
Emission factor						6.21	2.00	2.40	6.95
Forest Management (FM), 1993 – 2002	**Error % (biomass conversion)**						**Error % (C)**	**SE %**	**RMSE%**
New German Länder	**Spruce**	**Pine**	**Beech**	**Oak**	**Softwood$_{Foliage}$**	**All**			
Biomass$_{above-ground}$	11.34	24.66	17.35	12.93	37.15	9.03	2.00	5.43	10.73
Biomass$_{below-ground}$	30.38	27.74	38.90	43.94	22.49	16.82	2.00	5.93	17.94
Emission factor						8.16	2.00	5.51	10.05
Forest Management (FM), 2002 – 2008	**Error % (biomass conversion)**						**Error % (C)**	**SE %**	**RMSE%**
Germany	**Spruce**	**Pine**	**Beech**	**Oak**	**Softwood$_{Foliage}$**	**All**			
Biomass$_{above-ground}$	7.95	11.04	13.30	8.57	35.38	14.44	2.00	28.66	32.15
Biomass$_{below-ground}$	24.47	18.60	34.67	35.39	17.14	19.29	2.00	16.35	25.37
Emission factor						12.21	2.00	25.95	28.75
Forest Management (FM), 2008 – 2016	**Error % (biomass conversion)**						**Error % (C)**	**SE %**	**RMSE%**
Germany	**Spruce**	**Pine**	**Beech**	**Oak**	**Softwood$_{Foliage}$**	**All**			
Biomass$_{above-ground}$	7.95	11.04	13.29	8.56	35.37	5.70	2.00	11.66	13.14
Biomass$_{below-ground}$	24.47	18.60	34.65	35.37	17.14	12.35	2.00	10.86	16.57
Emission factor						5.22	2.00	11.29	12.60

Table 405: Uncertainties in emission factors for living biomass on afforestation areas, for various periods

Afforestation / Reforestation (AR), 1987 – 2002	Error % (biomass conversion)						Error % (C)	SE %	RMSE%
Old German Länder	**Spruce**	**Pine**	**Beech**	**Oak**	**Softwood$_{Foliage}$**	**All**			
Biomass$_{above-ground}$	11.23	15.62	18.80	12.10	50.00	12.14	2.00	7.39	14.35
Biomass$_{below-ground}$	34.60	26.30	49.00	50.00	24.23	19.19	2.00	8.00	20.88
Emission factor						10.59	2.00	7.41	13.08
Afforestation / Reforestation (AR), 2002 – 2016	**Error % (biomass conversion)**						**Error % (C)**	**SE %**	**RMSE%**
Germany	**Spruce**	**Pine**	**Beech**	**Oak**	**Softwood$_{Foliage}$**	**All**			
Biomass$_{above-ground}$	11.23	15.62	18.80	12.10	50.00	11.10	2.00	6.08	12.81
Biomass$_{below-ground}$	34.60	26.30	49.00	50.00	24.23	17.48	2.00	5.63	18.47
Emission factor						9.69	2.00	5.93	11.53

Table 406: Uncertainties in emission factors for living biomass on deforestation areas, for various periods

Deforestation (DF), 1987 – 2002	Error % (biomass conversion)						Error % (C)	SE %	RMSE%
Old German Länder	**Spruce**	**Pine**	**Beech**	**Oak**	**Softwood$_{Foliage}$**	**All**			
Biomass$_{above-ground}$	11.23	15.62	18.80	12.10	50.00	8.29	2.00	10.00	13.15
Biomass$_{below-ground}$	34.60	26.30	49.00	50.00	24.23	17.38	2.00	11.05	20.70
Emission factor						7.51	2.00	10.08	12.73
Deforestation (DF), 2002 – 2016	**Error % (biomass conversion)**						**Error % (C)**	**SE %**	**RMSE%**
Germany	**Spruce**	**Pine**	**Beech**	**Oak**	**Softwood$_{Foliage}$**	**All**			
Biomass$_{above-ground}$	11.23	15.62	18.80	12.10	50.00	8.97	2.00	7.27	11.72
Biomass$_{below-ground}$	34.60	26.30	49.00	50.00	24.23	16.94	2.00	7.04	18.45
Emission factor						8.04	2.00	7.17	10.95

Table 407: Uncertainties in emission factors for dead wood on Forest Land remaining Forest Land, for various periods

2002– 2008	**Error % (biomass conversion)**													**Error % (C)**	**SE %**	**RMSE%**
Germany	**N1**	**N2**	**N3**	**N4**	**L1**	**L2**	**L3**	**L4**	**EI1**	**EI2**	**EI3**	**EI4**	**all**			
> 20 cm	12.30	19.82	25.12	17.87	8.87	30.62	23.95	46.25	8.92	31.54	23.71	53.23	8.36	2.00	30.80	31.98
10 to 20 cm	12.30	19.82	25.12	17.87	8.87	30.62	23.95	46.25	8.92	31.54	23.71	53.23	10.09	2.00	50.00	51.05
Emission factor																**27.11**
Forest Management (FM), 2008 – 2016	**Error % (biomass conversion)**													**Error % (C)**	**SE %**	**RMSE%**
Germany	**N1**	**N2**	**N3**	**N4**	**L1**	**L2**	**L3**	**L4**	**EI1**	**EI2**	**EI3**	**EI4**	**all**			
> 20 cm	12.55	19.74	25.16	18.28	8.70	30.66	23.63	46.96	8.59	30.64	23.86	50.61	21.92	2.00	82.64	85.52
10 to 20 cm	12.26	19.77	25.14	17.82	8.54	30.60	23.57	46.41	8.54	30.66	23.67	47.47	13.23	2.00	30.91	33.69
Emission factor																**54.52**

where N = conifers (Nadelholz), L = deciduous trees (Laubholz), but not including oak, EI = oak (Eiche) and 1 – 4 = degree of decomposition

Table 408: Uncertainties in emission factors for dead wood on afforestation areas between 1990 and 2015

Afforestation / Reforestation (AR), 1987 – 2016	**Error % (biomass conversion)**													**Error % (C)**	**SE %**	**RMSE%**
Germany	N1	N2	N3	N4	L1	L2	L3	L4	EI1	EI2	EI3	EI4	all			
> 20 cm	17.20	27.92	35.46	25.20	12.07	43.24	33.33	65.38	12.07	43.24	33.33	65.38	10.55	2.00	35.11	36.72
10 to 20 cm	17.20	27.92	35.46	25.20	12.07	43.24	33.33	65.38	12.07	43.24	33.33	65.38	13.05	2.00	28.37	31.30
Emission factor																**24.84**

where N = conifers (Nadelholz), L = deciduous trees (Laubholz), but not including oak, EI = oak (Eiche) and 1 – 4 = degree of decomposition

Table 409: Uncertainties in emission factors for dead wood on deforestation areas, for various periods

Deforestation (DF), 2002 – 2008	**Error % (biomass conversion)**													**Error % (C)**	**SE %**	**RMSE%**
Germany	**N1**	**N2**	**N3**	**N4**	**L1**	**L2**	**L3**	**L4**	**EI1**	**EI2**	**EI3**	**EI4**	**all**			
> 20 cm	17.20	27.92	35.46	25.20	12.07								6.18	2.00	27.45	28.21
10 to 20 cm	17.20	27.92	35.46	25.20	12.07								13.05	2.00	50.00	51.10
Emission factor																**24.88**
Deforestation (DF), 2008 – 2016	**Error % (biomass conversion)**													**Error % (C)**	**SE %**	**RMSE%**
Germany	**N1**	**N2**	**N3**	**N4**	**L1**	**L2**	**L3**	**L4**	**EI1**	**EI2**	**EI3**	**EI4**	**all**			
> 20 cm		27.92	35.46	25.20									6.18	2.00	27.45	28.21
10 to 20 cm	17.20	27.92	35.46	25.20	12.07	43.24	33.33	65.38					16.79	2.00	41.11	44.46
Emission factor																**24.02**

where N = conifers (Nadelholz), L = deciduous trees (Laubholz), but not including oak, EI = oak (Eiche) and 1 – 4 = degree of decomposition

6.4.3.3 Uncertainties in estimation pertaining to emission factors of litter and mineral soils

6.4.3.3.1 Sampling error

In soil sampling, proper separation of litter and mineral soil can present a problem, since the transition between the two compartments cannot always be unambiguously identified. This problem becomes even more important in that carbon concentrations in litter differ considerably from those in the underlying mineral soil. In sampling, imprecise or improper separation of litter from mineral soil can thus have major impacts on the carbon stocks measured in a relevant horizon or depth layer.

6.4.3.3.2 Small-scale variability

Due to the high spatial variability in litter and mineral soil, and because carbon stocks maintain spatial continuity only over short distances, sampling of carbon stocks in such compartments is subject to a high degree of uncertainty. For litter in a beech forest, Schöning et al. (2006) calculated stocks of 4.0 t C ha^{-1}, with a variation coefficient of 38 %. In mineral soil (0 – 36 cm), they found carbon stocks of 64.0 t C ha^{-1}, with variation coefficients between 30 % and 43 %. Similar values were recorded by Liski (1995). He showed that carbon stocks under spruce, within a given horizon, were spatially independent as of a distance of 8 m.

6.4.3.3.3 Representativeness of points within strata

One problem in carrying out analysis in accordance with dominant soil units resulted from the different degrees to which classes were represented. Small classes lack statistical validity with respect to a major basic totality. Where no comparison between BZE I and BZE II data was possible, due to a lack of pertinent data, it was not possible to include the relevant forested dominant-soil-unit area in the calculation. In addition, it was not possible to have all dominant soil units represented, since some are found only on small areas of Germany's territory. Overall, as a result of these difficulties, 4.3 % of the forest area was not taken into account in this context.

6.4.3.3.4 Sampling error

In calculation of the sampling error with regard to stock changes in litter and mineral soil, paired and unpaired samples were differentiated, and stratification of mineral soils was taken into account. The variance of the mean stocks in stratum l, and of the unstratified total sample with n_l sample points, was calculated as follows:

Equation 45:

$$v\langle \bar{Y}_l \rangle = \frac{1}{n_l\,(n_l - 1)} \sum_{j=1}^{n_l} (Y_{lj} - \bar{Y}_l)^2$$

For paired samples, the variance of the mean stock changes in stratum l, between times t_1 and t_2, was calculated via:

Equation 46:

$$v\langle \bar{G}_l \rangle = v\langle \bar{Y}_{lt_2} \rangle + v\langle \bar{Y}_{lt_1} \rangle - 2r_{y^2y^1}\sqrt{v\langle \bar{Y}_{lt_2} \rangle}\sqrt{v\langle \bar{Y}_{lt_1} \rangle}$$

$$r_{y^2y^1} = \frac{s_{y^2y^1}}{s_{y^2y^1}}$$

and

$$s_{y^2y^1} = \frac{1}{n_l(n_l-1)}\sum_{j=1}^{n_l}(Y_{ljt_2}-\overline{Y}_{lt_2})(Y_{ljt_1}-\overline{Y}_{lt_1})$$

For unpaired samples, the variance of stock changes was calculated via:

Equation 47:

$$v\langle\overline{G}_l\rangle = v\langle\overline{Y}_{lt_2}\rangle + v\langle\overline{Y}_{lt_1}\rangle$$

The total variance, throughout all strata, was estimated, taking account of the area shares w_l / w for strata, as follows:

Equation 48:

$$v\langle\overline{Y}\rangle \approx \sum_{l=1}^{L}\left(\frac{w_l}{w}\right)^2 v\left[\overline{Y}_l\right]$$

and with

$$v\langle\overline{G}\rangle \approx \sum_{l=1}^{L}\left(\frac{w_l}{w}\right)^2 v\left[\overline{G}_l\right]$$

The carbon-stock changes for litter were calculated on the basis of stratified unpaired samples. A sampling error of 0.02 t C ha^{-1} a^{-1}, or 100 %, was obtained. In calculation of carbon-stock changes in mineral soils, the overall sample was divided into a set of paired and a set of unpaired samples. In addition, stratification was carried out, in keeping with the applicable dominant soil units and the two sample sets. Overall, the sampling error for mineral soils amounted to 0.037 t C ha^{-1} a^{-1}, or 9 %.

6.4.3.3.5 Quantification of methodologically related uncertainties

Another source of uncertainty, in addition to the sampling variance, consists of discrepancies, in individual measurements, which originate in measuring methods and processes. A group of several samples taken independently, at the same location, would exhibit fluctuations in both the carbon concentration and fine-soil fraction – throughout a range determined by the precision of the measuring equipment and methods being used. This fluctuation range in measurement of carbon concentrations was quantified on the basis of the results of ring analyses (Blum & Heinbach, 2006, 2007). In the ring analyses for the BZE II, the repeatability standard deviation for a set of carbon measurements was determined as the mean within-laboratory standard deviation (DIN ISO 5725 2) of several carbon measurements within the relevant laboratories, and the reference standard deviation was determined as the standard deviation of the mean values of the measurements. The reproducibility standard deviation was calculated from those standard deviations. The reproducibility standard deviation serves as a suitable estimate of the measurement uncertainty. The reproducibility standard deviations for mineral-soil measurements were as follows: 0.9 g kg^{-1} for (i.e. for measurements in) lime-free soils, 2.9 g kg^{-1} for calcareous soils and 20.2 g kg^{-1} for organic surface layers. With regard to the BZE I, the values provided by Wolff and Riek (1997) were used, including coefficients of variation ranging from 5-20 % for carbon measurements in mineral soils and from 5-10 % for carbon measurements in organic surface layers. The mean values of such coefficients were used in each case. No ring-analyses results were available as a basis for calculation of the uncertainties relative to fine-soil fractions. For this reason, all the BZE points were selected for which fine-soil-fraction results were available at both relevant inventory time points. The mean deviation between such measurement pairs was calculated. The mean deviation was 193 ± 35 t ha^{-1}. In keeping with the principle of conservative error estimation, it was assumed that the fine-soil fractions did not change between the two inventories, and that the mean deviation plus its spread serves as a measure of the uncertainty in measurement of fine-soil fractions. The uncertainty in the annual carbon-change rate was expanded to include the uncertainties in the relevant individual measurements (Equation49).

Equation49:

$$s_{total}^2 = se^2 + \left(\frac{C_1}{(t_{II} - t_I)} MA_{FBV}\right)^2 + \left(\frac{FBV_1}{(t_{II} - t_1)} s_{C_1}\right)^2 + \left(\frac{FBV_{II}}{(t_{II} - t_1)} s_{C_{II}}\right)^2$$

The uncertainties in estimation of the annual rate of change in mineral soils were as follows: for the sampling variance, 0.037 t C ha^{-1} a^{-1}; for the laboratory analysis for carbon determination at the time of the BZE I, 0.058 t C ha^{-1} a^{-1}; for such analysis at the time of the BZE II, 0.056 t C ha^{-1} a^{-1}; and for determination of fine-soil fractions, 0.05 t C ha^{-1} a^{-1}. These uncertainties yielded a total uncertainty of 0.11 t C ha^{-1} a^{-1}. The total uncertainty in estimation of the annual carbon-change rate in the organic surface layer was 0.035 t C ha^{-1} a^{-1}.

6.4.3.4 Time-series consistency

The following conditions are applied to the consistency of the time series:

- Throughout the entire time series, emissions must be calculated with the same method and the same or mutually consistent data sets.
- If any changes are made in a method, recalculations should be carried out with the new method throughout the entire time series.
- New data, such as data from repeat inventories, must be consistent with earlier data.
- If new data become available that lead to an improvement in the inventory, a recalculation should be carried out throughout the entire time series.
- If any errors are identified in estimates, they must be corrected, and the entire pertinent time series has to be recalculated.

These conditions have been systematically applied to all time series of the submission. Where "jumps" occur in time series, in certain years – for example, in the case of biomass (cf. Chapter 6.4.2.2) – then this is due to the periodicity of the available data within a consistent time series. This is because the same method, and the same data sets, have been used for all years of such time series.

6.4.4 Category-specific QA / QC and verification (4.A)

The QC/QA measures carried out for the entire LULUCF sector are set forth in Chapter 6.1.3.

The data sources used in preparation of this inventory fulfill the review criteria of the QSE manual for data sources (QSE-Handbuch für Datenquellen). Quality assurance for input data (ATKIS®, BÜK, official statistics, wildfire statistics; cf. Chapter 6.4.2.1) is the responsibility of the relevant data administrators (cf. the pertinent documentation in the inventory description).

Complete error analysis was carried out for the LULUCF sector, and an attempt was made to quantify all existing sources of error. That work included error calculations, relative to the forest categories, for biomass, dead wood, litter, mineral soils, organic soils and wildfires, and the GHG

CO_2, N_2O and CH_4. In Chapter 6.1.2.10, a total-error budget is presented that summarises the results of error analysis.

6.4.4.1 Biomass and dead wood

The estimates of carbon stocks, and of carbon-stock changes, in the biomass and dead-wood pools, at the various relevant times, are based on up-scaling that was carried out at the Thünen Institute for Forest Ecosystems (TI-WO), using data from the BWIs and from the 2008 Inventory Study. In the process, the stocks on a nationwide, permanent, systematic sample grid are repeatedly measured. In the BWI 2012, some 420,000 trees, on a total of about 60,000 forest sample plots, were surveyed. The stock changes are derived from the stocks. In each case, the stock change is the net change between the stocks of relevant individual inventory years. It includes the wood harvest and losses through natural disturbances such as storms and mortality. Extensive quality controls are carried out for the purpose of substantiating the results:

- quality checks during field surveys
- quality checks for the collected data sets
- plausibility checks

With regard to the quality assurance developed for the BWI, we refer to the literature for the National Forest Inventory (Schmitz et al., 2005))[113].

In work carried out independently of the TI-WO's calculations, the carbon stocks and carbon-stocks changes for biomass were calculated with a programme developed under the database management system PostgreSQL. The results of the two sets of calculations match.

6.4.4.2 Litter and mineral soils

In order to achieve a consistent standard of laboratory analysis in analysis of sampling carried out in the framework of the BZE, a ring analysis was initiated. To that end, all laboratories underwent a quality test carried out by the Gutachterausschuss Forstliche Analytik ("forestry analysis auditors' committee"; Blum and Heinbach (2006); Blum and Heinbach (2007)). To ensure the comparability of the applicable laboratory methods, only laboratories that participated successfully in the ring analysis were permitted to carry out analysis. Germany also participated in a similar ring analysis at the European level (Cools et al., 2006).

To harmonise laboratory measurements and topographical surveys, rules for determining relevant parameters were defined, in the framework of the BZE II survey, for participating laboratories. This was done with a view to preventing any discrepancies resulting from use of different analysis equipment or methods (König et al. (2005), Wellbrock et al. (2006)). Previous ring analyses served as the basis for approving analytics laboratories. A similar approach was taken with regard to field sampling. On the basis of various preliminary studies, suitable sampling methods were defined, specified and described in a field-sampling manual (Wellbrock et al., 2006).

6.4.4.3 Comparison with results of other countries

A comparison with the results of other countries can yield a basic context for understanding the circumstances prevailing in Germany. In the category Land converted to Forest Land in particular, the methods and procedures used to deal with transition time vary widely, and thus results in this area tend not to lend themselves directly to comparison.

The following tables present an intra-European comparison of implied emission factors (IEF) for various pools. The comparison data for the carbon-stock changes of other countries are obtained

[113] cf. also: https://bundeswaldinventur.de/ and https://bwi.info/

from the national inventory reports of countries neighbouring Germany. The emission factor data have been obtained from the 2017 Submission to the UNFCCC Secretariat.

Table 410: Carbon-stock changes in living biomass, in forests of various countries (Germany, for 2015 & 2017; other countries, for 2015)

Country	4.A.1 – Forest Land remaining Forest Land [t C ha-1 a-1]	4.A.2 – Land converted to Forest Land [t C ha-1 a-1]	4.A.2.1. – Cropland converted to Forest Land [t C ha-1 a-1]	4.A.2.2. – Grassland converted to Forest Land [t C ha-1 a-1]	4.A.2.3. – Wetlands converted to Forest Land [t C ha-1 a-1]	4.A.2.4. – Settlements converted to Forest Land [t C ha-1 a-1]	4.A.2.5. – Other Land converted to Forest Land [t C ha-1 a-1]
Belgium	0.94	2.51	2.22	2.43	3.08	2.36	NO
Denmark	1.21	-0.71	-0.75	-0.64	-7.62	NO	NO
France	0.61	1.24	1.48	1.24	1.19	1.15	0.72
UK	1.09	0.85	0.88	0.85	NO	0.85	0.84
Netherlands	1.15	3.27	3.37	3.11	3.53	3.52	3.53
Austria	0.31	1.19	1.22	1.20	1.22	1.24	1.16
Poland	0.78	1.02	1.04	0.94	NO	NO	NO
Switzerland	0.53	0.57	0.80	0.55	0.50	0.97	0.57
Czech Republic	0.67	1.88	1.85	1.85	1.90	1.90	1.90
Germany, 2015	**1.03**	**3.28**	**3.47**	**3.09**	**3.58**	**3.41**	**3.64**
Germany, 2017	**1.03**	**3.25**	**3.45**	**3.078**	**3.57**	**3.39**	**3.64**

Positive: Carbon sink; negative: Carbon source; Source: (UNFCCC, 2018a)

Table 411: Carbon-stock changes in dead wood, in forests of various countries (Germany, for 2015 & 2017; other countries, for 2015)

Country	4.A.1 – Forest Land remaining Forest Land [t C ha-1 a-1]	4.A.2 – Land converted to Forest Land [t C ha-1 a-1]	4.A.2.1. – Cropland converted to Forest Land [t C ha-1 a-1]	4.A.2.2. – Grassland converted to Forest Land [t C ha-1 a-1]	4.A.2.3. – Wetlands converted to Forest Land [t C ha-1 a-1]	4.A.2.4. – Settlements converted to Forest Land [t C ha-1 a-1]	4.A.2.5. – Other Land converted to Forest Land [t C ha-1 a-1]
Belgium	-	0.09	0.10	0.09	0.09	0.09	NO
Denmark	-0.02	-0.03	-0.03	-0.03	-0.03	NO	NO
France	-0.03	0.04	0.09	0.03	0.15	0.06	0.05
UK	IE	NO,IE	IE	IE	NO	IE	NO,IE
Netherlands	0.24	NO	NO	NO	NO	NO	NO
Austria	0.06	0.02	0.02	0.02	0.02	0.02	0.02
Poland	NO	NO	NO	NO	NO	NO	NO
Switzerland	0.04	0.21	0.19	0.21	0.36	0.23	0.24
Czech Republic	NO	0.01	0.01	0.01	0.01	0.01	0.01
Germany, 2015	-0.05	0.03	0.03	0.03	0.03	0.03	0.03
Germany, 2017	**-0.05**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**

Positive: Carbon sink; negative: Carbon source; Source: (UNFCCC, 2018a)

Table 412: Carbon-stock changes in litter, in forests of various countries (Germany, for 2015 & 2017; other countries, for 2015)

Country	4.A.1 – Forest Land remaining Forest Land [t C ha⁻¹ a⁻¹]	4.A.2 – Land converted to Forest Land [t C ha⁻¹ a⁻¹]	4.A.2.1. – Cropland converted to Forest Land [t C ha⁻¹ a⁻¹]	4.A.2.2. – Grassland converted to Forest Land [t C ha⁻¹ a⁻¹]	4.A.2.3. – Wetlands converted to Forest Land [t C ha⁻¹ a⁻¹]	4.A.2.4. – Settlements converted to Forest Land [t C ha⁻¹ a⁻¹]	4.A.2.5. – Other Land converted to Forest Land [t C ha⁻¹ a⁻¹]
Belgium	-	0.36	0.38	0.35	0.37	0.35	NO
Denmark	-0.97	-0.92	-0.9	-0.96	-1.11	NO	NO
France	NE	0.24	0.43	0.19	0.36	0.29	0.33
UK	0.04	0.02	0.02	0.02	NO	0.02	0.02
Netherlands	NO	NO	NO	NO	NO	NO	NO
Austria	NE,IE	1.22	1.35	1.25	0.79	1.23	1.22
Poland	NO	NO	NO	NO	NO	NO	NO
Switzerland	-0.02	1.27	0.32	1.31	0.82	0.36	1.07
Czech Republic	NO	0.54	0.54	0.54	0.54	0.54	0.54
Germany, 2015	-0.01	0.47	0.47	0.47	0.47	0.47	0.47
Germany, 2017	-0.01	0.47	0.47	0.47	0.47	0.47	0.47

Positive: Carbon sink; negative: Carbon source; Source: (UNFCCC, 2018a)

Table 413: Carbon-stock changes in mineral soils of various countries (Germany, for 2015 & 2017; other countries, for 2015)

Country	4.A.1 – Forest Land remaining Forest Land [t C ha⁻¹ a⁻¹]	4.A.2 – Land converted to Forest Land [t C ha⁻¹ a⁻¹]	4.A.2.1. – Cropland converted to Forest Land [t C ha⁻¹ a⁻¹]	4.A.2.2. – Grassland converted to Forest Land [t C ha⁻¹ a⁻¹]	4.A.2.3. – Wetlands converted to Forest Land [t C ha⁻¹ a⁻¹]	4.A.2.4. – Settlements converted to Forest Land [t C ha⁻¹ a⁻¹]	4.A.2.5. – Other Land converted to Forest Land [t C ha⁻¹ a⁻¹]
Belgium	0.53	1.39	2.68	1.18	0.85	3.05	NO
Denmark	NO,NA	0.1	0.18	NO	NO	NO	NO
France	NE	0.15	1.03	-0.02	NO	0.53	NE
UK	0.34	-1.19	-1.07	-1.21	NO	-1.16	-1.17
Netherlands	NO	-0.02	0.35	-0.40	0.06	0.35	2.15
Austria	-0.18	0.70	1.18	-0.78	NO	2.67	2.96
Poland	0.11	0.11	0.11	0.10	NO	NO	NO
Switzerland	0.00	0.62	0.58	0.53	1.16	1.45	4.16
Czech Republic	NO	0.12	0.49	0.01	NO	NO	NO
Germany, 2015	0.41	-0.36	0.04	-0.77	-0.05	0.12	0.22
Germany, 2017	0.41	-0.32	0.07	-0.69	-0.05	0.14	0.25

Positive: Carbon sink; negative: Carbon source; Source: (UNFCCC, 2018a)

Table 414: Carbon-stock changes in organic soils of various countries (Germany, for 2015 & 2017; other countries, for 2015)

Country	4.A.1 – Forest Land remaining Forest Land [t C ha⁻¹ a⁻¹]	4.A.2 – Land converted to Forest Land [t C ha⁻¹ a⁻¹]	4.A.2.1. – Cropland converted to Forest Land [t C ha⁻¹ a⁻¹]	4.A.2.2. – Grassland converted to Forest Land [t C ha⁻¹ a⁻¹]	4.A.2.3. – Wetlands converted to Forest Land [t C ha⁻¹ a⁻¹]	4.A.2.4. – Settlements converted to Forest Land [t C ha⁻¹ a⁻¹]	4.A.2.5. – Other Land converted to Forest Land [t C ha⁻¹ a⁻¹]
Belgium	NO	NO	NO	NO	NO	NO	NO
Denmark	-1.30	NO	-1.30	-1.30	-1.22	-1.22	-1.40
France	NO	NO,NE	NO	NO	NE	NO	NO
UK	0.64	IE	0.64	-1.90	-1.96	IE	-1.96
Netherlands	NO	-0.22	-0.23	-0.23	NO	-0.31	NO
Austria	NO	NO	NO	NO	NO	NO	NO
Poland	-0.56	-0.68	-0.68	-0.68	NO	NO	NO
Switzerland	-2.60	-2.60	-2.60	-2.60	-2.60	NO	-2.60
Czech Republic	NO	NO	NO	NO	NO	NO	NO
Germany, 2015	-2.23	-2.23	-2.23	-2.23	-2.23	-2.23	-2.23
Germany, 2017	-2.24	-2.24	-2.24	-2.24	-2.24	-2.24	-2.24

Positive: Carbon sink; negative: Carbon source; Source: (UNFCCC, 2018a)

6.4.5 Category-specific recalculations (4.A)

No recalculations were carried out for the present Submission.

6.4.6 Planned improvements, category-specific (4.A)

No further improvements are planned at present. Information about the implementation status of planned improvements in the LULUCF sector is presented in Chapter 6.1.4.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

6.5 Cropland (4.B)

6.5.1 Category description (4.B)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
L/T	4.B Cropland		CO_2	12,436.44	1.02%	14,506.31	1.63%	16.6%
-/-	4.B. Cropland		N_2O	312.32	0.03%	359.85	0.04%	15.2%
-/-	4.B. Cropland		CH_4	195.96	0.02%	249.17	0.03%	27.2%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 2	RS/NS	CS
N_2O	Tier 2	RS/NS	CS/D
CH_4	Tier 2	RS/NS	CS

The category *Cropland* (4.B) is a key source of CO_2 emissions in terms of emissions level, trend and Tier 2 analysis.

Reporting in the *Cropland* category covers emissions / removals of CO_2 from and to mineral and organic soils, and from and to above-ground and below-ground biomass. It also includes direct and indirect nitrous oxide emissions from humus losses from mineral soils, following land-use conversions to Cropland, and it covers methane emissions from organic soils. In keeping with the IPCC Guidelines (IPCC 2006), direct and indirect nitrous oxide emissions from fertiliser application (artificial fertiliser, manure, sewage sludge, etc.), crop residues and drainage of organic soils under cultivation are reported under Agriculture (CRF 3.D). For this reason, in the Cropland chapter, those categories are marked as "IE." Burning of fields and crop residues is prohibited by law in Germany (Federal Law Gazette (BGBl) 2004) and thus is not reported (NO).

Emissions from Cropland are listed, by pools, in Table 415 and in the CRF Tables 4, 4.B, 4.(II).B, 4.(III).B und 4.(IV).2. The total emissions from Cropland in 2017 in Germany amounted to 15,115.3 kt CO_2 equivalents. The main emissions sources are soils, especially organic soils under cultivation (77.0 %). Mineral soils contributed 21.6 % of the total emissions. Most emissions from mineral soils (99.6 % of the total for such soils) resulted from tillage of grassland (CRF 4.B.2.2.1; 4.(II).B; 4.(IV).2). The Cropland category registers very low levels of anthropogenically related net releases of CO_2 from biomass (1.2 %) and from dead organic matter (0.23 %).

The predominating GHG in the Cropland category is CO_2, accounting for 14,506.3 kt CO_2- eq. (96.0 %). The reported nitrous oxide emissions from decomposition of organic soil matter, as a result of land-use changes to Cropland, are low (the total is 2.4 %, and it consists of direct emissions (293.8 kt CO_2-eq. (CRF 4.(III)) and indirect emissions (66.1 kt CO_2-eq. (CRF 4.(IV)). A similar statement can be made for the relevant methane emissions (249.2 kt CO_2-eq. ≙ 1.6 % (CRF (4.II).B), from use of organic soils).

Table 415: CO_2, N_2O and CH_4 emissions [kt CO_2-eq.] from Germany's Cropland, 2017. The table includes both the relevant sums and the upper and lower bounds of the 95 % confidence interval.

Source category	GHG	Cropland, emissions, 2017				
		[kt CO_2-eq.]			[%]	
		Emission	2.5 perc.	97.5 perc.	2.5 perc.	97.5 perc.
$Cropland_{total}$ [114]		**15,115.3**	11,118.3	17,317.4	26.4	14.6
Mineral soils	CO_2 [115]	**2,903.1**	2,042.4	4,317.7	29.6	48.7
	N_2O_{direct} [116]	**293.8**	28.3	911.4	90.4	201.2
	$N_2O_{indirect}$ [117]	**66.1**	0	259.6	100.0	292.8
Organic soil	CO_2 [115]	**11,385.3**	7,488.6	12,874.2	34.2	13.1
	N_2O [118]	**IE**	IE	IE	IE	IE
	CH_4 [119]	**249.2**	124.6	685.9	50.0	175.3
Biomass	CO_2 [115]	**182.6**	145.3	220.2	20.4	20.6
Litter / dead wood	CO_2 [115]	**35.3**	30.0	40.5	14.9	14.9

Figure 62 and Figure 63 show the trends over time in emissions from Cropland. The total emissions in 2017 were 2,170.6 kt CO_2 ≙ 16.8 % higher than in the reference year 1990.

This general trend is due primarily to increases of emissions from organic soils in the category Cropland remaining Cropland. Those increases, in turn, have occurred because the relevant area has increased, mainly as a result of tillage of grassland (CRF 4.B.2.1.1). The decrease in the deforested area, amounting to -61.4 % since 1990, resulted in 75.0 % lower emissions from deforestation (Land converted to Cropland) in 2017, with respect to the base year. Those emissions account for a very small fraction of the total emissions from the Cropland category, 160.1 kt CO_2-eq. ≙ 1.1 %. Similar statements apply for land-use changes from Settlements to Cropland (49.0 kt CO2-eq. 0.32 %) and from Wetlands to Cropland (29.1 kt CO_2-eq. ≙ 0.19 %); here as well, the land conversions – and, thus, the emissions – have decreased with respect to 1990 (Settlements: -66.8 %; Wetlands: -82.4 %).

The trend reversal since 2005 is primarily due to emissions resulting from land-use change from Grassland (in the strict sense) to Cropland. Since 2005, the tilled grassland area on Germany's organic and mineral soils has increased by 296,301 ha ≙ 40.7 %, and that has increased emissions by 2,033.0 kt CO_2 ≙ 42.3 %.

The shapes of the time-series plots – especially the noticeable changes they show – are due primarily to the periodicity in surveying of the relevant area data (cf. Chapter , 6.3.5). Land-use changes were determined on the basis of spatially explicit data sets from the years 1990, 2000, 2005 2008, 2012 and 2015 (cf. Chapter 6.3). Land-use changes that occurred between those years were determined via linear interpolation, and thus the annual conversion areas did not change between the survey time points. The values for 2017 have been extrapolated. The main reason for

114 Sum of the emissions from CRF tables 4.B, 4.(II).B, 4.(III).B, 4.(IV).2

115 CRF table 4.B

116 CRF Table 4.(III).B

117 The category-specific indirect N_2O emissions are not included and shown as such in the CRF tables; they are included, however, in the sum presented in CRF Table 4.(IV).2 for all sub-categories.

118 CRF table 3.D.a.6

119 CRF Table 4.(II).B

the marked emissions decrease between 2000 and 2001 is a considerable decrease in deforestation.

Figure 62: GHG emissions from Cropland (total of CO_2, CH_4 and N_2O) [kt CO_2-eq.] as a result of land use and land-use changes, 1990-2017, by sub-categories (with uncertainties shown only for the total)

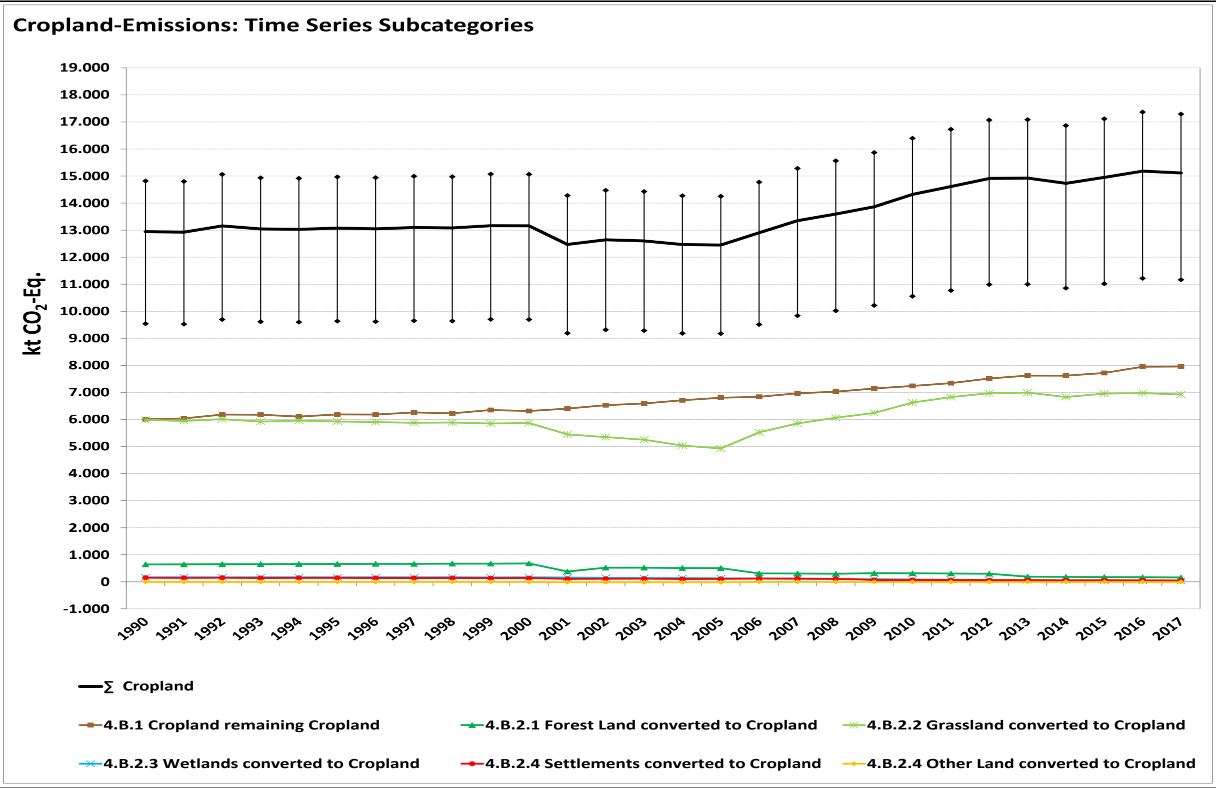
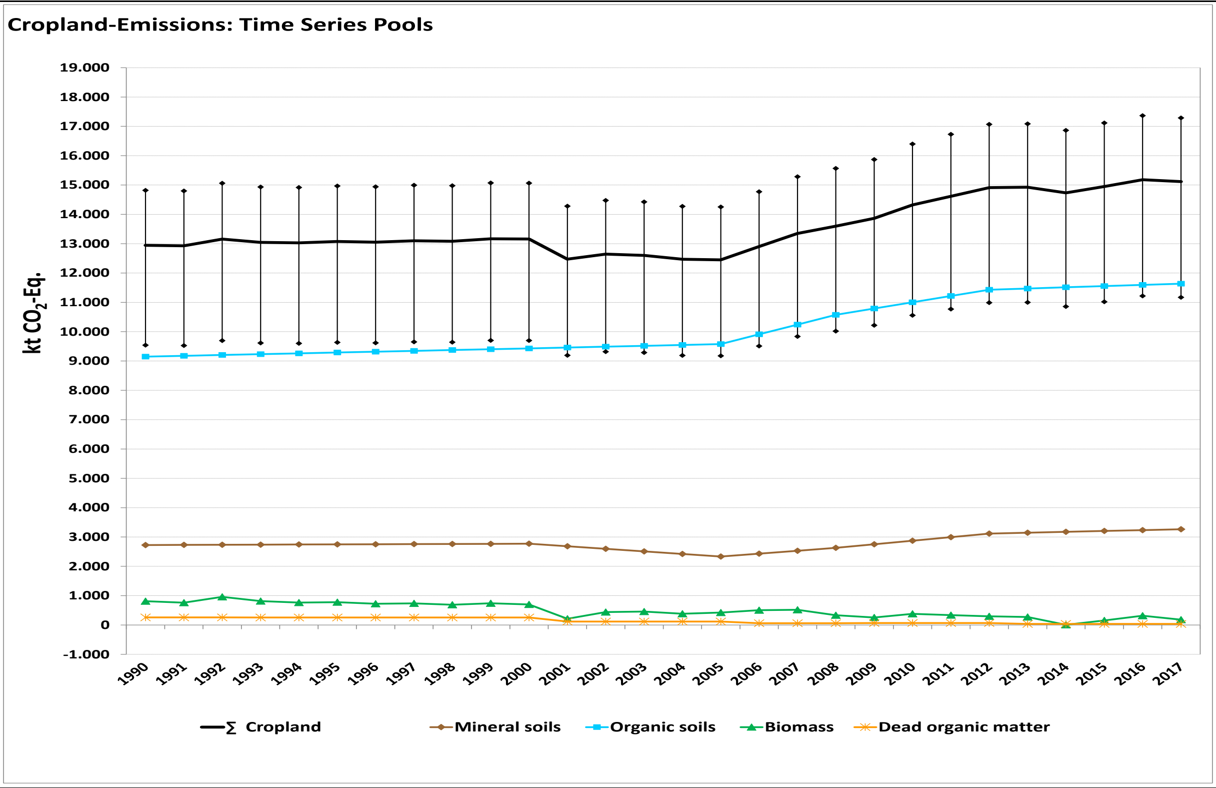


Figure 63: GHG emissions from Cropland (total of CO_2, CH_4 and N_2O) [kt CO_2-eq.] as a result of land use and land-use changes, 1990-2017, by pools (with uncertainties shown only for the total)



6.5.2 Methodological issues (4.B)

6.5.2.1 Data sources

The following data sources / sets have been used:

- Statistisches Bundesamt, Fachserie 3, Reihe 3, Land- und Forstwirtschaft, Fischerei, Landwirtschaftliche Bodennutzung und pflanzliche Erzeugung (Federal Statistical Office, Fachserie 3, Reihe 3, agriculture and forestry, fisheries, agricultural soil use and crop cultivation; (Statistisches Bundesamt, FS 3, R 3)),
- Statistisches Bundesamt, Fachserie 3, Reihe 3.2.1, Land- und Forstwirtschaft, Fischerei, Wachstum und Ernte – Feldfrüchte (Federal Statistical Office, Fachserie 3, Reihe 3, agriculture and forestry, fisheries, growth and harvests – crops; (Statistisches Bundesamt, FS 3, R 3.2.1)),
- Statistisches Bundesamt, Fachserie 3, Reihe 3.1.2, Land- und Forstwirtschaft, Fischerei,– Bodennutzung der Betriebe (Federal Statistical Office, Fachserie 3, Reihe 3, agriculture and forestry, fisheries – soil use by sectoral operations; (Statistisches Bundesamt, FS 3, R 3.1.2)),
- 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Agriculture, Forestry and Other Land Use (IPCC, 2006)
- "Ordinance on application of fertilisers, soil additives, culture substrates and plant additives according to the principles of good practice in fertilization (Ordinance on Fertilisation – Düngeverordnung (DüV))" (Ordinance on Fertilisation in the version as promulgated 27 February 2007 (Federal Law Gazette I, p. 221), last amended by Article 5 (36) of the Act of 24 February 2012 (Federal Law Gazette I p. 212) (Bundesgesetzblatt, 2012).

- Interim report in the research project "Methodenentwicklung zur Erfassung der Biomasse mehrjährig verholzter Pflanzen außerhalb von Wäldern" ("Development of methods for determining the biomass of plants, outside of forests, with multiple years of wood growth") (Pöpken, 2011).

6.5.2.2 Biomass

Carbon-stock changes in above-ground and below-ground phytomass of Cropland areas are reported as part of land-use conversions to Cropland, as well as – for the first time – in the category Cropland remaining Cropland. In the Cropland category, the phytomass pool is subdivided in accordance with basic characteristics of the plants concerned:

- herbaceous plants
- perennial woody crops (orchards and vineyards, Christmas tree plantations, tree nurseries and short-rotation plantations)

The assumptions and methods used for calculation of carbon-stock changes in above-ground and below-ground biomass of plants are described in Chapter 6.1.2.3, while the derivations of the emission factors are described in the following chapters:

- for herbaceous plants of annual crops, in Chapter 6.1.2.3.3;
- for fruit plantations, in Chapter 6.1.2.3.4.1;
- for vineyards, in Chapter 6.1.2.3.4.2;
- for Christmas tree plantations, in Chapter 6.1.2.3.4.3;
- for tree nurseries, in Chapter 6.1.2.3.4.4;
- for short-rotation plantations, in Chapter 6.1.2.3.4.5.

6.5.2.2.1 Land-use change

As Chapter 6.1.2.3.1 explains, the existing system for listing land-use changes does not make it possible to identify annual and perennial crops in a spatially explicit and complete manner. For this reason, in connection with land-use changes from and to Cropland, it is not clear whether annual or perennial Cropland is the initial or the final land use. This situation is addressed by deriving an area-weighted emission factor for the entire Cropland phytomass. It is obtained, via an area-weighting calculation, from the emission factors derived in Chapter 6.1.2.3.3 and Chapter 6.1.2.3.4.6, as follows:

$$EF_{crop_{Phyto}} = \frac{\left(EF_{crop_{an}} * A_{crop_{an}} + EF_{crop_{per}} * A_{crop_{per}}\right)}{\left(A_{crop_{an}} + A_{crop_{per}}\right)}$$

EF_crop_Phyto:	Area-weighted emission factor for the entire annual and perennial Cropland phytomass [Mg C ha^{-1}]
EF_crop_an:	Mean emission factor, weighted by crop type and area under cultivation, for herbaceous and annual Cropland phytomass [Mg C ha^{-1}]
A_crop_an:	Area under cultivation with herbaceous and annual biomass [ha]
EF_crop_per:	Mean emission factor, weighted by crop type and area under cultivation, for perennial woody phytomass on Cropland [Mg C ha^{-1}]
A_crop_per:	Area under cultivation with perennial woody phytomass on Cropland [ha]

The mean carbon stocks per area unit for the Cropland phytomass, and the emission factors, are shown in Table 416. They serve as the basis for all calculations of CO_2 removals and emissions to and from the Cropland-phytomass pool that occur as the result of land-use changes to and from Cropland.

Table 416: Mean area-weighted carbon stocks [t C ha^{-1} ± half of the 95 % confidence interval] in phytomass on Cropland

Year	Cropland phytomass, total Soil organic carbon stocks [t C ha^{-1}] Phytomass, total	Phytomass, above-ground	Phytomass, below-ground
1990	5.27 ± 0.60	3.78 ± 0.51	1.49 ± 0.32
1995	5.63 ± 0.65	4.17 ± 0.56	1.46 ± 0.32
2000	5.97 ± 0.69	4.44 ± 0.60	1.53 ± 0.33
2005	6.16 ± 0.71	4.62 ± 0.62	1.54 ± 0.33
2010	6.05 ± 0.69	4.56 ± 0.61	1.49 ± 0.32
2011	6.18 ± 0.71	4.60 ± 0.62	1.58 ± 0.34
2012	6.49 ± 0.74	4.88 ± 0.66	1.62 ± 0.35
2013	6.39 ± 0.73	4.84 ± 0.65	1.55 ± 0.34
2014	7.27 ± 0.83	5.48 ± 0.74	1.79 ± 0.39
2015	6.55 ± 0.75	4.98 ± 0.67	1.56 ± 0.34
2016	6.43 ± 0.74	4.85 ± 0.65	1.58 ± 0.34
2017	6.70 ± 0.77	4.99 ± 0.67	1.71 ± 0.37

6.5.2.2.2 The "remaining as" category

In the "remaining as" categories of all other land uses, the vegetation structures involved are homogeneous, and thus dynamic equilibria can be assumed with regard to phytomass (meaning that no emissions are estimated; cf. Chapter 6.1.2.3.1). The sub-category Cropland remaining Cropland includes herbaceous, annual crops and perennial woody crops that do not fit that description, however. Human-induced changes in land use between these crops thus entail carbon-stock changes in plant biomass. The resulting emissions from the phytomass pool are reported for the remaining category of Cropland.

Since the existing system for identifying land-use changes does not support spatially explicit and complete descriptions of area changes involving shifts between annual and perennial crops (cf. Chapter 6.1.2.3.1), the activity data needed for emissions estimation have to be obtained from official statistics (Statistisches Bundesamt, FS 3, R 3.1.2). The resulting values are shown in Table 417. The area sum proves to be relatively constant; the standard error for the sample mean is 0.9 % (half of the 95 % confidence interval). Short-rotation plantations play only a marginal role in Germany (1.7 % – 2.7 % of the area under cultivation with woody crops; 0.2 – 0.3 ‰ of Germany's total agricultural area). Statistics on such plantations have been recorded only since 2010.

Table 417: Areas [ha] under cultivation with perennial woody crops, within Germany's Cropland {pursuant to STATISTISCHES BUNDESAMT, various years}

Year	Woody crops on Cropland Area [ha]					
	Fruit cultivation	Wine-grape cultivation	Christmas tree plantations	Tree nurseries	Short-rotation plantations	∑ $Area_{woody\ crops}$
1990	80,856	104,973	5,467	26,788		218,084
1995	68,977	106,781	10,353	27,831		213,942
2000	69,500	104,724	13,400	24,800		212,424
2005	66,200	102,037	12,900	21,700		202,837
2010	65,287	102,197	14,625	20,860	3,501	206,470
2011	65,600	102,104	15,000	20,700	5,100	208,504
2012	64,300	102,172	15,600	21,200	4,400	207,672
2013	63,400	102,427	15,800	20,700	3,600	205,927
2014	63,800	102,439	17,900	20,800	4,800	209,739
2015	64,100	102,581	20,100	19,900	5,786	212,467
2016	64,078	102,493	16,379	19,278	5,688	207,916
2017	64,200	102,592	15,900	19,400	5,600	207,692

From statistics on cropland areas with woody-plants cultivation, and the annual area changes that can be derived from such statistics, carbon-stock changes in the phytomass of the remaining category can be estimated as a sum for Germany. Since the type and directions of pertinent land-use changes cannot be precisely described (cf. Chapter 6.1.2.3.1), and connections to other land-use categories cannot be proven – and thus cannot be reported – reporting in this area is based on the assumption that the annual area differences for permanent crops exclusively represent land-use changes within the cropland category.

Relevant calculations are carried out using the gain-loss method (2006 IPCC Guidelines) described in Chapter 6.1.2.3.2. In the interest of consistency in methods, the area-sum difference is multiplied by the weighted mean carbon stocks in woody phytomass (Chapter 6.1.2.3.3) or herbaceous phytomass (Chapter 6.1.2.3.4.6) and then entered into the balance with a reversed sign (i.e. plus or minus; positive area difference: woody biomass, positive sign (gain), herbaceous biomass, negative sign (loss); and vice-versa (cf. Table 364 in Chapter 6.1.2.3.2)).

6.5.2.3 Mineral soils

6.5.2.3.1 Land-use change

Calculation of CO_2 emissions resulting from area conversions leading to Cropland is described in Chapter 6.1.2.1, while calculation of direct N_2O emissions is described in Chapter 6.1.2.7 and calculation of indirect N_2O emissions is described in Chapter 6.1.2.8. The emission factors for carbon are shown in Table 350 and Table 351 (Chapter 6.1.2.1.1), while the emission factors for direct nitrous oxide emissions are shown in Table 377 (Chapter 6.1.2.7) and the emission factors for indirect N_2O emissions are shown in Table 378 (Chapter 6.1.2.8). The manner in which the emission factors have been derived is described in Chapter 6.1.2.1, while the pertinent uncertainties are listed in Table 418 (Chapter 6.6.3). The results for emissions from mineral soils are presented as follows:

- CO_2 emissions in CRF tables 4.B.2.1-4.B.2.5,
- direct N_2O emissions in CRF tables 4.III.2.1-4.III.2.5,
- indirect N_2O emissions in CRF table 4.IV.2.

6.5.2.3.2 The remaining category

For areas in the category Cropland remaining Cropland, no carbon-stocks changes in mineral soils are listed; consequently, no nitrous oxide is released via mineralisation of organic soil substance.

The assumption that mineral soils in continuous use as cropland in Germany are not a source of carbon and nitrogen emissions is supported by the following arguments:

- Results from 140 regional long-term-study areas (Höper and Schäfer (2012); Fortmann (2012) and Blum and Heinbach (2007)) that show the constancy of carbon stocks since the beginning of the 1990s.
- Initial studies of the carbon balance of cropland areas, carried out at 180 sites of the country-wide Agricultural Soil Inventory (Dreysse, 2015). The models used included the VDLUFA-Humusbilanzierung ("VDLUFA humus balancing") model, which was developed for practical advising (Körschens et al. (2004); Körschens et al. (2004)), and the "CandyCarbonBalance" model, which is process-controlled and site-adapted (Franko et al., 2011). Both models clearly show that the studied cropland soils under long-term use are no sources of CO_2 (Dreysse, 2015).
- More-recent meta-studies (Baker et al. (2007); Luo et al. (2010)) that have shown that the type of soil tillage applied used has no influence on the total carbon stocks in mineral soils down to depths of more than 60 cm.

Along with this evidence, extensive proof of the correctness of the above assumptions can be listed:

1. The results of the nationwide evaluation of German long-term soil monitoring sites (Marx et al., 2016).
2. Time-series analysis for carbon inputs via organic fertilisers and crop residues. The carbon inputs are derived from the relevant nitrogen inputs into Germany's croplands, as calculated for the source categories of the agricultural sector (CRF Table 3.D).
3. The fertilisation recommendations for implementation of the German Fertiliser Ordinance (Düngeverordnung) and the EU Nitrates Directive;

Regarding 1.) The findings obtained in a research project on long-term soil monitoring sites of the German Länder have been compiled, harmonised and synthetically evaluated on a nationwide basis (Marx et al., 2016). The key findings include:

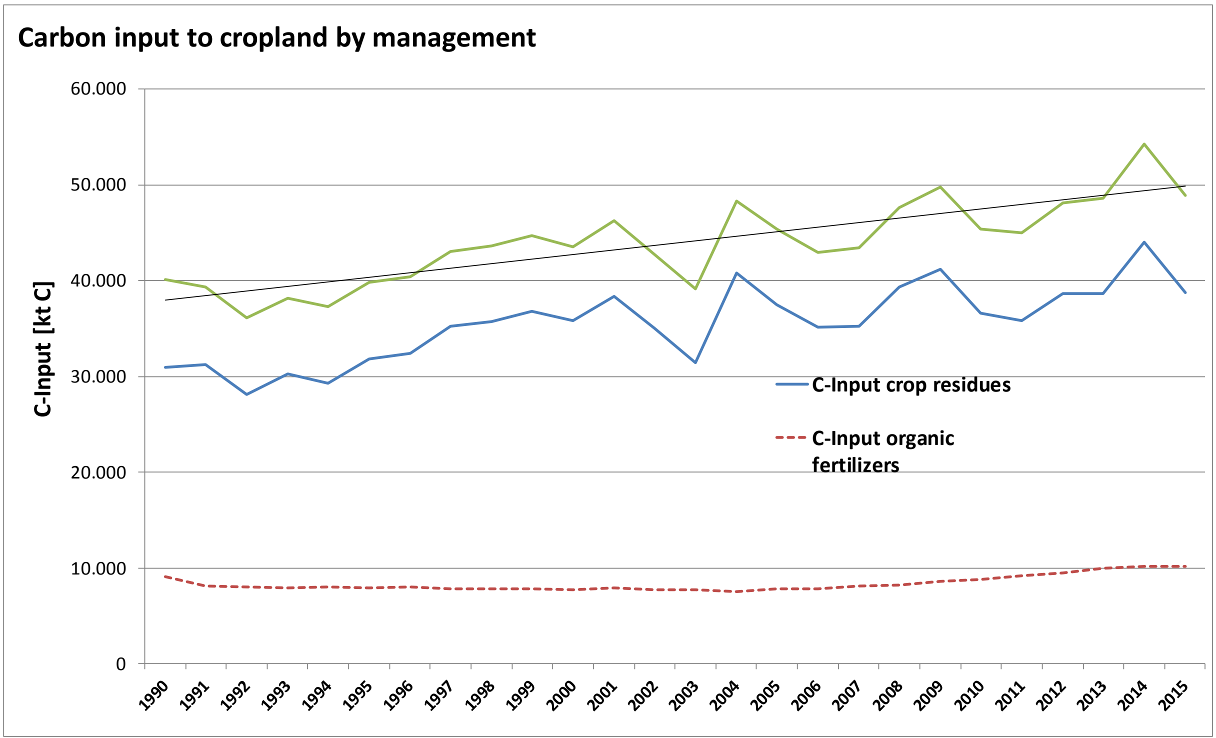
- The nationwide evaluation of the long-term soil monitoring sites, with respect to carbon-stock changes, has confirmed the findings drawn to date at the Länder level. The shares of sites at which no statistically proven changes have occurred clearly predominate. For example, 77 % of the cultivated mineral soils show no carbon-stock change, while 10 % show a significant increase and 13 % show a significant decrease (Marx et al., 2016).
- At 157 long-term (cropland) soil monitoring sites, data suitable for correlation analysis of soil organic carbon stocks and management are available. A positive significant correlation between soil-organic -carbon stock differences and management was found at only two sites, or about 1.3 % of all sites. The impacts of management on carbon content are marginal (Marx et al., 2016).
- Marx et al. (2016) found that the most important factors influencing soil organic carbon are clay content, precipitation and temperature, followed by other site parameters. Factors tied to management contributed insignificantly to explanation of carbon-content variance in mineral soils under cropland. The study found that the most important factors influencing long-term changes of carbon content were outset carbon content and clay content.

The results of the nationwide evaluation of long-term soil-monitoring sites carried out by Marx et al. (2016) confirm the assumption that the net carbon-stock changes in mineral soils of cropland sites are zero on average, and that changes that occur are primarily site-related, and not tied to management.

Regarding 2.) The trend for carbon inputs via organic fertilisers and crop residues supports independent estimation of the influence of management on the humus balance. A positive trend implies a net carbon sink, while a negative trend is an indication of a possible decrease of carbon stocks. The trend estimate is based on the nitrogen inputs into mineral soils, as determined for the agricultural sector (CRF Table 3.D) section of the German GHG inventory. From those inputs, the carbon inputs via organic fertilisers can be approximated, by multiplying the nitrogen inputs by a mean C/N ratio of 12 (representative for the liquid-manure and solid-manure mixture that predominates in organic fertilisers). 66 % of the organic fertilisers used in Germany are used on cropland, while 34 % are used on grassland (Statistisches Bundesamt, FS 3, R 3.2.2). Figure 64 shows the results.

- The carbon inputs via organic fertilisers have remained largely constant since 1990.
- The carbon inputs via crop residues have increased considerably.
- Overall, carbon inputs into mineral soils under Cropland have increased since 1990.

Figure 64: Carbon inputs [kt C] via organic fertilisers and crop residues, in Cropland, 1990 – 2015



The results of this national analysis confirm, independently from the findings obtained via long-term soil monitoring, that mineral soils in the category Cropland remaining Cropland tend to be a net carbon sink, rather than a source. The fact that crops contribute less per carbon unit than organic fertilisers, to the soils' humus balance, is further confirmation of the robustness of the assumption that mineral soils under remaining cropland use in Germany are not an emissions source.

Regarding 3.) Yet another indication that mineral soils under permanent cropland do not lose any organic soil substance is provided by the recommendations for fertilisation of annual crops that are given to farmers by the agricultural authorities of the German Länder. The recommendations support the aims of German legislation on fertilisation, the purposes of which include implementing the European Nitrates Directive. Art. 6 of the Fertiliser Ordinance (DüV; Bundesgesetzblatt (2012)) establishes mandatory limits for nitrogen surpluses on cropland. Conformance with the limits is monitored by authorities. The competent authorities of the Länder provide farmers with data and tools for determination of fertilisation requirements. The Fertiliser

Ordinance explicitly defines the applicable parameters (such as various site factors, cultivation conditions, management methods, crops, preceding crops, residual content, use of organic fertilisers, etc.). It also calls on farmers to take the results of regional field trials into account in determining fertilisation requirements (Art 3 (2) DüV Bundesgesetzblatt (2012)). In keeping with this orientation, the tools developed by the various Länder for estimation of nitrogen-fertiliser requirements, and the data underlying such tools, are based on regional measurements and fertilisation trials. None of these systems address nitrogen losses from mineralisation of organic soil substance as an issue. Clearly, the only nitrogen sources involved are organic fertilisers and crop residues – mineralisation of organic soil substance does not play a role. It thus follows, as a complement to the results in 1.), that no N_2O emissions from mineralisation of organic soil substance occur in the category Cropland remaining Cropland.

In CRF Table 4.B.1, therefore, NE (not estimated)) is entered in the column for carbon-stock changes in mineral soils in the "remaining as" category; and NE is also entered for N_2O emissions in CRF Table 3.D.5.

The EU Commission, in its "Member State recommendations on reporting systems for cropland & grazing land management emissions & removals" {ECOFYS 2017}, had recommended that a system be developed, for Germany, that would be able to record and report on carbon-stock changes in soils that result from cultivation measures aimed at lowering emissions, or at sequestering carbon. This recommendation is being implemented; pertinent means of creating such a system are currently being developed and reviewed.

6.5.2.4 Organic soils

The way in which CO_2, N_2O and CH_4 emissions from organic soils, as a result of land use and land-use changes, have been calculated, and the way in which the relevant emission factors have been derived, are described in Chapter 6.1.2.2. The manner in which the relevant areas and area land uses have been determined is described in Chapter6.3.1 ff. The annual emissions from land-use changes are calculated in the same way as the emissions from Cropland remaining Cropland. The latter emissions are listed in CRF Table 4.B.1, while emissions from land-use changes in are listed in CRF Tables 4.B.2.1 - 4.B.2.5.

N_2O emissions from cultivated organic soils are reported as part of the Agriculture sector, under Chapter 3.D.a.6 "Cultivation of Histosols." To prevent double-counting, in LULUCF CRF Table 4.II.B, those emissions are marked IE.

The areas reported on in the Agriculture sector, under Chapter 3.D.a.6 "Cultivation of Histosols", differ from those reported on in the LULUCF sector. The reasons for this are presented in Chapter 6.1.2.2.1.

The methane emissions from organic soils and from drainage ditches are shown in CRF Table 4(II).B.

6.5.3 Uncertainties and time-series consistency (4.B)

The uncertainties for the emission factors and the activity data were determined in accordance with the 2006 IPCC Guidelines (IPCC, 2006). Additional relevant information is provided in Chapter 6.1.2.10. Table 418 shows the uncertainties in the emission factors for the Cropland category, by pools and sub-categories.

Table 418 highlights the fact that distributions based on natural processes are often not symmetric and thus often have to be described with left-skewed and right-skewed (with steep sloping on the one side or the other) distributions. Only the EF for biomass show normal distributions or distributions that are approximately normal. Furthermore, the uncertainties seen in this area are the smallest of all relevant uncertainties. With the exception of the EF for CO_2 from organic soils, which exhibits a right-skewed distribution, the other EF for soils tend to show log-normal distributions. The EF for N_2O emissions from mineral soils show the largest uncertainties. This is due primarily to use of the IPCC default factors.

In Gaussian calculation of error propagation, uncertainties of more than 100 % were calculated for the lower bound of the 95 % confidence interval for the uncertainties for the factors for indirect N_2O emissions. While this calculation method conforms to the applicable rules, mathematical rigour dictates that it not be used in the present context. Pursuant to the assumptions underlying the relevant calculation method, no negative emissions can occur in connection with indirect N_2O emissions from mineral soils. For this reason, the uncertainty for the lower bound has been set to 100 %.

The large uncertainty seen in the EF for methane and nitrous oxide from organic soils is due to those factors' extremely large variability in field measurements, as well as to the fact that negative emissions are possible for methane (cf. Chapter 6.1.2.2.2).

The uncertainties for the activity data have a normal distribution, and half of the 95 % confidence interval falls within the range 1.0 – 180.2 %. For system-related reasons, the sampling error with the sample-grid system depends on the sample size, and thus on the relevant sub-category's share of the total area (cf. Chapter 6.3). Consequently, in the Cropland category major uncertainties are seen only for those sector sub-categories whose share of the total Cropland area is less than 0.1 %. Area-weighted derivation of a total uncertainty for the area data in the Cropland category yields an uncertainty of 1.01 % [half of the 95% confidence interval].

The total uncertainty for the land-use category Cropland is 26.4 % [half of the 95 % confidence interval]. The main contribution to this comes from CO_2 emissions from organic soils. Emissions from mineral soils – primarily as a result of grassland tillage – are the only other factor to influence this uncertainty figure noticeably.

A similar picture emerges with respect to the LULUCF inventory as a whole: While emissions from the Cropland category, with respect to organic soils, account for a considerable share of national LULUCF emissions, emissions from mineral soils play a noticeable role only in the case of grassland tillage.

Table 418: Uncertainties of emission factors [2.5 and 97.5 percentile, in % of location scale] used for calculation of GHG emissions from Germany's croplands in 2017, by pools and sub-categories

Cropland		Emission factor	Uncertainty bounds	
Initial land use	Final land use		lower	upper
Mineral soils, CO_2-C[120]		[t C ha^{-1} a^{-1}]	[%]	[%]
Forest Land	Cropland	-0.042	16.8	24.8
Grassland (in the strict sense)	Cropland	-0.870	29.6	49.1
Woody Grassland	Cropland	-0.658	27.9	51.1
Terr. Wetlands	Cropland	-0.699	28.4	36.8
Waters	Cropland	0.000	33.0	50.5
Settlements	Cropland	0.068	27.9	49.2
Other Land	Cropland	0.221	27.4	51.8

120 Calculation covers a 20-year period; stock change: positive ≙ sink; negative ≙ source

Cropland		Emission factor	Uncertainty bounds	
Initial land use	Final land use		lower	upper
Mineral soils, N_2O_{direct}[121]		[kg N_2O ha^{-1} a^{-1}]	[kg N_2O ha^{-1} a^{-1}]	[%]
Forest Land	Cropland	0.053	72.0	201.5
Grassland (in the strict sense)	Cropland	1.078	91.0	211.9
Woody Grassland	Cropland	0.845	90.4	212.4
Terr. Wetlands	Cropland	0.711	90.6	209.4
Mineral soils, $N_2O_{indirect}$[121]		[kg N_2O ha^{-1} a^{-1}]	[kg N_2O ha^{-1} a^{-1}]	[%]
Forest Land	Cropland	0.012	100	287.8
Grassland (in the strict sense)	Cropland	0.243	100	295.2
Woody Grassland	Cropland	0.190	100	295.5
Terr. Wetlands	Cropland	0.160	100	293.4
Biomass[122]		[t C ha^{-1} a^{-1}]	[t C ha^{-1} a^{-1}]	[%]
Croplandperennial [123]	Croplandannual [124]	-5.02	**11.0**	**11.0**
Cropland, annual [124]	Cropland, perennial [123]	5.02	**11.0**	**11.0**
Forest Land	Cropland[125]	-47.96	22.3	22.3
Grassland (in the strict sense)	Cropland[125]	-0.11	16.3	16.6
Woody Grassland	Cropland[125]	-36.46	47.8	47.0
Terr. Wetlands	Cropland[125]	-12.23	32.3	31.7
Waters	Cropland[125]	6.7	11.5	11.5
Settlements	Cropland[125]	-5.79	31.4	30.9
Other Land	Cropland[125]	6.80	11.5	11.5
Dead organic matter[122]		[t C ha^{-1} a^{-1}]	[t C ha^{-1} a^{-1}]	[%]
Forest Land	Cropland	-20.65	6.2	6.2

Table 419: Uncertainties for emission factors [2.5 and 97.5 percentile, in % of location scale] for emissions from organic soils on cropland, 2017

Land use	GHG	Emission factor	Uncertainty bounds lower	upper
Organic soil[126]		[t CO_2-eq. ha^{-1} a^{-1}]	[%]	[%]
Cropland	CO_2	29.70	45.7	17.4
Cropland	N_2O	5.01	85.5	286.5
Cropland	CH_4	0.65	66.7	233.9

The calculations are spatially consistent over time and complete for the entire reporting period, 1990-2016.

6.5.4 Category-specific quality assurance / control and verification (4.B)

Details regarding this year's reviews are provided in Chapter 6.1.3.

The data sources used in preparation of this inventory fulfill the review criteria of the QSE manual for data sources (QSE-Handbuch für Datenquellen). Quality assurance for input data (ATKIS®, BÜK, official statistics; cf. Chapter 6.3) is the responsibility of the relevant data administrators (cf. the pertinent documentation in the inventory description).

121 Calculation covers a 20-year period; emission: positive ≙ source; negative ≙ sink
122 Calculation only for first year of land-use change, stock change: positive ≙ sink; negative ≙ source
123 Mean for perennial crops; cf. Chapter 6.1.2.3.4.6
124 Mean for annual crops; cf. Chapter 6.1.2.3.3
125 Weighted mean of perennial and annual crops; cf. Chapter 6.5.2.1.2
126 Annual calculation; emission: positive ≙ source; negative ≙ sink

The emissions-calculation results as presented in the present report cannot be compared with other relevant data sources for Germany, since no such other data sources exist that meet applicable requirements, i.e. provide nationwide coverage, are comprehensive and are independent of the methods and data sources described in the present report.

The following tables present an intra-European comparison of implied emission factors (IEF) for various pools. Values of neighbouring countries, obtained from the 2017 Submission to the Climate Secretariat (UNFCCC NIR Submission 2017 – Inventory year 2015, UNFCCC (2018a)), were used for this comparison. The 2017 values for Germany have come from the current 2019 Submission. The comparison, especially when the large uncertainties and the scattering in the reported values (cf. Chapter 6.5.3) are taken into account, shows fluctuations, some of them considerable (organic soils pool LUC 4.A.1, with sink performance values between -10 and -1 t C ha^{-1} a^{-1}; and the biomass pool LUC 4.A.2.1, with sink performance values between -13.91 and 0 t C ha^{-1} a^{-1}).

Table 420: Carbon-stock changes in living biomass, in croplands of various countries (Germany, for 2015 & 2017; other countries, for 2015)

Country	4.B.1. - Cropland Remaining Cropland [t C ha⁻¹ a⁻¹]	4.B.2 - Land Converted To Cropland [t C ha⁻¹ a⁻¹]	4.B.2.1 - Forest Land Converted To Cropland [t C ha⁻¹ a⁻¹]	4.B.2.2 - Grassland Converted To Cropland [t C ha⁻¹ a⁻¹]	4.B.2.3 - Wetlands Converted To Cropland [t C ha⁻¹ a⁻¹]	4.B.2.4 - Settlements Converted To Cropland [t C ha⁻¹ a⁻¹]	4.B.2.5 - Other Land Converted To Cropland [t C ha⁻¹ a⁻¹]
Belgium	0.0036	-0.2568	-13.9163	NO	NO	NO	NO
Denmark	-0.0396	0.2497	-3.6637	0.4073	-0.9024	NO	NO
France	-0.0016	-0.2427	-4.2848	-0.0826	NE	-0.0223	NE
UK	0.0068	-0.0304	0	-0.0304	NO	-0.0316	NO
Netherlands	NE	-0.2098	-9.75	-0.1424	0.462	0.4831	0.3326
Austria	-0.0313	0.1158	-1.114	0.1875	NO	NO	NO
Poland	0.0349	NO	NO	NO	NO	NO	NO
Switzerland	-0.4962	-0.0798	-1.1935	-0.094	0.1136	0.1023	0.2027
Czech Republic	0.0001	-0.1388	-2.4133	-0.031	0.0958	NO	NO
Germany, 2015	**0.0011**	**-0.0512**	**-0.7054**	**-0.0273**	**0.0043**	**-0.1423**	**NO**
Germany, 2017	**- 0.0001**	**-0.0440**	**-0.8602**	**-0.0194**	**0.0067**	**-0.1555**	**NO**

Positive: Carbon sink; negative: Carbon source; Source: (UNFCCC, 2018a)

Table 421: Carbon-stock changes in dead organic matter, in croplands of various countries (Germany, for 2015 & 2017; other countries, for 2015)

Country	4.B.1. - Cropland Remaining Cropland [t C ha⁻¹ a⁻¹]	4.B.2 - Land Converted To Cropland [t C ha⁻¹ a⁻¹]	4.B.2.1 - Forest Land Converted To Cropland [t C ha⁻¹ a⁻¹]	4.B.2.2 - Grassland Converted To Cropland [t C ha⁻¹ a⁻¹]	4.B.2.3 - Wetlands Converted To Cropland [t C ha⁻¹ a⁻¹]	4.B.2.4 - Settlements Converted To Cropland [t C ha⁻¹ a⁻¹]	4.B.2.5 - Other Land Converted To Cropland [t C ha⁻¹ a⁻¹]
Belgium	NO	-0.0199	-1.081	NO	NO	NO	NO
Denmark	NO	-0.1341	-3.4971	NO,NA	NO	NO	NO
France	NE	-0.0175	-0.4488	NE	NE	NE	NE
UK	NO	0	0	IE	NO	NO,IE	NO
Netherlands	NE	-0.0327	-3.7997	NE	NE	NE	NE
Austria	NO	-0.0344	-0.624	NO	NO	NO	NO
Poland	NO	NO	NO	NO	NO	NO	NO
Switzerland	NO	-0.0014	-0.3179	NO	NO	NO	NO
Czech Republic	NO	-0.0037	-0.0723	NO	NO	NO	NO
Germany, 2015	**IE**	**-0.0087**	**-0.3031**	**IE**	**IE**	**IE**	**IE**
Germany, 2017	**IE**	**-0.0087**	**-0.3703**	**IE**	**IE**	**IE**	**IE**

Positive: Carbon sink; negative: Carbon source; Source: (UNFCCC, 2018a)

Table 422: Carbon-stock changes in mineral soils, in croplands of various countries (Germany, for 2015 & 2017; other countries, for 2015)

Country	4.B.1. - Cropland Remaining Cropland [t C ha⁻¹ a⁻¹]	4.B.2 - Land Converted To Cropland [t C ha⁻¹ a⁻¹]	4.B.2.1 - Forest Land Converted To Cropland [t C ha⁻¹ a⁻¹]	4.B.2.2 - Grassland Converted To Cropland [t C ha⁻¹ a⁻¹]	4.B.2.3 - Wetlands Converted To Cropland [t C ha⁻¹ a⁻¹]	4.B.2.4 - Settlements Converted To Cropland [t C ha⁻¹ a⁻¹]	4.B.2.5 - Other Land Converted To Cropland [t C ha⁻¹ a⁻¹]
Belgium	-0.0379	-1.3009	-3.0994	-1.3106	-2.5779	0.462	
Denmark	0.0467	-0.0038	-0.0865	NO,IE	-0.5322	NO	NO
France	0.0689	-1.1072	-1.2367	-1.1711	NO	0.0632	NE
UK	-0.3291	-1.2662	-2.6406	-1.2772	NO	0.9406	NO
Netherlands	NO	-0.8027	-0.277	-0.8159	-1.3611	-0.3819	3.4957
Austria	0.0752	-0.9803	-0.9029	-0.9848	NO	NO	NO
Poland	-0.002	-0.0505	NO	-1.031	NO	NO	NO
Switzerland	NO	-0.3169	-0.6921	-0.4722	1.9766	0.9987	2.6701
Czech Republic	0.0072	-0.3269	-0.3938	-0.4896	NO	NO	NO
Germany, 2015	NA	-0.7916	-0.0087	-0.8678	NO	0.0677	0.2212
Germany, 2017	NA	-0.8034	-0.0422	-0.8683	NO	0.0677	0.2212

Positive: Carbon sink; negative: Carbon source; Source: (UNFCCC, 2018a)

Table 423: Carbon-stock changes in organic soils, in croplands of various countries (Germany, for 2015 & 2017; other countries, for 2015)

Country	4.B.1. - Cropland Remaining Cropland [t C ha⁻¹ a⁻¹]	4.B.2 - Land Converted To Cropland [t C ha⁻¹ a⁻¹]	4.B.2.1 - Forest Land Converted To Cropland [t C ha⁻¹ a⁻¹]	4.B.2.2 - Grassland Converted To Cropland [t C ha⁻¹ a⁻¹]	4.B.2.3 - Wetlands Converted To Cropland [t C ha⁻¹ a⁻¹]	4.B.2.4 - Settlements Converted To Cropland [t C ha⁻¹ a⁻¹]	4.B.2.5 - Other Land Converted To Cropland [t C ha⁻¹ a⁻¹]
Belgium	-10	NO	NO	NO	NO	NO	NO
Denmark	-6.5506	-0.0814	IE	-5.0019	NO	NO	NO
France	NO	NO,NE	NO	NO	NE	NO	NO
UK	-5	-5	NO,IE	-5	NO	NO,IE	NO
Netherlands	-3.9712	-4.1219	-3.3454	-4.1322	-4.0158	-4.2415	-3.5512
Austria	NO	NO	NO	NO	NO	NO	NO
Poland	-1	NO	NO	NO	NO	NO	NO
Switzerland	-9.52	-8.9835	-9.52	-9.52	-9.52	-5.1069	2.48
Czech Republic	NO	NO	NO	NO	NO	NO	NO
Germany, 2015	**-8.1**	**-8.1**	**-8.1**	**-8.1**	**-8.1**	**-8.1**	**-8.1**
Germany, 2017	**-8.1**	**-8.1**	**-8.1**	**-8.1**	**-8.1**	**-8.1**	**-8.1**

Positive: Carbon sink; negative: Carbon source; Source: (UNFCCC, 2018a)

6.5.5 Category-specific recalculations (4.B)

No recalculations were carried out for the present Submission.

6.5.6 Planned improvements, category-specific (4.B)

No further improvement measures are planned at present. Information about the implementation status of planned improvements in the LULUCF sector is presented in Chapter 6.1.4.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

6.6 Grassland (4.C)

6.6.1 Category description (4.C)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
L/T	**4.C Grassland**		**CO_2**	**25,543.59**	**2.09%**	**21,935.06**	**2.46%**	**-14.1%**
-/-	4.C. Grassland		CH_4	593.83	0.05%	507.28	0.06%	-14.6%
-/-	4.C. Grassland		N_2O	87.80	0.01%	105.65	0.01%	20.3%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 2	RS/NS	CS
N_2O	Tier 2	RS/NS	CS/D
CH_4	Tier 2	RS/NS	CS

The category *Grassland* (4.C) is a key source of CO_2 emissions in terms of emissions level, trend and Tier 2 analysis.

In 2017, the net anthropogenic GHG emissions from grassland amounted to 22,548.0 kt CO_2 equivalents (95% confidence interval: 12,982.1 kt CO_2-eq. ≙ 42.2 % - 27,587.4 kt CO_2-eq. ≙ 22.4%). Drainage of organic grassland soils resulted in emissions of 24,353.5 kt CO_2, 507.3 kt CO_2-eq. of methane, and 98.6 kt CO_2-eq. of nitrous oxide. Losses via decomposition of dead wood and litter from deforestation amounted to 195.2 kt CO_2. In the Grassland sector, both biomass (-658.2 kt CO_2) and mineral soils (-1955.5 kt CO_2) functioned as carbon sinks.

These emissions consist of the sum of the emissions from the sub-categories Grassland (in the strict sense) and Woody Grassland, whose GHG emissions differ considerably, both quantitatively and qualitatively. As Table 424 and Figure 65 and Figure 66 show, Grassland (in the strict sense) is a significant CO_2 source. Its absolute emissions level, 22,381.8 kt CO_2-eq., is determined primarily by emissions from organic soils (23,109.8 kt CO_2-eq. ≙ 103.3 %), with the fraction for CO_2 (97.9 %) greatly exceeding that of methane (2.1 %). While biomass and dead organic matter also function as small CO_2 sources (2.2 %), mineral soils under Grassland (in the strict sense) are a lasting carbon sink. They reduce the gross emissions in the sub-category Grassland (in the strict sense) by 7.3 %.

Table 424: CO_2, N_2O and CH_4 emissions [kt CO_2-eq.] from Grassland, 2017, by sub-categories. The table includes both the relevant sums and the upper and lower bounds of the 95 % confidence interval.

Sub-category / Pool	GHG	Grassland (in the strict sense) Emissions, 2017 [kt CO_2-eq.]			[%]	
		Emission	2.5 perc.	97.5 perc.	2.5 perc.	97.5 perc.
Grassland (in the strict sense)$_{total}$[127]		**22,381.8**	11,839.0	27,919.0	47.1	24.7
Mineral soils	**CO_2[128]**	**-1,754.9**	-1,357.2	-2,405.3	22.7	37.1
	N_2O_{direct}[129]	**0**	0	0	0	0
	$N_2O_{indirect}$[130]	**0**	0	0	0	0
Organic soil	**CO_2[131]**	**23,109.8**	10,899.4	29,378.2	52.8	27.1
	N_2O[132]	**IE**	**IE**	**IE**	**IE**	**IE**
	CH_4[133]	**489.7**	270.6	591.8	44.7	246.8
Biomass	CO_2[131]	**406.9**	322.2	491.7	20.8	20.8
Dead organic matter	CO_2[131]	**130.3**	104.6	156.1	19.8	19.8
Sub-category / Pool	**GHG**	**Woody Grassland, emissions, 2017 [kt CO_2-eq.]**			**[%]**	
		Emission	**2.5 perc.**	**97.5 perc.**	**2.5 perc.**	**97.5 perc.**
Woody Grassland$_{total}$[134]		**166.2**	138.3	198.6	16.8	19.5
Mineral soils	**CO_2[135]**	**-200.5**	-161.7	-263.7	19.4	31.5
	N_2O_{direct}[136]	**5.8**	0.2	18.2	95.7	215.6
	$N_2O_{indirect}$[137]	**1.3**	0.0	5.2	100.0	297.8
Organic soil	CO_2[131]	**1,243.7**	1,006.1	1,521.3	19.1	22.3
	N_2O[136]	**98.6**	14.9	2766	84.9	181.6
	CH_4[138]	**17.5**	2.4	178.1	86.2	915.2
Biomass	CO_2[131]	**-1,065.0**	-682.6	-1,453.2	35.9	36.4
Dead organic matter	CO_2[131]	**64.9**	47.9	81.9	26.2	26.2

In 2017, the time series for total emissions from Grassland (in the strict sense) includes emissions that have decreased by 14.3 % with respect to the base year. The time series for total emissions is dominated by emissions from organic soils; as a result, the total emissions basically reflect the area changes in such soils over time (r = 0.997). The highest emissions occurred in the base year. Since then, they have been decreasing, as a result of intensified transfers of organic grassland areas into other land-use categories, especially Cropland. Along with emissions from organic soils, emissions from biomass and dead organic matter have been influencing the shape of the trend curve – as a result of deforestation and, more recently, decreases in deforestation. Unlike such sources, mineral soils function as a sink. Over time, that sink function has exhibited a highly significant negative trend; it has decreased by 29.4 % with respect to the base year.

127 Subtotal of emissions from CRF tables 4.C, 4.(II).C, 4.(IV).2
128 Subtotal of emissions from CRF table 4.C
129 CRF Table 4.(III).C
130 The category-specific indirect N_2O emissions are not included and shown as such in the CRF tables; they are included, however, in the sum, for all sub-categories, presented in CRF Table 4.(IV).2
131 Subtotal, CRF table 4.C
132 CRF table 3.D.a.6
133 Subtotal, CRF table 4.(II).C
134 Subtotals of emissions from CRF tables 4.C, 4.(II).C, 4.(IV).2, and sum from 4.(III).C
135 Subtotal of emissions from CRF table 4.C
136 CRF Table 4.(III).C
137 The category-specific indirect N_2O emissions are not included and shown as such in the CRF tables; they are included, however, in the sum presented in CRF Table 4.(IV).2 for all sub-categories.
138 Subtotal, CRF table 4.(II).C

This has been the result of a decrease in conversion of Forest Land, Cropland, Wetlands and other areas to Grassland (-28.9 %). The category Cropland converted to Grassland accounts for 67.8 % of the area sum for land-use conversions to Grassland. As a result, the decrease in area transfers from Cropland (-29.6 % with respect to the base year) is the main reason for the decrease in the sink performance.

The shapes of the time-series plots – especially the noticeable changes they show – are due primarily to the area changes that have occurred as of the relevant explicitly defined survey dates (cf. Chapter 6.3.5). This applies especially to the sub-category Woody Grassland.

Figure 65: CO_2 emissions [kt CO_2-eq.] from Grassland (in the strict sense), as a result of land use and land-use changes, 1990-2017, by sub-categories

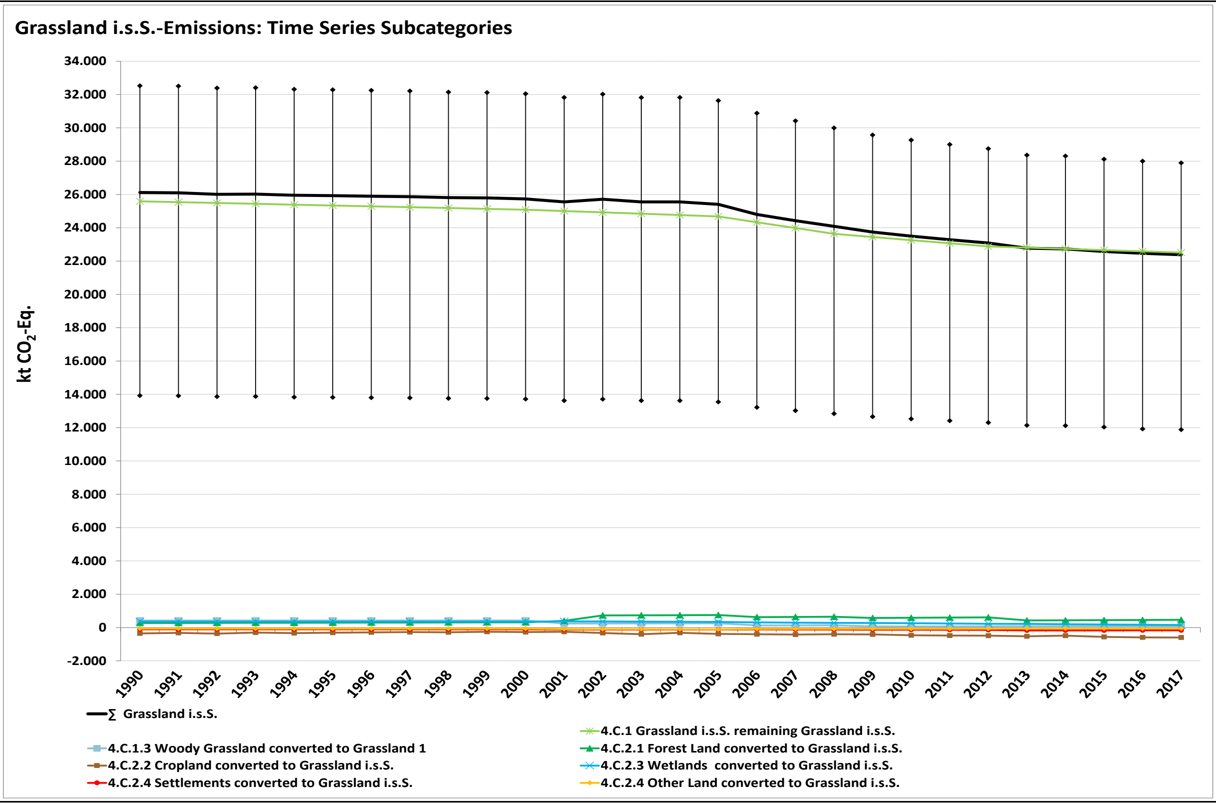
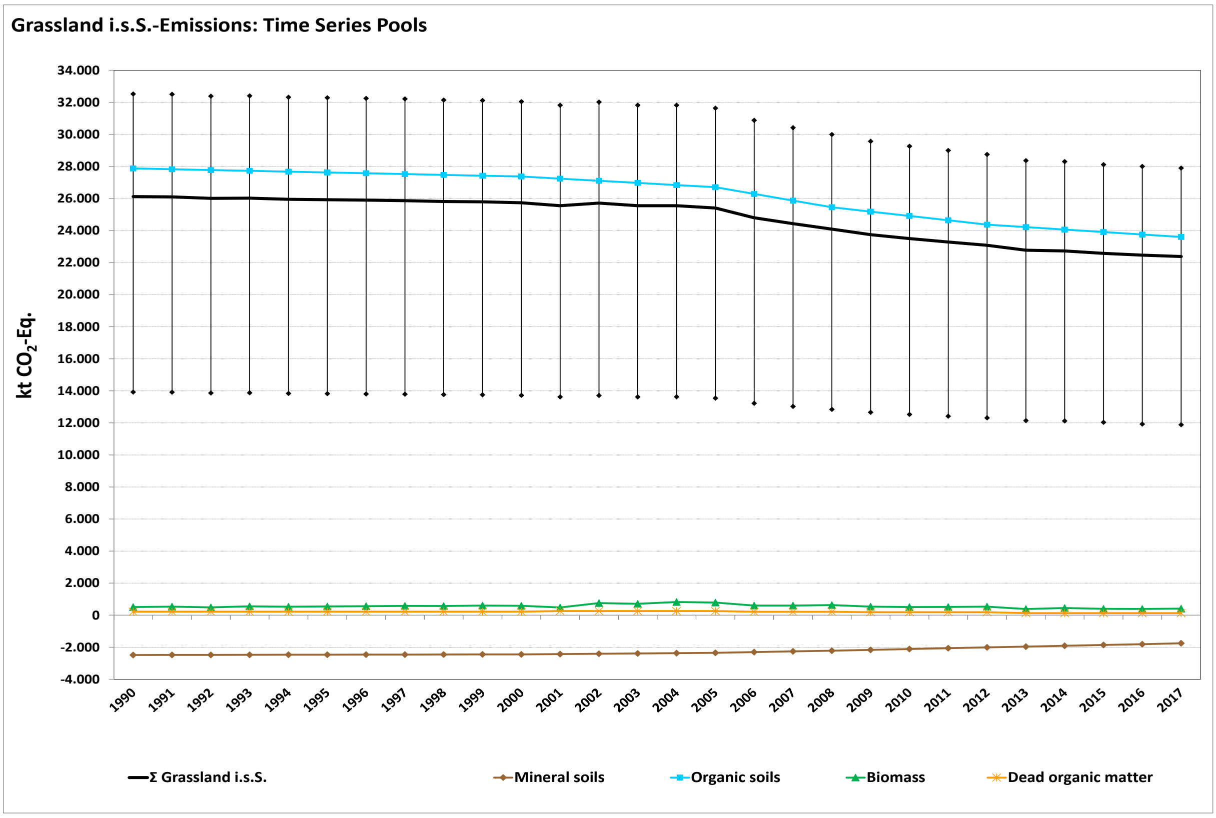


Figure 66: CO_2 emissions [kt CO_2-eq.] from Grassland (in the strict sense), as a result of land use and land-use changes, 1990-2017, by pools



In 2017, the sub-category Woody Grassland was a small CO_2 source (166.2 kt CO_2-eq.; Table 424 and Figure 65 / Figure 66). The net emissions are dominated by the pools biomass and organic soils. The latter, with emissions of 1,359.8 kt CO_2-eq., are the main source of GHG emissions (95.0 %) in the sub-category Woody Grassland; emissions from dead organic matter (4.5 %) and nitrous oxide, via humus decomposition in mineral soils following land-use changes from Grassland (in the strict sense) and from Terrestrial Wetlands (0.5 %), are very low. Such emissions are offset by CO_2 removals in mineral soils (-200.5 kt CO_2-eq.) and in biomass (-1,065.0 kt CO_2-eq.).

The shape of the time-series plots in Figure 67 and Figure 68 show that the source function has increased by 55.4% with respect to the base year. The plots also show that this category is highly dynamic, because land-use changes to and from the sub-category Woody Grassland involve significant carbon stocks found in the biomass pool. The plots thus reflect the decommissioning phase that took place in the German agricultural sector around the turn of the millennium, as well as the increasing agricultural intensification that has occurred over the past few years. The shapes of the plots – especially the noticeable changes they show – are primarily due to the changes in area data that have occurred as of the relevant explicitly defined survey dates. This applies especially to the sub-category Woody Grassland (cf. Chapter 6.3.5, Table 385).

Figure 67: CO_2 emissions [kt CO_2-eq.] from Woody Grassland, as a result of land use and land-use changes, 1990-2017, by sub-categories

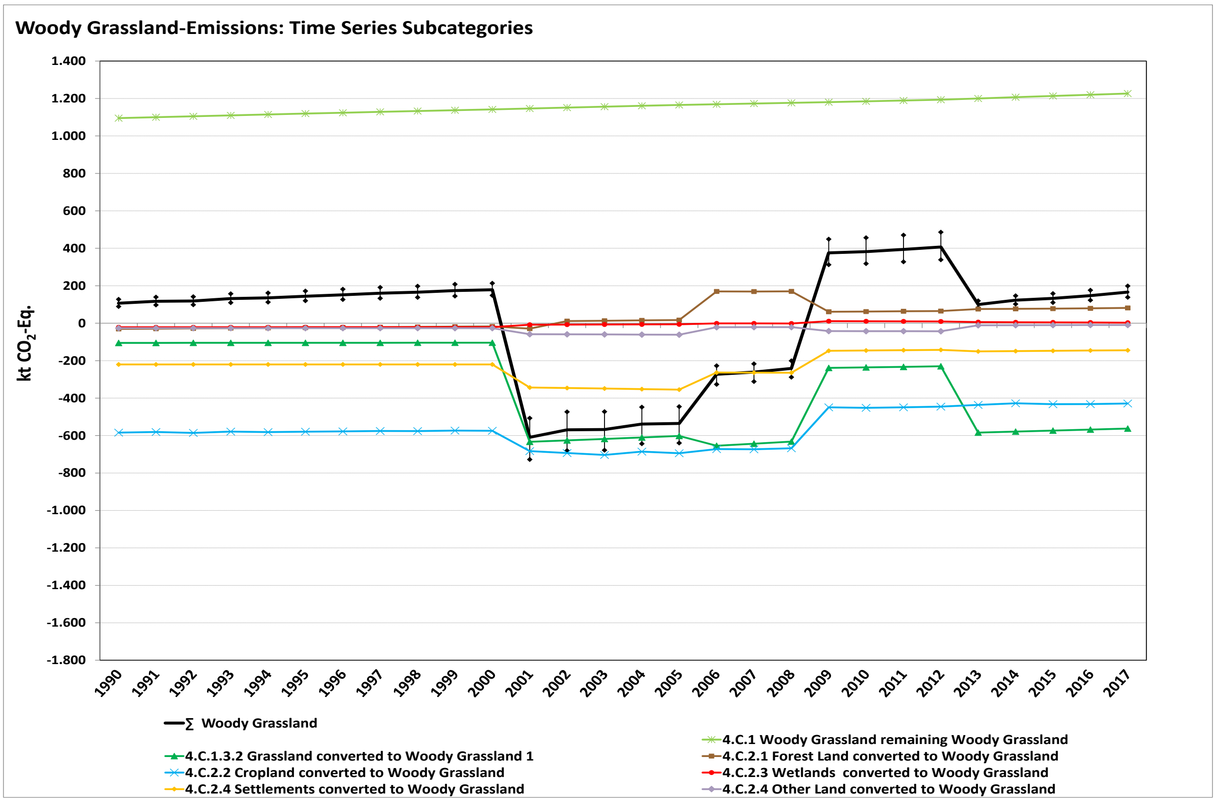
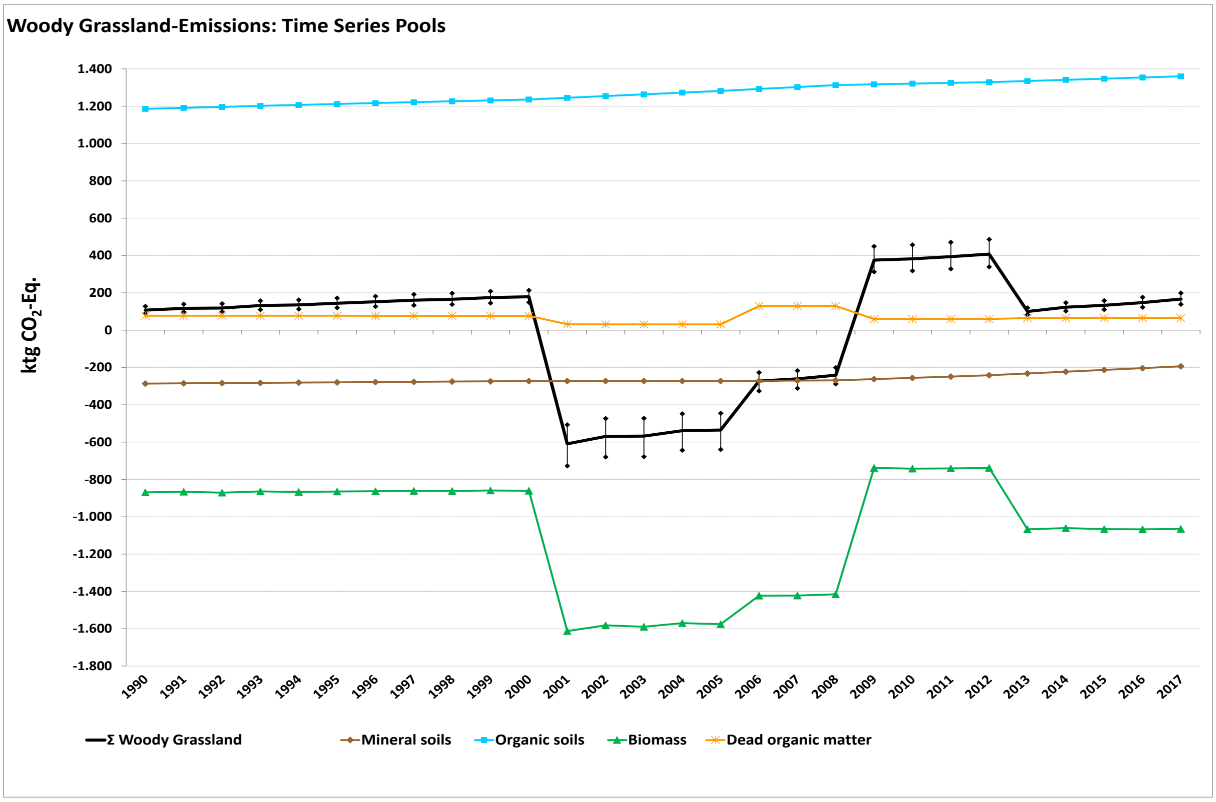


Figure 68: CO_2 emissions [kt CO_2-eq.] from Woody Grasslands, as a result of land use and land-use changes, 1990-2017, by pools



6.6.2 Methodological issues (4.C)

6.6.2.1 Data sources

The following data sources / sets have been used:

- Statistisches Bundesamt, Fachserie 3, Reihe 3, Land- und Forstwirtschaft, Fischerei, Landwirtschaftliche Bodennutzung und pflanzliche Erzeugung (Federal Statistical Office, Fachserie 3, Reihe 3, agriculture and forestry, fisheries, agricultural soil use and crop cultivation; (Statistisches Bundesamt, FS 3, R 3)),
- Statistisches Bundesamt, Fachserie 3, Reihe 3.2.1, Land- und Forstwirtschaft, Fischerei, Wachstum und Ernte – Feldfrüchte (Federal Statistical Office, Fachserie 3, Reihe 3, agriculture and forestry, fisheries, growth and harvests – crops; (Statistisches Bundesamt, FS 3, R 3.2.1)),
- Statistisches Bundesamt, Fachserie 3, Reihe 3.1.2, Land- und Forstwirtschaft, Fischerei,– Bodennutzung der Betriebe (Federal Statistical Office, Fachserie 3, Reihe 3, agriculture and forestry, fisheries – soil use by sectoral operations; (Statistisches Bundesamt, FS 3, R 3.2.1)),
- 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Agriculture, Forestry and Other Land Use (IPCC, 2006)
- "Ordinance on application of fertilisers, soil additives, culture substrates and plant additives according to the principles of good practice in fertilization (Ordinance on Fertilisation – Düngeverordnung (DüV))" (Ordinance on Fertilisation in the version as promulgated 27 February 2007 (Federal Law Gazette I, p. 221), last amended by Article 18 of the Act of 31 July 2009 (Federal Law Gazette I p. 2585) (Bundesgesetzblatt, 2012).
- Interim report in the research project "Methodenentwicklung zur Erfassung der Biomasse mehrjährig verholzter Pflanzen außerhalb von Wäldern" ("Development of methods for determining the biomass of plants, outside of forests, with multiple years of wood growth") (Pöpken, 2011).

6.6.2.2 Biomass

For calculation of carbon-stock changes in biomass, in connection with land-use changes to and from Grassland, constant (over time) carbon stocks were determined for the sub-categories Grassland (in the strict sense) and Woody Grassland. Conversions from Grassland (in the strict sense) to Woody Grassland and vice-versa are treated like land-use changes. In the CRF tables, they are aggregated under 4.C.1 (Grassland remaining Grassland), however.

No carbon-stock changes are given for the biomass of areas in the sub-categories remaining in a given land use (e.g. Grassland (i.t.s.s.) and Woody Grassland), since the carbon fluxes and the wood biomass in these categories are assumed to be in an equilibrium; under the gain-loss method, therefore, $\Delta C = 0$ (Equation 2.7 in the 2006 IPCC Guidelines). The reasons for this are presented in Chapter 6.1.2.3.1. Consequently, NA (not applicable) has been entered in CRF table 4.C.1, under the headings "living biomass" and "dead organic matter," for the categories remaining in Grassland (in the strict sense) and Woody Grassland.

The method with which CO_2 emissions from biomass, as a result of land-use changes, are calculated is presented in Chapter 6.1.2.3.2, while the method used to determine activity data is described in Chapter 6.3. The emission factors, and their uncertainties, for Grassland (in the strict sense), are shown in Table 366 in Chapter 6.1.2.3.3, while those for Woody Grassland are shown in Table 376 in Chapter 6.1.2.3.5.

6.6.2.3 Mineral soils

No change in carbon stocks in mineral soils is listed for areas remaining as Grassland. The constant level of carbon stocks has been substantiated by the results obtained on 42 German long-term soil monitoring sites (Höper and Schäfer (2012), Fortmann (2012) and BLfU (2011)). The pertinent long-term observations cover a period of 20 – 25 years. During that period, most of the areas studied exhibited no changes in the carbon stocks in mineral soils. Some soils showed slight reductions, while others exhibited slight increases that nearly exactly offset the decreases, in absolute terms. There are no indications that any major changes in management of permanent grassland have occurred since 1990 that could affect carbon stocks in mineral soils. In CRF Table 4.C.1, NO (not occurring) has thus been entered in the spaces "carbon-stock changes in mineral soils" in the final land-use categories of Grassland (in the strict sense) and Woody Grassland.

Calculation of CO_2 emissions resulting from conversions to Grassland (in the strict sense) and to Woody Grassland is described in Chapter 6.1.2.1, while the pertinent emission factors and their uncertainties are described in Table 425 and Table 427 in Chapter 6.6.3. The emissions in the categories remaining in a land use are listed in CRF Table 4.C.1, while the emissions resulting from land-use changes are listed in CRF Tables 4.C.2.1-4.C.2.5. The nitrous oxide emissions from mineral soils are included in the values in CRF Tables 4(III).C and 4 (IV).2.

6.6.2.4 Organic soils

In the land-use category Grassland, CO_2, CH_4 and N_2O emissions from organic soils are reported; nitrous oxide emissions are reported solely for the sub-category Woody Grassland, however. N_2O emissions from organic soils under Grassland (in the strict sense) are reported as part of the Agriculture sector, in CRF Table 3.D.a.6 "Cultivation of Histosols" (cf. Chapter 6.5.2). To prevent double-counting, N_2O emissions from organic soils that result from conversions to grassland (in a strict sense) are listed in the LULUCF tables with the notation key "IE". A discussion of the area differences with regard to Grassland as reported in the LULUCF sector and the relevant values listed in CRF Table 3.D.a.6 "Cultivation of Histosols," for the agricultural sector, is provided in Chapter 6.1.2.2.1. The methods used to calculate emissions from organic soils, and to derive the relevant emission factors, are described in Chapter 6.1.2.2.

The annual emissions following land-use changes to Grassland (in the strict sense) are calculated with the same methodology used for emissions from organic soils in the sub-category Grassland (in a strict sense) remaining Grassland (in the strict sense). A similar approach is taken with emissions from organic soils following land-use conversions to Woody Grassland; they are calculated in same way that emissions from the category Woody Grassland remaining Woody Grassland are calculated. The emissions in the categories in the same land use are listed in CRF Table 4.C.1, while the emissions resulting from land-use changes are listed in CRF Tables 4.C.2.1-4.C.2.5. Methane emissions from organic soils and from drainage ditches are included in the values in CRF Table 4.II.C, while nitrous oxide emissions from the sub-category Woody Grassland are presented in 4(II).H.

6.6.3 Uncertainties and time-series consistency (4.C)

Table 425 The total uncertainty for the land-use category Grassland is 42.4 % (half of the 95 % confidence interval), while that for the sub-category Grassland (in the strict sense) is 47.1 %, and that for Woody Grassland is 19.5 %. In the sub-category Grassland (in the strict sense), CO_2 emissions from organic soils make the largest contribution to the sub-category's total uncertainty, and they dominate the Grassland category's contribution to the uncertainty of the overall inventory. In the sub-category Woody Grassland, the phytomass pool is particularly noticeable. Its contribution to the uncertainty of the inventory as a whole is marginal, however.

Table 425and Table 428 show the uncertainties relative to the emission factors for the sub-categories Grassland (in the strict sense) and Woody Grassland. As a rule, the distribution functions show a log-normal distribution, and they are characterised by their upper and lower uncertainty boundaries. The uncertainties for the mineral soils pool in the two sub-categories are of about the same order of magnitude. With regard to biomass, the uncertainties for the emission factors are higher for the sub-category Woody Grassland. Those uncertainties reflect the great diversity of relevant grasslands with woody content in Germany. With respect to the uncertainties for the emission factors for CO_2, nitrous oxide and methane from organic soils, the statements made in Chapter 6.5.3 apply.

The uncertainties for the activity data have a normal distribution, with values between 0.6 – 209.2 % for half of the 95 % confidence interval. In this case as well, the uncertainty depends on the sample size, i.e. on the area share being considered. Weighted by area, the total uncertainty for activity data in the category Grassland is 1.34 %.

The total uncertainty for the land-use category Grassland is 42.4 % (half of the 95 % confidence interval), while that for the sub-category Grassland (in the strict sense) is 47.1 %, and that for Woody Grassland is 19.5 %. In the sub-category Grassland (in the strict sense), CO_2 emissions from organic soils make the largest contribution to the sub-category's total uncertainty, and they dominate the Grassland category's contribution to the uncertainty of the overall inventory. In the sub-category Woody Grassland, the phytomass pool is particularly noticeable. Its contribution to the uncertainty of the inventory as a whole is marginal, however.

Table 425: Emission factors [t C ha^{-1} a^{-1}], with uncertainties [% of location scale], as used for calculation of 2017 GHG emissions from Grassland (in the strict sense)

Grassland$_{i.t.s.s.}$ Initial land use Mineral soils CO_2-C[139]	Final land use	Emission factor [t C ha^{-1} a^{-1}]	Uncertainty bounds upper [%]	lower [%]
Forest Land	Grassland$_{i.t.s.s.}$	0.76	25.3	42.3
Cropland	Grassland$_{i.t.s.s.}$	0.87	29.6	49.1
Woody Grassland	Grassland$_{i.t.s.s.}$	0.21	31.5	56.9
Terr. Wetlands	Grassland$_{i.t.s.s.}$	0.17	31.8	47.4
Waters	Grassland$_{i.t.s.s.}$	0.00	45.9	77.9
Settlements	Grassland$_{i.t.s.s.}$	0.94	32.6	57.5
Other Land	Grassland$_{i.t.s.s.}$	1.09	32.6	59.7
Biomass[140]		**[t C ha^{-1} 1 a^{-1}]**	**[t C ha^{-1} 1 a^{-1}]**	**[%]**
Forest Land	Grassland$_{i.t.s.s.}$	-47.85	22.4	22.4
Cropland	Grassland$_{i.t.s.s.}$	0.11	16.3	16.3
Woody Grassland	Grassland$_{i.t.s.s.}$	-36.35	47.0	47.9
Terr. Wetlands	Grassland$_{i.t.s.s.}$	-12.12	34.0	34.6
Waters	Grassland$_{i.t.s.s.}$	6.81	30.3	30.3
Settlements	Grassland$_{i.t.s.s.}$	-5.68	32.2	32.8
Other Land	Grassland$_{i.t.s.s.}$	6.81	30.3	30.3
Dead organic matter[141]		**[t C ha^{-1} 1 a^{-1}]**	**[t C ha^{-1} 1 a^{-1}]**	**[%]**
Forest Land	Grassland$_{i.t.s.s.}$	-20.65	6.2	6.2

Forest Land, Cropland: annually variable; all other factors are constant

[139] Calculation covers a 20-year period; stock change: positive ≙ sink; negative ≙ source

[140] Calculation only for first year of land-use change, stock change: positive ≙ sink; negative ≙ source

[141] Calculation only for first year of land-use change, stock change: positive ≙ sink; negative ≙ source

Table 426: Uncertainties for emission factors [2.5 and 97.5 percentile, in % of location scale] for emissions from organic soils, Grassland (in a strict sense), 2017

Land use Organic soil[142]	GHG	Emission factor [t CO_2-eq. ha^{-1} a^{-1}]	Uncertainty bounds lower [%]	 upper [%]
Grassland in the strict sense	CO_2	25.05	55.4	28.4
Grassland in the strict sense	N_2O	1.17	99.4	222.7
Grassland in the strict sense	CH_4	0.53	46.9	258.6

Table 427: Emission factors [t C ha^{-1} a^{-1}], with uncertainties [% of location scale], as used for calculation of GHG emissions in 2017 from Woody Grassland

Woody Grassland Initial land use Mineral soils CO_2-C[143]	Final land use	Emission factor [t C ha^{-1} a^{-1}]	Uncertainty bounds upper [%]	 lower [%]
Forest Land	Woody Grassland	0.52	23.2	44.0
Cropland	Woody Grassland	0.66	27.9	51.1
Grassland in the strict sense	Woody Grassland	-0.21	31.5	56.9
Terr. Wetlands	Woody Grassland	-0.04	30.7	49.1
Waters	Woody Grassland	0.00	42.9	83.3
Settlements	Woody Grassland	0.73	31.2	85.0
Other Land	Woody Grassland	0.88	31.1	62.0
Mineral soil, N_2O_{direct}[144]		[kg N_2O ha^{-1} a^{-1}]	[kg N_2O ha^{-1} a^{-1}]	[%]
Grassland in the strict sense	Woody Grassland	0.263	91.6	213.9
Terr. Wetlands	Woody Grassland	0.042	91.3	211.9
Mineral soil, $N_2O_{indirect}$[145]		[kg N_2O ha^{-1} a^{-1}]	[%]	[%]
Grassland in the strict sense		0.059	100	296.6
Terr. Wetlands		0.009	100	295.2
Biomass[146]		[Mg C ha^{-1} a^{-1}]	[Mg C ha^{-1} a^{-1}]	[%]
Forest Land	Woody Grassland	-11.50	27.7	28.1
Cropland	Woody Grassland	36.46	46.6	47.8
Grassland in the strict sense	Woody Grassland	36.35	47.0	47.9
Terr. Wetlands	Woody Grassland	24.23	34.0	34.6
Waters	Woody Grassland	43.16	54.2	55.2
Settlements	Woody Grassland	30.67	43.3	44.2
Other Land	Woody Grassland	43.16	54.2	55.2
Dead organic matter[147]		[Mg C ha^{-1} a^{-1}]	[Mg C ha^{-1} a^{-1}]	[%]
Forest Land	Woody Grassland	-20.65	6.2	6.2

Forest Land, Cropland: annually variable; all other factors are constant

142 Annual calculation; emission: positive ≙ source; negative ≙ sink
143 Calculation covers a 20-year period; stock change: positive ≙ sink; negative ≙ source
144 Calculation covers a 20-year period; emission: positive ≙ source; negative ≙ sink
145 Calculation covers a 20-year period; emission: positive ≙ source; negative ≙ sink
146 Calculation only for first year of land-use change, stock change: positive ≙ sink; negative ≙ source
147 Calculation only for first year of land-use change, stock change: positive ≙ sink; negative ≙ source

Table 428: Uncertainties for emission factors [2.5 and 97.5 percentile, in % of location scale] for emissions from organic soils under Woody Grassland, 2017

Land use	GHG	Emission factor	Uncertainty bounds	
			lower	upper
Organic soil[148]		[t CO_2-eq. ha^{-1} a^{-1}]	[%]	[%]
Woody Grassland	CO_2	10.46	21.0	24.6
Woody Grassland	N_2O	0.34	93.8	200.7
Woody Grassland	CH_4	0.15	95.2	1,011.6

For both the sub-categories Grassland (in the strict sense) and Woody Grassland, the calculations are spatially and chronologically consistent and complete for the entire reporting period, 1990-2016.

6.6.4 Category-specific quality assurance / control and verification (4.C)

Details regarding this year's reviews are provided in Chapter 6.1.3.

The data sources used in preparation of this inventory fulfill the review criteria of the QSE manual for data sources (QSE-Handbuch für Datenquellen). Quality assurance for input data (ATKIS®, BÜK, official statistics) is the responsibility of the relevant data administrators (cf. the pertinent documentation in the inventory description).

The emissions-calculation results as presented in the present report cannot be compared with other relevant data sources for Germany, since no such other data sources exist that meet applicable requirements, i.e. provide nationwide coverage, are comprehensive and are independent of the methods and data sources described in the present report.

To provide context for the German results, the national IEF for the various pools were compared with the corresponding values for Germany's neighbours. For this comparison, the emission factors given in the 2017 Submissions to the UNFCC Secretariat were used. The 2017 factors for Germany were taken from the current 2019 Submission. As the following tables show, Germany's IEF for CO_2 from drainage of organic soils under grassland is similar to those of neighbouring countries with similarly intensive peatland use, such as Switzerland and the Netherlands.

In category 4.C.1, the carbon-stock changes in mineral soils and in biomass, as reported for Germany, refer to changes between Grassland (in the strict sense) and Woody Grassland. The mean emission factors are very low, since only a small area share is involved. Such changes are handled very differently from country to country, and thus the relevant mean emission factors of different countries cannot be directly compared.

In Germany, the land-use changes to Grassland have produced a strong carbon sink in mineral soils; the pertinent values are similar to those of two countries that share borders with Germany, Austria and France. Overall, the German IEF for 2015/2017 is somewhat higher than the average of the values for the other countries. In addition, Germany's IEF for biomass in conversion categories does not differ significantly from those of the neighbouring countries. It is similar to the values of Belgium and the UK, it is nearly neutral (slight source) and it is somewhat higher than the mean value, which corresponds to a stronger source. The spread for the IEF for biomass is considerably larger than it is in connection with mineral soils, however. The reason for this has to do with country-specific category boundaries – and, thus, with category composition (in Germany, the figure is a mixed value reflecting Grassland (in the strict sense) and Woody Grassland).

[148] Annual calculation; emission: positive ≙ source; negative ≙ sink

Table 429: Carbon-stock changes in living biomass, in grassland of various countries (Germany, for 2015 & 2017; other countries, for 2015)

Country	4.C.1. - Grassland Remaining Grassland [t C ha^{-1} a^{-1}]	4.C.2 – Land Converted To Grassland [t C ha^{-1} a^{-1}]	4.C.2.1 - Forest Land Converted To Grassland [t C ha^{-1} a^{-1}]	4.C.2.2 - Cropland Converted To Grassland [t C ha^{-1} a^{-1}]	4.C.2.3 - Wetlands Converted To Grassland [t C ha^{-1} a^{-1}]	4.C.2.4 - Settlements Converted To Grassland [t C ha^{-1} a^{-1}]	4.C.2.5 - Other Land Converted To Grassland [t C ha^{-1} a^{-1}]
Belgium	NO	-1.19	-11.63	NO	NO	NO	NO
Denmark	-0.36	-0.35	-4.85	-0.25	-2.66	NO	NO
France	0.02	-0.08	-1.14	0.03	NE	0.53	NE
UK	-0.001	-0.02	-2.33	0.03	NO,IE	-0.04	NO
Netherlands	NE	-0.17	-6.66	0.13	0.5	0.62	0.55
Austria	NO	-0.86	-1.28	-0.43	NO	NO	NO
Poland	NO	0.36	NO	NO,IE	2.1	2.1	NO
Switzerland	0.01	-0.8	-3.55	0.08	0.52	0.21	0.45
Czech Republic	NO	0.001	-3.24	0.05	0.27	NO	NO
Germany, 2015	**0.03**	**-0.002**	**-1.27**	**0.17**	**0.04**	**0.03**	**NO**
Germany, 2017	**0.0325**	**0.0068**	**-1.3140**	**0.1716**	**-0.0416**	**0.0285**	**NO**

Positive: Carbon sink; negative: Carbon source; Source: (UNFCCC, 2018a)

Table 430: Carbon-stock changes in dead organic matter, in grassland of various countries (Germany, for 2015 & 2017; other countries, for 2015)

Country	4.C.1. - Grassland Remaining Grassland [t C ha^{-1} a^{-1}]	4.C.2 – Land Converted To Grassland [t C ha^{-1} a^{-1}]	4.C.2.1 - Forest Land Converted To Grassland [t C ha^{-1} a^{-1}]	4.C.2.2 - Cropland Converted To Grassland [t C ha^{-1} a^{-1}]	4.C.2.3 - Wetlands Converted To Grassland [t C ha^{-1} a^{-1}]	4.C.2.4 - Settlements Converted To Grassland [t C ha^{-1} a^{-1}]	4.C.2.5 - Other Land Converted To Grassland [t C ha^{-1} a^{-1}]
Belgium	NO	-0.09	-0.85	NO	NO	NO	NO
Denmark	NO	-0.09	-4.18	NO	NO	NO	NO
France	NE	-0.02	-0.13	NE	NE	NE	NE
UK	NO	-0.01	-0.42	IE	NO,IE	NO,IE	NO
Netherlands	NE	-0.15	-2.65	NE	NE	NE	NE
Austria	NO	-0.42	-0.81	NO	NO	NO	NO
Poland	NO	NO,IE	NO	IE	NO	NO	NO
Switzerland	NO	-0.34	-1.29	NO	NO	NO	NO
Czech Republic	NO	-0.001	-0.08	NO	NO	NO	NO
Germany, 2015	**IE**	**-0.07**	**-0.73**	**IE**	**IE**	**IE**	**IE**
Germany, 2017	**IE**	**-0.0745**	**-0.7586**	**IE**	**IE**	**IE**	**IE**

Positive: Carbon sink; negative: Carbon source; Source: (UNFCCC, 2018a)

Table 431: Carbon-stock changes in mineral soils, in grassland of various countries (Germany, for 2015 & 2017; other countries, for 2015)

Country	4.C.1. - Grassland Remaining Grassland [t C ha^{-1} a^{-1}]	4.C.2 – Land Converted To Grassland [t C ha^{-1} a^{-1}]	4.C.2.1 - Forest Land Converted To Grassland [t C ha^{-1} a^{-1}]	4.C.2.2 - Cropland Converted To Grassland [t C ha^{-1} a^{-1}]	4.C.2.3 - Wetlands Converted To Grassland [t C ha^{-1} a^{-1}]	4.C.2.4 - Settlements Converted To Grassland [t C ha^{-1} a^{-1}]	4.C.2.5 - Other Land Converted To Grassland [t C ha^{-1} a^{-1}]
Belgium	0.2	1.43	-1.2	1.8	-0.72	1.73	
Denmark	NO	0.001	0.05	IE	-0.32	NO	NO
France	-0.003	0.97	0.01	1.08	NO	1.78	NE
UK	0.12	0.63	-1.44	0.6	NO,IE	1.8	NO
Netherlands	0.0004	0.68	0.59	0.7	0.02	0.6	3.62
Austria	0.002	0.89	0.8	1	NO	NO	NO
Poland	-0.01	0.84	NO	1.02	NO	NO	NO
Switzerland	0.01	0.49	-0.64	0.51	2.24	1.26	2.07
Czech Republic	0.09	0.47	0.17	0.52	NO	NO	NO
Germany, 2015	**-0.002**	**0.82**	**0.75**	**0.84**	**0.01**	**0.89**	**1.05**
Germany, 2017	**-0.0024**	**0.8133**	**0.6962**	**0.8418**	**0.0193**	**0.8873**	**1.0544**

Positive: Carbon sink; negative: Carbon source; Source: (UNFCCC, 2018a)

Table 432: Carbon-stock changes in organic soils, in grassland of various countries (Germany, for 2015 & 2017; other countries, for 2015)

Country	4.C.1. - Grassland Remaining Grassland [t C ha^{-1} a^{-1}]	4.C.2 – Land Converted To Grassland [t C ha^{-1} a^{-1}]	4.C.2.1 - Forest Land Converted To Grassland [t C ha^{-1} a^{-1}]	4.C.2.2 - Cropland Converted To Grassland [t C ha^{-1} a^{-1}]	4.C.2.3 - Wetlands Converted To Grassland [t C ha^{-1} a^{-1}]	4.C.2.4 - Settlements Converted To Grassland [t C ha^{-1} a^{-1}]	4.C.2.5 - Other Land Converted To Grassland [t C ha^{-1} a^{-1}]
Belgium	-2.5	NO	NO	NO	NO	NO	NO
Denmark	-5.4	-8.73	-8.73	IE	NO	NO	NO
France	NO	NO,NE	NO	NO	NE	NO	NO
UK	NO,IE	-0.25	NO,IE	-0.25	-0.25	NO,IE	NO
Netherlands	-4.62	-4.21	-2.89	-4.21	-4.53	-4.47	-2.05
Austria	-6.4	NO	NO	NO	NO	NO	NO
Poland	-0.25	NO	NO	NO	NO	NO	NO
Switzerland	-9.07	-9.02	-8.73	-9.29	-8.17	-5.36	2.87
Czech Republic	NO	NO	NO	NO	NO	NO	NO
Germany, 2015	**-6.19**	**-6.37**	**-6.01**	**-6.57**	**-6.08**	**-5.96**	**-6.83**
Germany, 2017	**-6.1749**	**-6.3561**	**-6.0540**	**-6.5654**	**-6.0273**	**-5.9008**	**-6.8276**

Positive: Carbon sink; negative: Carbon source; Source: (UNFCCC, 2018a)

6.6.5 Category-specific recalculations (4.C)

No recalculations were carried out for the present Submission. .

6.6.6 Planned improvements, category-specific (4.C)

No further improvement measures are planned at present. Information about the implementation status of planned improvements in the LULUCF sector is presented in Chapter 6.1.4.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

6.7 Wetlands (4.D)

6.7.1 Category description (4.D)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
L/T	**4.D Wetlands**		**CO_2**	**4,063.95**	**0.33%**	**3,968.72**	**0.45%**	**-2.3%**
-/-	4.D. Wetlands		CH_4	41.76	0.00%	43.77	0.00%	4.8%
-/-	4.D. Wetlands		N_2O	21.56	0.00%	22.63	0.00%	4.9%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 2	RS/NS	CS
N_2O	Tier 2	RS/NS	CS/D
CH_4	Tier 2	RS/NS	CS

The source category *Wetlands* is a key category for CO_2 emissions in terms of emissions level and trend.

In Germany, the land-use category Wetlands primarily includes the country's few undrained semi-natural peatlands that are largely free of anthropogenic impacts. It also includes a range of other wetlands that in the present report are combined under the sub-categories Terrestrial Wetlands, Waters and flooded land, and Peat-extraction areas used for production of horticultural peat.

Quantified area allocations to the individual sub-categories, as well as remarks regarding the pools and GHG from the remaining and conversion categories that, pursuant to the 2006 IPCC Guidelines (IPCC, 2006) and the 2013 IPCC Wetland Supplements (IPCC et al., 2014b), are to be reported on, are presented in Chapter 6.2.4.

The results of the emissions calculations for the year 2017 are shown in Table 433, while the emissions trends, by categories and sub-categories, are presented in Figure 69 and Figure 70.

Table 433: CO_2, N_2O and CH_4 emissions [kt CO_2-eq.] from Germany's wetlands, 2017. The table includes both the relevant sums and the upper and lower bounds of the 95 % confidence intervals.

Sub-category / Pool	GHG	Peat extraction [kt CO_2-eq.] Emission	2.5 perc.	97.5 perc.	[%] 2.5 perc.	97.5 perc.
Peat extraction$_{total}$		**2,138.3**	1,341.2	2,935.5	37.3	37.3
Mineral soils	CO_2	NO	NO	NO	NO	NO
	N_2O	NO	NO	NO	NO	NO
Organic soil	CO_2	**2,124.9**	1,327.7	2,921.9	37.5	37.5
	N_2O	7.9	2.9	12.9	63.4	63.4
	CH_4	5.6	1.9	10.7	65.3	92.9
Biomass	CO_2	/	/	/	/	/
Litter / dead wood	CO_2	/	/	/	/	/
Waters						
Sub-category / Pool	**GHG**	**[kt CO_2-eq.] Emission**	**2.5 perc.**	**97.5 perc.**	**[%] 2.5 perc.**	**97.5 perc.**
Waters$_{total}$		57.5	42.4	73.1	26.5	26.7
Mineral soils	CO_2	/	/	/	/	/
	N_2O	/	/	/	/	/
Organic soil	CO_2	/	/	/	/	/
	N_2O	/	/	/	/	/
	CH_4	/	/	/	/	/
Biomass	CO_2	52.2	37.2	67.4	28.8	29.0
Litter / dead wood	CO_2	5.4	2.6	8.2	51.6	51.6
Terrestrial Wetlands						
Sub-category / Pool	**GHG**	**[kt CO_2-eq.] Emission**	**2.5 perc.**	**97.5 perc.**	**[%] 2.5 perc.**	**97.5 perc.**
Terrestrial Wetlands$_{total}$		**1,839.1**	1,013.7	2,505.1	44.9	36.2
Mineral soils	CO_2	**0.7**	0.2	1.2	66.0	69.1
	N_2O_{direct}	**0.3**	0.0	1.1	100	234.4
	$N_2O_{indirect}$[149]	**0.1**	0.0	0.3	100.0	311.7
Organic soil	CO_2	**1,821.6**	950.8	2,493.4	47.8	36.9
	N_2O	**14.3**	0.0	49.2	100.0	243.4
	CH_4	**38.2**	14.2	241.7	62.9	532.5
Biomass	CO_2	-40.6	-28.5	-52.9	29.9	30.2
Litter / dead wood	CO_2	4.6	2.1	7.0	53.5	53.5

In 2017, a total of 4,035.1 kt CO_2-eq. were released from Wetlands (95 % confidence interval: 2,883.3 – 5,073.8 kt CO_2-eq.). As Table 433 shows, emissions from the land-use category Wetlands come primarily from organic soils, and in such soils the emissions break down into the two nearly equal parts of CO_2 emissions via peat extraction (53.8 %) and CO_2 emissions via drainage of terrestrial organic soils (46.2 %). Releases of methane (1.1 %) and nitrous oxide (0.6 %) are very low, in comparison to the total emissions, as are CO_2 emissions from dead organic matter (0.25 %) and biomass (0.29 %). In the sub-category Waters, the latter (CO_2 releases from biomass) function as a source, while in the sub-category Terrestrial Wetlands, they function as a sink. The emissions from mineral soils are negligibly low (< 0.03 %). .

Emissions from industrial peat extraction are divided into emissions that occur in extraction areas, during peat extraction (on-site emissions), and emissions that are released during application of peat products (off-site emissions). In 2017, the latter amounted to 2,007.6 ± 750.9 kt CO_2-eq. and thus were the main factor responsible for the magnitude of total emissions from peat extraction (93.9 %). The on-site emissions, at 130.7 kt CO_2-eq., (-9.9 % ± 11.5 %), are relatively low by contrast. Their dominant component is CO_2 (89,7 %); methane (4.3 %) and nitrous oxide emissions (6.1 %) play marginal roles.

As the time series in Figure 69 and Figure 70 show, total emissions decreased in 2017 with respect to the base year (-2.2 %), but the individual changes over time remained incremental overall. The

[149] The category-specific indirect N_2O emissions are not included and shown as such in the CRF tables; they are included, however, in the sum presented in CRF Table 4.(IV).2 for all sub-categories.

shape of the curve is determined primarily by peat extraction – it reflects the annual peat-production quantities – while emissions from organic soils in the sub-category Terrestrial Wetlands remain at a rather constantly high level, with few changes over the period concerned (± 2.2 %).

Figure 69: CO_2 emissions [kt CO_2-eq.] from Wetlands, as a result of land use and land-use changes, 1990-2017, by sub-categories

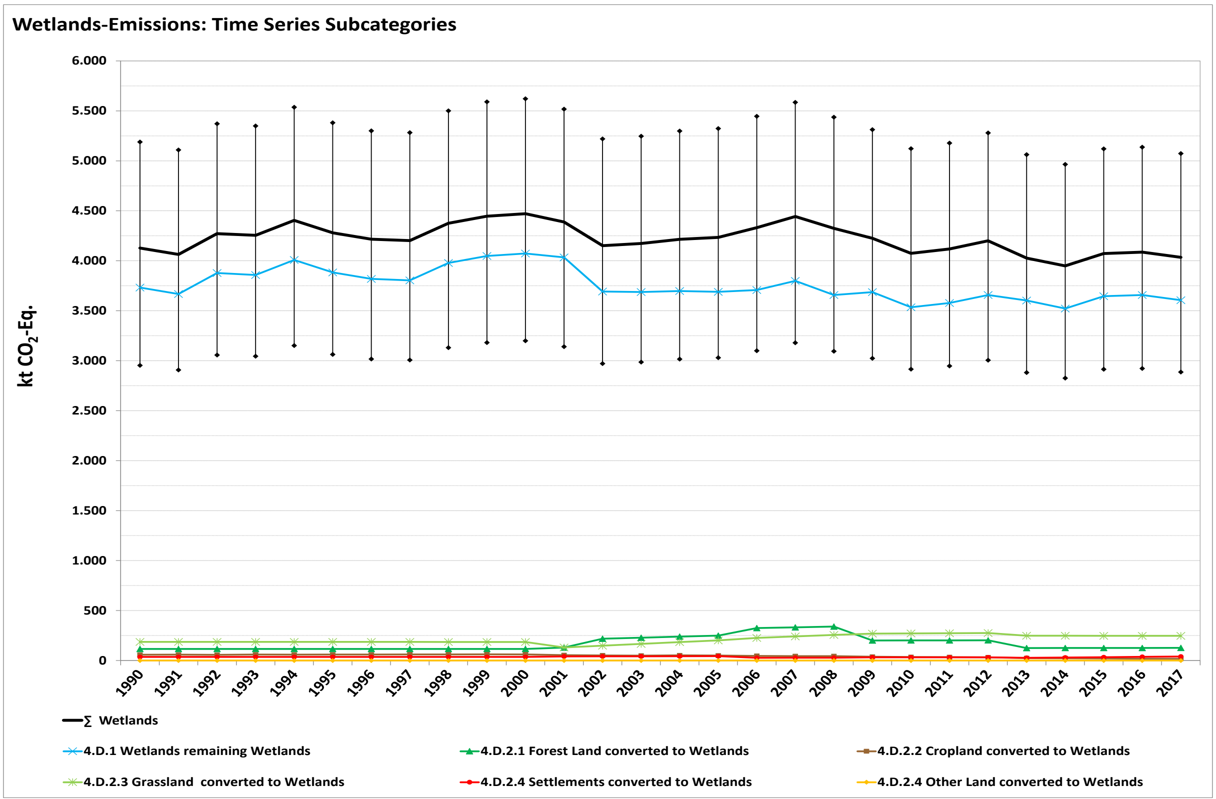
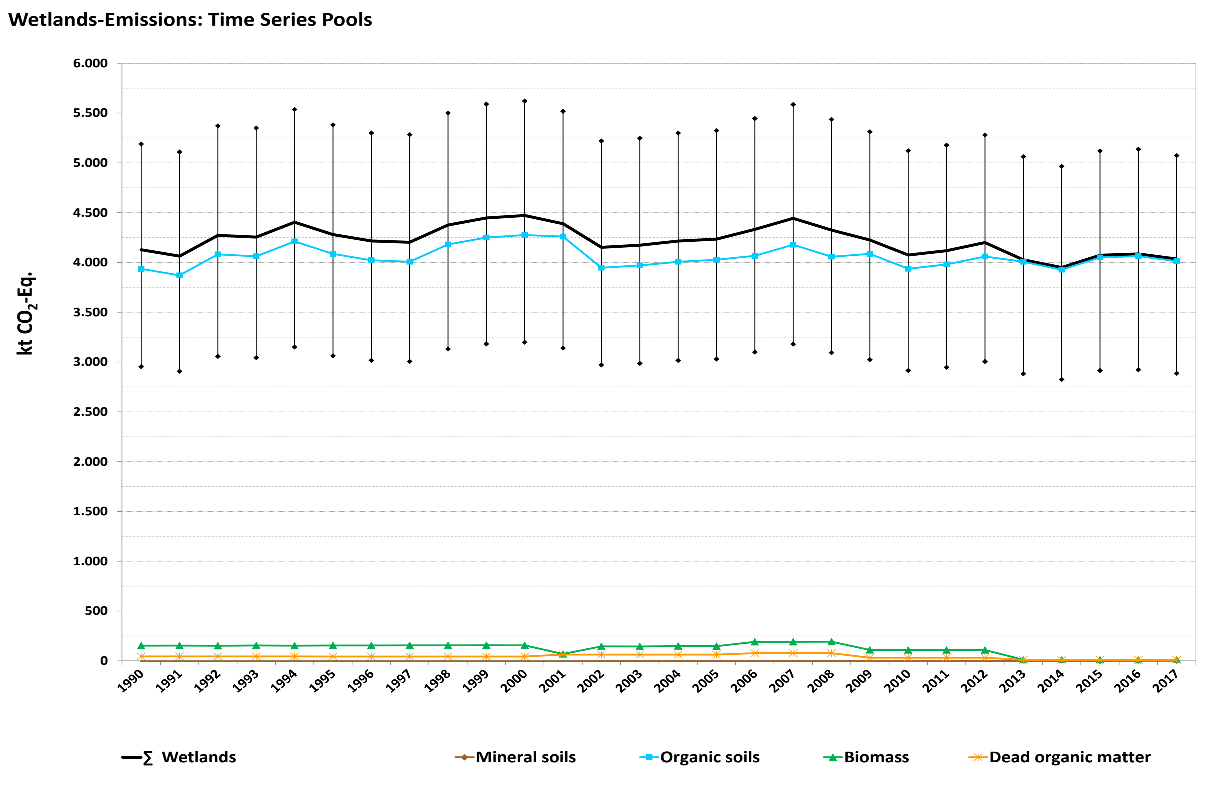


Figure 70: **CO_2 emissions [kt CO_2-eq.] from Wetlands, as a result of land use and land-use changes, 1990-2017, by pools**



6.7.2 Methodological issues (4.D)

6.7.2.1 Data sources

The production-quantity data for industrial peat extraction were taken from official German statistics (Statistisches Bundesamt, FS 4, R 3.1).

For further sources, cf. Chapters 6.3.2 and 6.2.

6.7.2.2 Biomass

Water areas are free of vegetation cover, and thus the biomass carbon stocks are zero and are always reported in the CRF tables as NO (not occurring).

For the sub-category Terrestrial Wetlands, changes in biomass carbon stocks, as a result of land-use changes, are calculated with the procedures and methods described in Chapter 6.1.2.3.

As a rule, Terrestrial Wetlands are covered with trees and shrubs (throughout a spectrum ranging from scattered bushes to actual forests), mosses and grasses, with mosses and grasses predominating. Accordingly, the inventory uses the following assumption relative to the area-related distribution of carbon stocks in biomass: 1/3 trees and shrubs and 2/3 mosses and grasses.

Since no biomass surveys of such lands have been carried out in Germany, the relevant values for Woody Grassland and Grassland (in the strict sense) are used as approximations. **Therefore, the reporting methods are in keeping with those set forth in Chapter 6.6.2.2.**

The carbon stocks in Terrestrial Wetlands can then be calculated pursuant to Equation50. The relevant results are shown in Table 434.

Equation50:

$$C\ stocks_{terr.\ wetlands} = C\ stocks_{Woody\ Grassland} * 0.333 + C\ stocks_{Grassland\ (in\ the\ strict\ sense)} * 0.667$$

Table 434: Area-related carbon stocks [t C ha^{-1}] for biomass in Terrestrial Wetlands (95% confidence interval)

Terr. Wetlands	Carbon stocks [t C ha^{-1}] Biomass, total	Biomass, above-ground	Biomass, below-ground
Terr. Wetlands	18.93 (10.84 - 27.16)	13.42 (6.04 - 20.91)	5.51 (2.65 - 8.49)

The emission factors and pertinent uncertainties are presented in Table 436 (Chapter 6.7.3).

In keeping with the statements made in Chapter **6.6.2.2**, living biomass and dead organic matter are reported as NO (not occurring) in the relevant categories remaining in a land use of CRF table 4.D.1.

6.7.2.3 Mineral soils

It was assumed that no changes in the carbon stocks of mineral soils occurred in connection with land-use conversions to water bodies (NO in CRF table 4.D.1).

For the sub-category Terrestrial Wetlands, changes in mineral-soil organic carbon stocks, as a result of land-use changes, are calculated with the procedures and methods described in Chapter 6.1.2.1.

The emission factors and pertinent uncertainties are presented in Table 436 (Chapter 6.7.3).

6.7.2.4 Organic soils

Country-specific emission factors for organic soils in the sub-category Terrestrial Wetlands were determined in a national research project. As a result, carbon-dioxide, nitrous-oxide and methane releases are also reported in this sub-category (cf. Chapter 6.1.2.2).

6.7.2.4.1 Peat extraction

Greenhouse-gas emissions from peat extraction were calculated in conformance with the provisions of the 2006 IPCC Guidelines, following the Tier 2 methodology. The total emissions, comprising both on-site and off-site emissions, were calculated via the equations 7.2 - 7.5 of the 2006 IPCC Guidelines (IPCC, 2006). In the sub-category Peat extraction, CO_2 emissions (on-site (emissions and DOC); off-site), CH_4 emissions (emissions, and emissions from drainage ditches) and N_2O emissions (on-site) are reported. The manner in which the relevant emission factors are derived is described in Chapter 6.1.2.2. The estimates are based on the following activity data:

- Calculation of on-site emissions: The areas of the lands on which industrial peat extraction takes place were determined with the help of the Basis-DLM (cf. Chapter 6.3). Since the relevant complete data sets were not added to the Basis-DLM until the year 2011, the peat-extraction area determined for 2011 has been used for calculation of on-site emissions for all relevant years. The total extraction area has been a constant 19,857 ha.
- Calculation of off-site emissions: annual production quantities; these are obtained from official German statistics (Statistisches Bundesamt, FS 4, R 3.1).

Equation 7.3 (IPCC, 2006)

$$CO_2\text{-eq.}_{peat\ extraction} = CO_2\text{-eq.}_{on\text{-}site} + CO_2\text{-eq.}_{off\text{-}site}$$

CO_2-eq.$_{peat\ extraction}$: GHG emissions from peat extraction [t CO^2-eq. a^{-1}]

CO_2-eq.$_{on\text{-}site}$: GHG emissions that occur on-site, during production [t CO_2-eq. a^{-1}]

CO_2-eq.$_{off\text{-}site}$: GHG emissions that occur via extracted peat that is spread for horticultural purposes [t CO_2-eq. a^{-1}]

In Germany, only peat from raised bogs is extracted. For this reason, Equation 7.4 (IPCC, 2006) was modified in the following manner:

$$CO_2\text{-eq.}_{\text{on-site}} = A_{\text{peat, oligotrophic}} \times (EF_{\text{peat, oligotrophic\_CO2}} + EF_{\text{peat, oligotrophic\_N2O}} + EF_{\text{peat, oligotrophic\_CH4}})$$

CO_2-eq. $_{\text{on-site}}$: On-site emissions that occur on site during peat production [t CO_2-eq. a^{-1}]

$A_{\text{peat, oligotrophic}}$: Peat-extraction area on raised bogs [ha]

$EF_{\text{peat, oligotrophic\_(CO2, N2O, CH4)}}$: Country-specific emission factors for raised bogs on which peat extraction is taking place [t CO_2-eq. ha^{-1} a^{-1}] (cf. Chapter 6.1.2.2)

Off-site emissions were calculated with Equation 7.5 (IPCC, 2006):

$$CO_2\text{-eq.}_{\text{off-site}} = Vol_{\text{peat\_dry}} \times Cfraction_{\text{vol\_peat}}$$

$CO_{2\text{off-site}}$: CO_2-eq. emissions that occur via extracted peat that is spread for horticultural purposes [t CO_2-eq. a^{-1}]

$Vol_{\text{peat\_dry}}$: Volume of air-dried peat [m^3]

$C_{\text{fraction vol\_peat}}$: Carbon fraction with respect to the volume of air-dried peat [0.2567 t CO_2-eq. m^3 air-dried peat (IPCC (2006), Tab. 7.5)]

Table 435: Implied emission factors (IEF) [t CO_2-eq. ha^{-1} a^{-1}] and emissions [kt CO_2-eq.] from peat extraction in Germany

Peat extraction	IEF			Emissions [t CO_2-eq.]		
Year	[t CO_2-eq. ha^{-1} a^{-1}]	on-site CO_2	on-site NO	on-site CH_4	off-site	Σ peat extraction
1990	108.79	117.2	7.9	5.6	2,029.5	2,160.2 ± 800.7
1995	117.57	117.2	7.9	5.6	2,203.9	2,334.6 ± 869.0
2000	128.26	117.2	7.9	5.6	2,416.2	2,546.9 ± 952.3
2005	116.35	117.2	7.9	5.6	2,179.6	2,310.3 ± 859.5
2010	106.87	117.2	7.9	5.6	1,991.5	2,122.2 ± 785.8
2011	108.84	117.2	7.9	5.6	2,030.5	2,161.2 ± 801.1
2012	112.64	117.2	7.9	5.6	2,106.0	2,236.7 ± 830.7
2013	109.42	117.2	7.9	5.6	2,042.0	2,172.7 ± 805.6
2014	104.92	117.2	7.9	5.6	1,952.7	2,083.4 ± 765.6
2015	110.65	117.2	7.9	5.6	2,066.4	2,197.1 ± 810.2
2016	110.80	117.2	7.9	5.6	2,069.5	2,200.2 ± 811.4
2017	107.68	117.2	7.9	5.6	2,007.6	2138.4 ± 787.1

6.7.3 Uncertainties and time-series consistency (4.D)

The time series for activity data provided by the Federal Statistical Office for peat extraction are consistent and available for the entire reporting period. Pursuant to the Federal Statistical Office, the uncertainties for these activity data are "0", since the data have been obtained via an exhaustive survey entailing an obligation to provide information. Nonetheless, an uncertainty of 20 % is assumed, in keeping with the 2006 IPCC Guidelines. That uncertainty is due primarily to the uncertainty in conversion, for peat, of volume units to mass units. The uncertainties listed in Table 436 and Table 437, ranging up to 40 % for Peat extraction, are the result of uncertainties propagation. They are due especially to the large uncertainties in the IPCC default values used. The statements made in Chapter 6.5.3 and Chapter 6.6.3 also apply to the uncertainties for the emission factors for methane and nitrous oxide.

The activity data and area data have a normal distribution. Their uncertainties, depending on the area and sampling sizes involved, range from 3 to 200 %. The total uncertainty for the area data in the category Wetlands is 4.5 %.

The total uncertainty for the category Wetlands is 28.6 % [half of the 95% confidence interval], while that for the sub-category Terrestrial Wetlands is 44.9 %, that for Waters is 26.7 % and that for Peat extraction is 37.3 %. The Wetlands category's contributions to the total emissions and the total uncertainty in the LULUCF sector are very small. Only the values relating to Peat extraction are large enough to be noticeable.

Table 436: Emission factors and uncertainties [in % of location scale] used for calculation of GHG emissions from Germany's Wetlands in 2016, by pools and sub-categories

Wetlands$_{terrestrial}$ Initial land use	Final land use	Emission factors	Uncertainty bounds lower	Uncertainty bounds upper	Waters Final land use	Emission factors	Uncertainty bounds upper	Uncertainty bounds lower
Mineral soils CO_2-C[150]		[t C ha^{-1} a^{-1}]	[%]	[%]		[t C ha^{-1} a^{-1}]	[%]	[%]
Forest Land	**Wetlands$_{terrestrial}$**	0.67	23.8	28.2	**Waters**	No emissions		
Cropland	**Wetlands$_{terrestrial}$**	0.70	28.4	36.8	**Waters**	No emissions		
Grassland$_{i.t.s.s.}$	**Wetlands$_{terrestrial}$**	-0.17	31.8	47.4	**Waters**	No emissions		
Woody Grassland	**Wetlands$_{terrestrial}$**	0.04	30.7	49.1	**Waters**	No emissions		
Settlements	**Wetlands$_{terrestrial}$**	0.77	31.6	47.6	**Waters**	No emissions		
Waters	**Wetlands$_{terrestrial}$**	0	43.9	52.5	**Waters**	No emissions		
Other Land	**Wetlands$_{terrestrial}$**	0.92	31.5	49.8	**Waters**	No emissions		
Mineral soil, N_2O_{direct}[151]		[kg N_2O ha^{-1} a^{-1}]	[kg N_2O ha^{-1} a^{-1}]	[%]	[%]		[kg N_2O ha^{-1} a^{-1}]	[kg N_2O ha^{-1} a^{-1}]
Grassland$_{i.t.s.s.}$	**Wetlands$_{terrestrial}$**	0.213	91.7	211.5	**Waters**	No emissions		
Mineral soil, $N_2O_{indirect}$[152]		[kg N_2O ha^{-1} a^{-1}]	[kg N_2O ha^{-1} a^{-1}]	[%]	[%]		[kg N_2O ha^{-1} a^{-1}]	[kg N_2O ha^{-1} a^{-1}]
Grassland$_{i.t.s.s.}$	**Wetlands$_{terrestrial}$**	0.048	100.0	294.9	**Waters**	No emissions		
Biomass[153]		[t C ha^{-1} a^{-1}]	[%]	[%]		[t C ha^{-1} a^{-1}]	[%]	[%]
Forest Land	**Wetlands$_{terrestrial}$**	-35.73	21.6	21.7	**Waters**	-54.66	25.0	25.0
Cropland	**Wetlands$_{terrestrial}$**	12.23	31.7	32.3	**Waters**	-6.70	11.5	11.5
Grassland (in the strict sense)	**Wetlands$_{terrestrial}$**	12.12	32.4	33.0	**Waters**	-6.81	30.3	30.3
Woody Grassland	**Wetlands$_{terrestrial}$**	-24.24	34.0	34.6	**Waters**	-43.16	54.2	55.2
Wetlands$_{terrestrial}$	**Wetlands$_{terrestrial}$**	0	0	0	**Waters**	-18.93	42.7	43.5
Waters	**Wetlands$_{terrestrial}$**	18.93	42.7	43.5	**Waters**	0	0	0
Settlements	**Wetlands$_{terrestrial}$**	6.43	31.8	32.4	**Waters**	-12.49	47.0	47.9
Other Land	**Wetlands$_{terrestrial}$**	18.93	42.7	43.5	**Waters**	0	0	0
Dead organic matter		[t C ha^{-1} a^{-1}]	[t C ha^{-1} a^{-1}]	[%]	[%]		[%]	[%]
Forest Land	**Wetlands$_{terrestrial}$**	-20.65	6.2	6.2	Waters	-20.65	6.2	6.2

Positive: sink; negative: source

150 Calculation covers a 20-year period; stock change: positive ≙ sink; negative ≙ source

151 Calculation covers a 20-year period; emission: positive ≙ source; negative ≙ sink,

152 Calculation covers a 20-year period; emission: positive ≙ source; negative ≙ sink,

153 Calculation only for the first year following the pertinent land-use change

Table 437: **Uncertainties for emission factors [2.5 and 97.5 percentile, in % of location scale] for emissions from organic soils, for Wetlands and peat extraction, 2017**

Land use	GHG	Emission factor	Uncertainty bounds	
			lower	upper
Organic soil[154]		[t CO_2-eq. ha^{-1} a^{-1}]	%	%
$Wetlands_{terrestrial}$	CO_2	18.25	59.9	46.1
$Wetlands_{terrestrial}$	N_2O	0.14	100.0	306.2
$Wetlands_{terrestrial}$	CH_4	0.38	78.9	669.9
Peat extraction	CO_2	5.90	9.7	11.2
Peat extraction	N_2O	0.40	46.9	258.9
Peat extraction	CH_4	0.28	65.3	92.9

The calculations are spatially and chronologically consistent and complete for the entire reporting period, 1990 – 2017.

6.7.4 Source-specific QA/QC and verification (4.D)

Details regarding this year's reviews are provided in Chapter 6.1.3.

The data sources used in preparation of this inventory fulfill the review criteria of the QSE manual for data sources (QSE-Handbuch für Datenquellen). Quality assurance for input data (ATKIS®, BÜK, official statistics) is the responsibility of the relevant data administrators (cf. the pertinent documentation in the inventory description).

The emissions-calculation results as presented in the present report cannot be compared with other relevant data sources for Germany, since no such other data sources exist that meet applicable requirements, i.e. provide nationwide coverage, are comprehensive and are independent of the methods and data sources described in the present report.

A comparison of Germany's implied emission factors, in the Wetlands category, with those of European neighbouring countries (Table 438) shows that the IEF hardly lend themselves to comparison. This is due to differences between the pertinent combinations of soil types. In the organic soils pool, for example, in category 4.D.1, Germany has the second-largest emission factor (after that of the UK). In Germany, peat extraction is counted with off-site emissions included. National definitions play an especially strong role in the Wetlands category. Since the applicable national circumstances differ widely from country to country, the various implied emission factors span a wide range overall.

Values of neighbouring countries, as reported in the countries' 2017 Submissions to the UNFCC Secretariat, were used for this comparison. The values for Germany were obtained from the current 2019 Submission.

[154] Annual calculation; emission: positive ≙ source; negative ≙ sink

Table 438: Carbon-stock changes in various pools, in wetlands of various countries (Germany, for 2015 & 2017; other countries, for 2015)

Country	4.D.1. 4.E.1 – Wetlands Remaining Wetlands			4.D.2 – Land Converted To Wetlands			
	Biomass	Dead organic matter	Organic soils	Biomass	Dead organic matter	Mineral soils	Organic soils
	[t C ha⁻¹ a⁻¹]	[t C ha⁻¹ a⁻¹]	[t C ha⁻¹ a⁻¹]	[t C ha⁻¹ a⁻¹]	[t C ha⁻¹ a⁻¹]	[t C ha⁻¹ a⁻¹]	[t C ha⁻¹ a⁻¹]
Belgium	NO	NO	NO	NO,IE	0.22	1.13	NO
Denmark	NO,NE	NO,NE	-3.83	0.001	NO	NO	NO
France	NE	NE	NE	-0.5	-0.06	NO	NE
UK	NE,NA,NO	NE,NA,NO	-12.95	0	NO	NO	-0.2
Netherlands	NO,NE	NO,NE	NO	-0.65	-0.11	0.68	-0.32
Austria	NO,NE	NO,NE	NO,NE	-0.48	-0.15	NO	NO
Poland	-0.002	NO	-3.33	-0.07	NO,NA	-0.06	NO
Switzerland	0.0001	NO,IE	-4.87	-1.01	-0.18	-0.79	-4.09
Czech Republic[1)]	NO	NO	NO	-0.52	-0.01	NO	NO
Germany, 2015	**0.0001**	**NO**	**-8.77**	**-0.04**	**-0.03**	**0.001**	**-4.03**
Germany, 2017	**0.0001**	**IE**	**-8.5841**	**-0.0382**	**-0.0318**	**-0.0032**	**-4.0603**

Positive: Carbon sink; negative: Carbon source; Source: (UNFCCC, 2018a)

[1)] "Land Converted to Wetland" values only for "FL, CL, GL converted to other wetlands"

6.7.5 Category-specific recalculations (4.D)

No recalculations were carried out for the present Submission.

6.7.6 Planned improvements, category-specific (4.D)

No further improvements are planned at present. Information about the implementation status of planned improvements in the LULUCF sector is presented in Chapter 6.1.4.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

6.8 Settlements (4.E)

6.8.1 Category description (4.E)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
L/T	**4.E Settlements**		**CO_2**	**1,810.65**	**0.15%**	**3,472.35**	**0.39%**	**91.8%**
-/-	4.E. Settlements		N_2O	143.05	0.01%	226.15	0.03%	58.1%
-/-	4.E. Settlements		CH_4	24.02	0.00%	45.13	0.01%	87.9%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	Tier 2	RS/NS	CS
N_2O	Tier 2	RS/NS	CS/D
CH_4	Tier 2	RS/NS	CS

The category *Settlements* is a key category for CO_2 emissions in terms of emissions level and trend, and pursuant to Tier 2 analysis.

Reporting for the land-use category Settlements has to cover CO_2 emissions / removals in the pools soil, biomass and dead organic matter on land designated for settlement and transport uses. Precise definitions and category allocations are presented in Chapter 6.2. The results of the estimation of relevant GHG emissions are presented in Table 439 and in Figure 71 and Figure 72.

Table 439: CO_2, N_2O and CH_4 emissions [kt CO_2-eq.] from Germany's Settlements, 2017. The table includes both the relevant sums and the upper and lower bounds of the 95 % confidence interval.

Category	GHG	Emissions, Settlements, 2017 [kt CO_2-eq.] Emission	2.5 perc.	97.5 perc.	[%] 2.5 perc.	97.5 perc.
Settlements$_{total}$ [155]		**3,743.6**	3,200.6	4,224.9	14.5	12.9
Mineral soils	CO_2[156]	**1,038.1**	759.2	1,513.7	26.9	45.8
	N_2O_{direct} [157]	**103.6**	26.8	281.4	74.1	171.6
	$N_2O_{indirect}$ [158]	**23.0**	0	77.7	99.9	237.5
Organic soil	CO_2[156]	**2,129.4**	1,449.5	2,486.3	31.9	16.8
	N_2O[159]	**99.2**	42.7	225.7	57.0	127.5
	CH_4[159]	**45.1**	32.9	111.9	27.1	148.0
Biomass	CO_2[156]	**-45.8**	-38.1	-53.7	16.9	17.1
Litter / dead wood	CO_2[156]	**350.7**	298.0	403.4	15.0	15.0

In 2017, the CO_2 emissions from Germany's settlement and transport areas, as a result of land use and land-use changes, amounted to 3,743.6 kt CO_2 (Table 439). The majority (60.7 %) of that quantity was caused by drainage of organic soils. Emissions from mineral soils also contributed significantly to the emissions sum, with a share of 31.1 %. These emissions are caused primarily by land-use changes from Cropland(59.6 %), Grassland (in the strict sense) (26.7 %) and Forest Land (9.9 %) to Settlements (Figure 71).

With respect to the base year, a net emissions increase of 1,765.9 kt CO_2 ≙ 89.3 % occurred in 2017 (cf. Figure 71 and Figure 72). The trend has a clear direction, and it is being driven primarily by conversion of Cropland and Grassland areas for settlement purposes (in previous years, it was also driven significantly by conversion of Forest Land). An emissions increase (Grassland, 47 %; Forest Land, 120 %; Wetlands, 440 %), and a considerable decrease in sink function (Cropland, -56 %; Other Land, -81 %), are seen in all categories. In addition, conversion of wetlands areas in particular has led to a continual increase of emissions from organic soils.

The shapes of the time-series plots – especially the noticeable changes they show – are due primarily to the changes in area data that have occurred as of the relevant explicitly defined survey dates (cf. Chapter 6.3.5).

155 Sum of the emissions from CRF tables 4.E, 4.(II).H, 4.(III).E, 4.(IV).2
156 CRF table 4.E
157 CRF table 4.(III).E
158 The category-specific indirect N_2O emissions are not included and shown as such in the CRF tables; they are included, however, in the sum, for all sub-categories, presented in CRF Table 4.(IV).2.
159 CRF table 4.(II).H

Figure 71: CO_2 emissions [kt CO_2-eq.] as a result of settlement-related land use and land-use changes, 1990 – 2017, by sub-categories

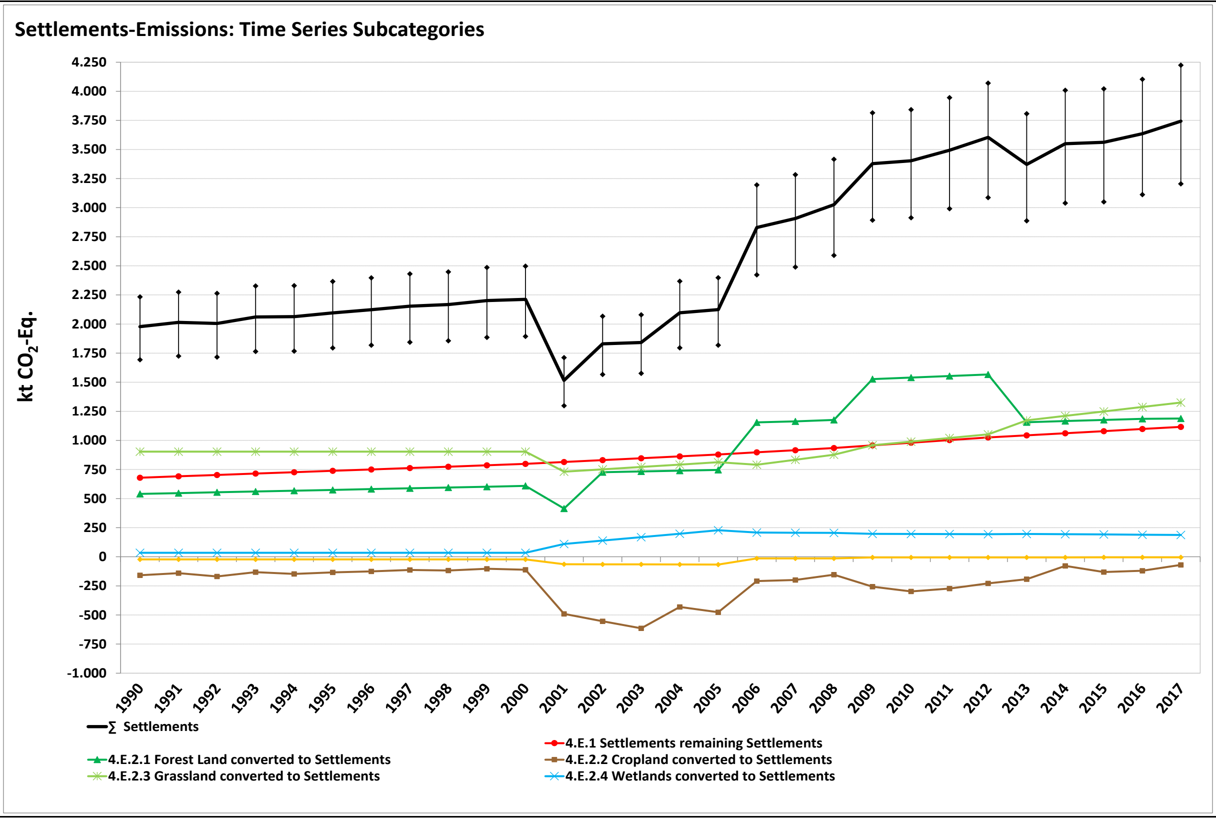
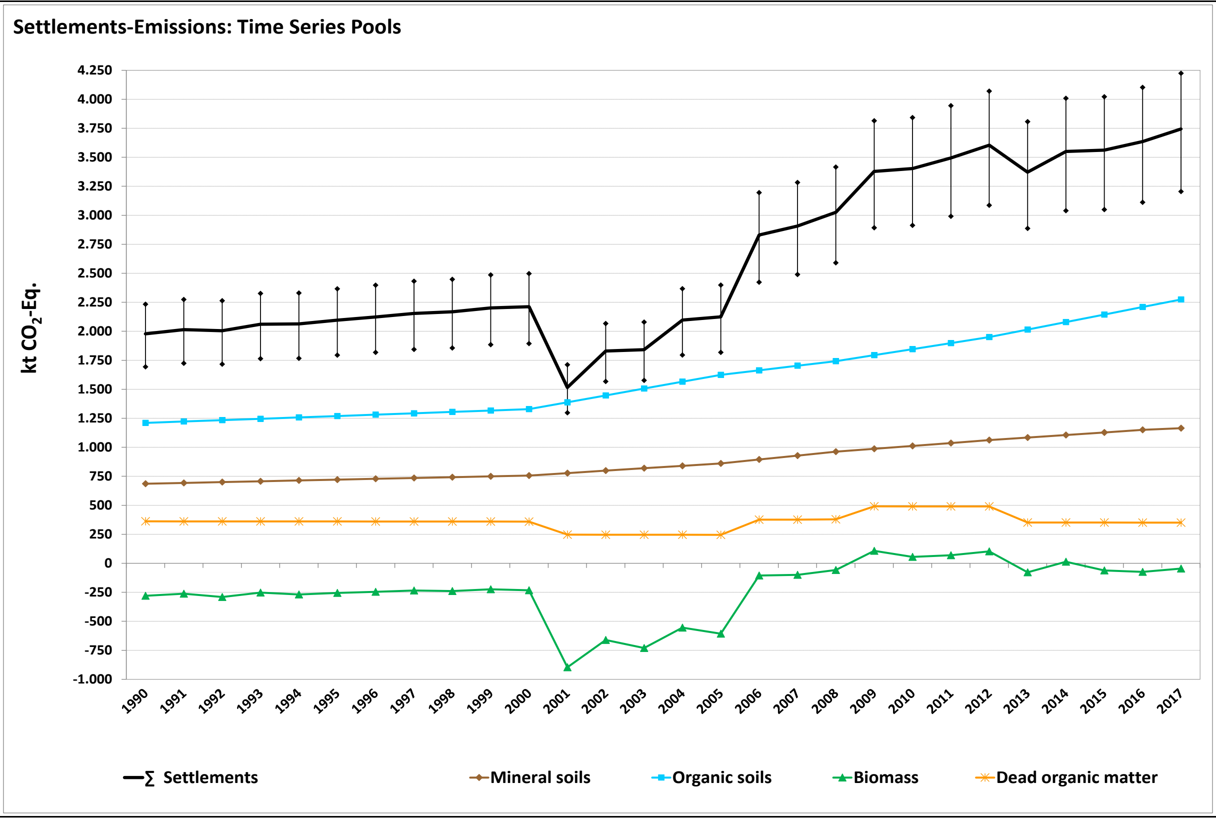


Figure 72: CO_2 emissions [kt CO_2-eq.] from Germany's Settlements, as a result of land use and land-use changes, 1990 – 2017, by pools



6.8.2 Methodological issues (4.E)

6.8.2.1 Data sources

Further information about the data sources is provided in Chapter 6.3.2.

6.8.2.2 Biomass

Settlement and transport areas tend to feature significant portions of unsealed land that is covered with vegetation. Representative-sample studies of the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR), an institute sited within the Federal Office for Building and Regional Planning (BBR), have shown that built-over and sealed areas account for 40 – 50 % of designated settlement and transport areas (EINIG et al., 2009). In the German inventory, areas covered with vegetation are thus assumed to account for an average of 50 % of settlement areas.

No data have been collected specifically for biomass and carbon stocks on such areas within Germany's settlement and transport areas. The following assumption is used as a way of compensating for that lack: half of all areas covered with vegetation consist of ecosystems similar to Woody Grassland and half consist of green areas similar to Grassland (in the strict sense). That assumption is approximately in keeping with the corresponding basic figures used in Switzerland. Via remote sensing, it was determined there that trees and shrubs account for 47.4 % of plant cover, with trees accounting for 32.1 % and shrubs accounting for 15.3 % (FOEN 2010). Since settlement and transport areas tend to have an enormous variety of trees and shrubs – including small-garden shrubs, many different types of hedges and large trees along roads and in forests – the tree/shrub biomass in this land-use category was determined on the basis of the country-specific value for Woody Grassland. **For this reason, no carbon-stock changes in woody-plant biomass are reported in the category Settlements remaining Settlements** (NO in CRF table 4.E.1 for living biomass and dead organic matter). **In addition, the calculation rules as described in Chapter 6.6.2.2 apply.** The carbon stocks in the biomass of settlement areas can then be calculated pursuant to Equation51. The relevant results are shown in Table 440.

Equation51:

$$C\ stocks_{settlements} = (C\ stocks_{Woody\ Grassland} * 0.5 + C\ stocks_{Grassland\ (in\ the\ strict\ sense)} * 0.5) * 0.5$$

Table 440: Area-related carbon stocks [t ha^{-1}] in biomass on settlement areas (95% confidence interval)

Settlements	Carbon stocks [t C ha^{-1}]		
	Biomass, total	Biomass, above-ground	Biomass, below-ground
Settlements	12.49 (6.62 - 18.47)	9.12 (3.55 - 14.77)	3.38 (1.51 - 5.32)

6.8.2.3 Mineral soils

In the case of Settlements remaining Settlements, it is assumed that no carbon-stock changes in mineral soils occur. Carbon-stock changes are reported for land-use conversions to Settlements, however. Further information about the methods used is provided in Chapter 6.1.2.1. The manner in which the emission factor has been derived and verified, with the sealed area being taken into account, is described in Chapter 6.1.2.1.66.1.2.1.6.

6.8.2.4 Organic soils

It has also been assumed that organic soils in Settlements have been drained. Since no data have been collected specifically with regard to drainage of organic soils in Settlements, it is assumed that such soils are drained in the same manner that Grassland is drained, and thus the relevant emission factor for such drainage is used (Chapter 6.6.2.4).

In cases involving land-use conversions to Settlements, the relevant value for Settlements remaining Settlements is used from the outset.

6.8.3 Uncertainties and time-series consistency (4.E)

The consistency of the time series is assured with regard to the activity data and emission factors.

The emission factors and uncertainties for the land-use category Settlements are listed in Table 441 and Table 442. In general, the uncertainties show a log-normal distribution, with the exception of those for CO_2 from organic soils, which have a right-skewed distribution. The remarks presented in Chapter 6.5.3 apply to the major uncertainties relative to direct and indirect nitrogen emissions. The uncertainties for the activity data, depending on the area size concerned, range from 2.5% to -91.5 % for the year 2017. The total uncertainty for the activity data in the Settlements category is 2.3 %.

The total uncertainty for the Settlements land-use category is 14.5 % [half of the 95-% confidence interval]. It is determined, to equal degrees, by emissions from organic soils, biomass and mineral soils.

Table 441: Uncertainties of emission factors [in % of location scale] used for calculation of GHG emissions from Germany's settlement and transport areas in 2017, by pools and sub-categories

Settlements	Area	Emission factor	Uncertainty bounds	
Initial land use	Final land use		upper	lower
Mineral soils CO_2-C[160]		[t C ha^{-1} a^{-1}]	[%]	[%]
Forest Land	Settlements	-0.18	22.1	40.5
Cropland	Settlements	-0.07	27.9	49.2
Grassland in the strict sense	Settlements	-0.94	32.6	57.5
Woody Grassland	Settlements	-0.73	31.2	59.7
Terr. Wetlands	Settlements	-0.77	31.6	47.6
Waters	Settlements	0.00	45.1	85.0
Other Land	Settlements	0.15	31.7	62.8
Mineral soil, N_2O_{direct}[161]		[kg N_2O ha^{-1} a^{-1}]	[%]	[%]
Forest Land	Settlements	0.150	73.4	204.1
Cropland	Settlements	0.087	90.4	211.9
Grassland (in the strict sense)	Settlements	1.162	92.0	214.6
Woody Grassland	Settlements	0.932	96.2	222.3
Terr. Wetlands	Settlements	0.780	91.6	211.6
Mineral soil, $N_2O_{indirect}$[162]		[kg N_2O ha^{-1} a^{-1}]	[%]	[%]
Forest Land	Settlements	0.034	100.0	289.6
Cropland	Settlements	0.019	100.0	295.2
Grassland (in the strict sense)	Settlements	0.261	100.0	296.7
Woody Grassland	Settlements	0.210	100.0	297.1
Terr. Wetlands	Settlements	0.175	100.0	294.9
Biomass[163]		[kt C ha^{-1} 1 a^{-1}]	[%]	[%]
Forest Land	Settlements	-42.17	22.1	22.2
Cropland	Settlements	5.79	30.9	31.4
Grassland in the strict sense	Settlements	5.68	32.2	32.8
Woody Grassland	Settlements	-30.67	43.3	44.1
Terr. Wetlands	Settlements	-6.43	31.8	32.4
Waters	Settlements	12.49	47.0	47.8
Other Land	Settlements	12.49	47.0	47.9
Dead organic matter[164]		[kt C ha^{-1} 1 a^{-1}]	[kt C ha^{-1} 1 a^{-1}]	[%]
Forest Land	Settlements	-20.65	6.2	6.2

160 Calculation covers a 20-year period; stock change: positive ≙ sink; negative ≙ source
161 Calculation covers a 20-year period; emission: positive ≙ source; negative ≙ sink
162 Calculation covers a 20-year period; emission: positive ≙ source; negative ≙ sink
163 Calculation only for first year of land-use change, stock change: positive ≙ sink; negative ≙ source
164 Calculation only for first year of land-use change, stock change: positive ≙ sink; negative ≙ source

Table 442: Uncertainties for emission factors [2.5 and 97.5 percentile, in % of location scale] for emissions from organic soils in Settlements, 2017

Land use	GHG	Emission factor	Uncertainty bounds	
			lower	upper
Organic soil[165]		[t CO_2-eq. ha^{-1} a^{-1}]	[%]	[%]
Settlements	CO_2	27.1	55.4	28.4
Settlements	N_2O	1.3	99.4	222.7
Settlements	CH_4	0.6	46.9	258.6

6.8.4 Source-specific quality assurance / control and verification (4.E)

Details regarding this year's reviews are provided in Chapter 6.1.3.

The data sources used in preparation of this inventory fulfill the review criteria of the QSE manual for data sources (QSE-Handbuch für Datenquellen). Internally, data processing is checked pursuant to Thünen Institute (2012). Quality assurance for input data (ATKIS®, BÜK, official statistics) is the responsibility of the relevant data administrators (cf. the pertinent documentation in the inventory description).

The emissions-calculation results as presented in the present report cannot be compared with other relevant data sources for Germany, since no such other data sources exist that meet applicable requirements, i.e. provide nationwide coverage, are comprehensive and are independent of the methods and data sources described in the present report.

The following tables compare Germany's implied emission factors, for the category Settlements, with those of European neighbouring countries. Values of neighbouring countries, as reported in the countries' 2017 Submissions to the UNFCC Secretariat, were used for this comparison. The values for Germany were obtained from the current 2019 Submission. .

Only Germany, Switzerland, the Netherlands and the UK report CO_2 emissions from drained organic soils in settlement areas. The implied emission factors are referenced to the total settlement land area. Consequently, they also reflect organic soils' share of that total area. In the German inventory, other carbon-source categories are calculated only in connection with land-use conversions to Settlements (4.E.2). The emissions from soils are a source in this category. Other neighbouring countries (except for the Netherlands) report larger sources – in some cases, considerably larger – for mineral soils. Only the value for Switzerland, which comprises both organic and mineral soils, is directly comparable, however. In the current submission, the IEF for biomass shows this pool as a sink. Only Austria still reports a sink performance in the pool/sub-category combination. In all other countries included in the comparison, the biomass pool is a small-to-medium-sized source. The implied emission factors for the pools of the conversion categories depend strongly on the initial land uses involved in each case, and thus the wide range seen throughout European countries ultimately cannot be interpreted without knowledge of such land uses.

165 Annual calculation; emission: positive ≙ source; negative ≙ sink

Table 443: Carbon-stock changes in living biomass in Settlements of various countries (Germany, for 2015 & 2017; other countries, for 2015)

Country	4.E.1. - Settlements Remaining Settlements [t C ha⁻¹ a⁻¹]	4.E.2 - Land Converted To Settlements [t C ha⁻¹ a⁻¹]	4.E.2.1 - Forest Land Converted To Settlements [t C ha⁻¹ a⁻¹]	4.E.2.2 - Cropland Converted To Settlements [t C ha⁻¹ a⁻¹]	4.E.2.3 - Grasslands Converted To Settlements [t C ha⁻¹ a⁻¹]	4.E.2.4 - Wetlands Converted To Settlements [t C ha⁻¹ a⁻¹]	4.E.2.5 - Other Land Converted To Settlements [t C ha⁻¹ a⁻¹]
Belgium	NO	-0.94	-8.33	NO	NO	NO	NO
Denmark	NO	-0.18	-2.82	-0.22	-0.06	-4.64	NO
France	-0.03	-0.65	-3.93	-0.03	-0.34	NE	NE
UK	NO	-0.03	-3.14	0.07	0.04	NO	NO
Netherlands	NE	-0.81	-5.87	-0.2	-0.41	NE	NE
Austria	NO	0.45	-0.74	0.5	0.55	NO	NO
Poland	0.03	-0.18	-4.24	-0.04	NO,IE	NO	NO
Switzerland	-0.01	-0.53	-4.5	-0.07	-0.23	0.05	0.04
Czech Republic	NO	-0.3	-3.12	NO	NO	NO	NO
Germany, 2015	**NO**	**0.02**	**-2.07**	**0.31**	**0.16**	**0.09**	**NO**
Germany, 2017	**NO**	**0.0132**	**-2.0712**	**0.2899**	**0.1573**	**0.0985**	**NO**

Positive: Carbon sink; negative: Carbon source; Source: (UNFCCC, 2018a)

Table 444: Carbon-stock changes in dead organic matter in Settlements of various countries (Germany, for 2015 & 2017; other countries, for 2015)

Country	4.E.1. - Settlements Remaining Settlements [t C ha⁻¹ a⁻¹]	4.E.2 - Land Converted To Settlements [t C ha⁻¹ a⁻¹]	4.E.2.1 - Forest Land Converted To Settlements [t C ha⁻¹ a⁻¹]	4.E.2.2 - Cropland Converted To Settlements [t C ha⁻¹ a⁻¹]	4.E.2.3 - Grasslands Converted To Settlements [t C ha⁻¹ a⁻¹]	4.E.2.4 - Wetlands Converted To Settlements [t C ha⁻¹ a⁻¹]	4.E.2.5 - Other Land Converted To Settlements [t C ha⁻¹ a⁻¹]
Belgium	NO	-0.05	-0.42	NO	NO	NO	NO
Denmark	NO	-0.03	-2.27	NO	NO	NO	NO
France	NE	-0.06	-0.48	NE	NE	NE	NE
UK	NO	-0.01	-0.57	IE	NO,IE	NO	NO
Netherlands	NE	-0.19	-2.16	NE	NE	NE	NE
Austria	NO	-0.03	-0.52	NO	NO	NO	NO
Poland	NO	0.004	0.1	NO	NO	NO	NO
Switzerland	NO	-0.08	-0.93	NO	NO	NO	NO
Czech Republic	NO	-0.01	-0.08	NO	NO	NO	NO
Germany, 2015	**IE**	**-0.1**	**-1.01**	**IE**	**IE**	**IE**	**NO**
Germany, 2017	**IE**	**-0.1008**	**-1.0143**	**IE**	**IE**	**IE**	**NO**

Positive: Carbon sink; negative: Carbon source; Source: (UNFCCC, 2018a)

Table 445: Carbon-stock changes in mineral soils, in Settlements of various countries (Germany, for 2015 & 2017; other countries, for 2015)

Country	4.E.1. - Settlements Remaining Settlements [t C ha⁻¹ a⁻¹]	4.E.2 - Land Converted To Settlements [t C ha⁻¹ a⁻¹]	4.E.2.1 - Forest Land Converted To Settlements [t C ha⁻¹ a⁻¹]	4.E.2.2 - Cropland Converted To Settlements [t C ha⁻¹ a⁻¹]	4.E.2.3 - Grasslands Converted To Settlements [t C ha⁻¹ a⁻¹]	4.E.2.4 - Wetlands Converted To Settlements [t C ha⁻¹ a⁻¹]	4.E.2.5 - Other Land Converted To Settlements [t C ha⁻¹ a⁻¹]
Belgium	NO	-1.35	-3.03	-0.36	-1.78	-2.71	NO
Denmark	NO	-0.38	-0.52	-0.28	-0.55	0	NO
France	NE	-0.97	-1.64	-0.17	-1.56	NO	NE
UK	-0.37	-3.13	-4.59	-1.96	-3.59	NO	NO
Netherlands	NE	-0.24	-0.43	0.42	-0.6	-0.38	2.76
Austria	NO	-1.11	-2.84	-0.52	-1.52	NO	NO
Poland	NO	-1.52	-0.29	-2.24	-1.03	NO	NO
Switzerland	-0.02	-1.12	-1.6	-0.85	-1.21	-0.06	0.52
Czech Republic	NO	NO	NO	NO	NO	NO	NO
Germany, 2015	**NO**	**-0.31**	**-0.16**	**-0.07**	**-0.93**	**NO**	**0.15**
Germany, 2017	**NO**	**-0.3115**	**-0.1785**	**-0.0677**	**-0.9269**	**NO**	**0.1535**

Positive: Carbon sink; negative: Carbon source; Source: (UNFCCC, 2018a)

Table 446: Carbon-stock changes in organic soils, in Settlements of various countries (Germany, for 2015 & 2017; other countries, for 2015)

Country	4.E.1. - Settlements Remaining Settlements [t C ha⁻¹ a⁻¹]	4.E.2 - Land Converted To Settlements [t C ha⁻¹ a⁻¹]	4.E.2.1 - Forest Land Converted To Settlements [t C ha⁻¹ a⁻¹]	4.E.2.2 - Cropland Converted To Settlements [t C ha⁻¹ a⁻¹]	4.E.2.3 - Grasslands Converted To Settlements [t C ha⁻¹ a⁻¹]	4.E.2.4 - Wetlands Converted To Settlements [t C ha⁻¹ a⁻¹]	4.E.2.5 - Other Land Converted To Settlements [t C ha⁻¹ a⁻¹]
Belgium	NO	NO	NO	NO	NO	NO	NO
Denmark	NO	NO	NO	NO	NO	NO	NO
France	NO	NO,NE	NO	NO	NO	NE	NO
UK	NO,IE	-5	NO,IE	NO,IE	-5	NO	NO
Netherlands	-4.5	-4.4	-4.1	-4.24	-4.49	-4.47	-4.54
Austria	NO	NO	NO	NO	NO	NO	NO
Poland	NO	NO	NO	NO	NO	NO	NO
Switzerland	-2.86	-7.53	-7.05	-7.52	-7.63	-7.36	NO
Czech Republic	NO	NO	NO	NO	NO	NO	NO
Germany, 2015	**-7.4**	**-7.4**	**-7.4**	**-7.4**	**-7.4**	**-7.4**	**-7.4**
Germany, 2017	**-7.4**	**-7.4**	**-7.4**	**-7.4**	**-7.4**	**-7.4**	**-7.4**

Positive: Carbon sink; negative: Carbon source; Source: (UNFCCC, 2018a)

6.8.5 Category-specific recalculations (4.E)

For the present Submission, no pool-specific or sub-category-specific recalculations were carried out in the Settlements category.

6.8.6 Planned improvements, category-specific (4.E)

No further improvements are planned at present. Information about the implementation status of planned improvements in the LULUCF sector is presented in Chapter 6.1.4.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

6.9 Other Land (4.F)

6.9.1 Category description (4.F)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
-/-	4.F. Other Land	0	CO_2	0.0	0.00%	0.0	0.00%	---

Since, by definition, the areas in the land-use category Other Land consist of areas that are not managed, the sizes of such areas are included solely for the purpose of completing the area matrix. Emissions within the meaning of the 2006 IPCC Guidelines cannot occur on such areas. Therefore, no emissions are reported. For this reason, NO is entered in all relevant cells of CRF table 4.F, with the exception of the space for the area of the remaining category.

6.9.2 Methodological issues (4.F)

In emissions calculation, Other Land areas are taken into account solely as the initial land-use category in connection with land-use conversions to other categories. No conversions back to Other Land take place, since, by definition, land that has been used once can no longer be returned to an unused land-use category.

The carbon stocks in the categories biomass, dead wood and dead organic matter of Other Land are zero.

The carbon stocks in mineral soils of Other Land are listed in Chapter 6.1.2.

Organic soils in Other Land are not drained.

6.9.3 Uncertainties and time-series consistency (4.F)

The uncertainties for the emission factors and the activity data were determined in accordance with the 2006 IPCC Guidelines (IPCC, 2006). Additional relevant information is provided in Chapter 6.1.2.10.

The time series is complete and consistent.

6.9.4 Source-specific quality assurance / control and verification (4.F)

Details regarding this year's reviews are provided in Chapter 6.1.3.

6.9.5 Category-specific recalculations (4.F)

Not applicable, since no greenhouse-gas sources and sinks are reported in this category.

6.9.6 Planned improvements, category-specific (4.F)

Not applicable, since no greenhouse-gas sources and sinks are reported in this category.

6.10 Harvested wood products (4.G)

6.10.1 Category description (4.G)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
L/T	4.G Harvested wood products		CO_2	-1,330.35	-0.11%	-3,036.67	-0.34%	128.3%

Gas	Method used	Source for the activity data	Emission factors used
CO_2	CS/Tier 2	IS/NS	D

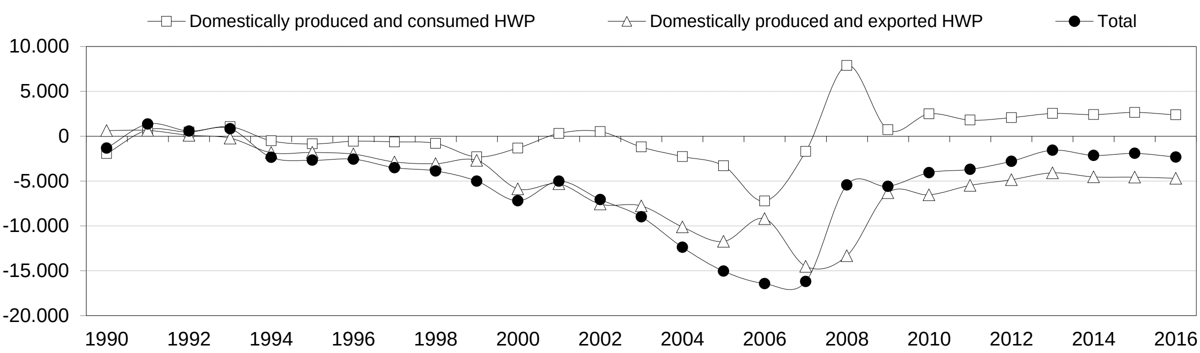
The source category Harvested Wood Products is a key category in terms of emissions level and trend.

As in the previous years, the contribution of HWP in the LULUCF sector in Germany, in terms of greenhouse emissions by sources and removals by sinks, was estimated with the WoodCarbonMonitor model, via a calculation approach based on production data for wood products. The estimation covers all harvested wood products that are produced in Germany, that consist of wood which originates from trees harvested in Germany and that are used for their material (not energy) value.

For reasons of consistency, the calculation conforms to the methods prescribed in Chapter 2.8 of the 2013 IPCC KP Supplement (IPCC et al., 2014a) since, pursuant to Footnote 12 in CRF Table 4.G-s1 in Annex II of Decision 24/CP.19 on revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention[166] (UNFCCC, 2014), the approach chosen (approach B; in the present case, based on production data) may refer either to the 2006 IPCC Guidelines (IPCC, 2006) or to any other IPCC methodological guidance reflecting this approach. The system boundaries described in the rules of the 2013 IPCC KP Supplement (IPCC et al., 2014a), for estimation of the contribution of HWP, are consistent with the system boundaries of the approach referred to in Table 12.1 of the 2006 IPCC Guidelines (IPCC, 2006) as "variable 2A" (production-oriented approach for wood products for material use).

In the interest of transparency, pursuant to CRF Table 4.G-s1, wood products for material use are divided into products that, following their production, are used in Germany, and products that are exported following their production. The carbon stored in wood in landfills is not taken into account. The biomass of short-rotation plantations in Germany is used exclusively for energy purposes (cf. category 1.A, Chapter 3.2), and thus that biomass is not reported under "harvested wood products" (HWP).

Figure 73: Net CO_2 emissions and removals in HWP (in kt CO_2)



6.10.2 Methodological issues (4.G)

6.10.2.1 Activity data

Figure 74 shows the development of production quantities in the semi-finished-product categories sawnwood, and wood materials, broken down by the wood quantities remaining in Germany (production, less exports) and the quantities exported (exports), since 1990. The figure is based on data of the Food and Agriculture Organization of the United Nations (FAO) (FAO 2018}. These time series are in keeping with the data proposed in the 2006 IPCC Guidelines (IPCC, 2006)

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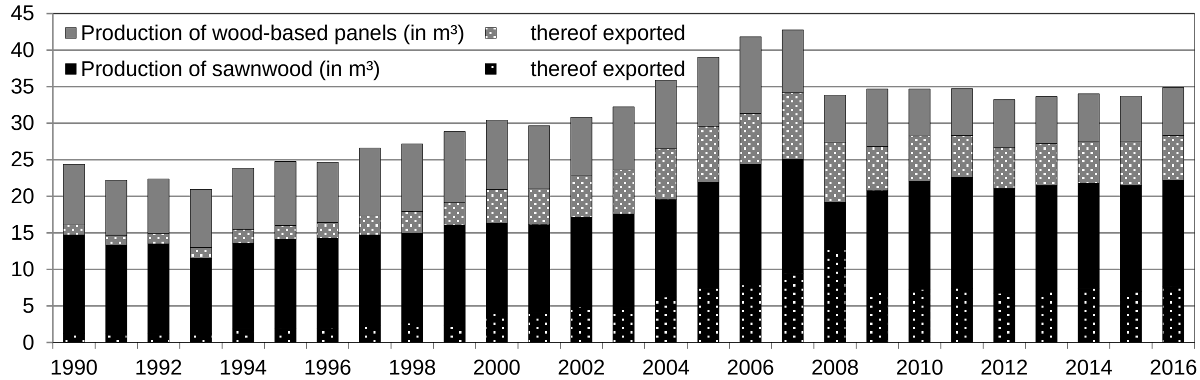
for estimation of the contribution of HWP following the Tier 1 methodology (Chapter 12.2.1 IPCC (2006): 12.9).

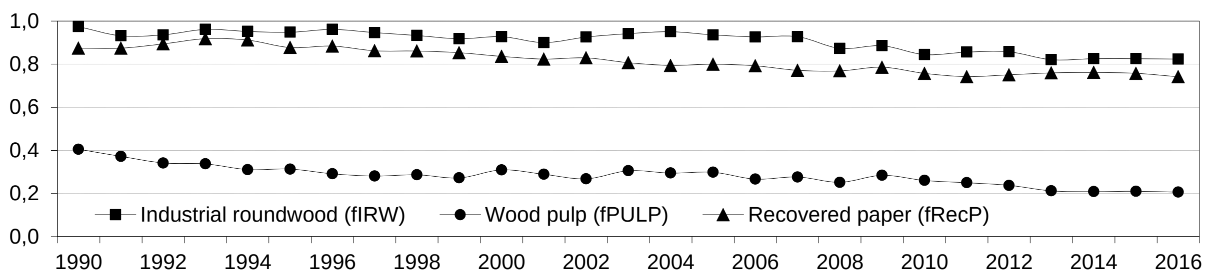
Figure 74: Sawn wood and wood materials produced in Germany [Mm³] (FAO, 2017)



In line with the IPCC Guidelines, and in a first step, the feedstock fraction in HWP from domestically harvested wood was calculated, and a domestic feedstock factor $f_{DP}(i)$ was determined. For the semi-finished-product categories sawnwood and wood materials, this factor is based on the UN FAO data on the feedstock category *industrial roundwood*. For calculation of the domestically harvested fraction in the product category paper and paperboard, the use of recovered paper in paper production was taken into account, in addition to the *wood pulp* feedstock category as proposed in the 2013 IPCC KP Supplement (IPCC et al., 2014a), since the recovered-paper fraction in produced paper and paperboard in Germany has been growing continually in recent years and now exceeds 70 %. As in the previous reporting years, the fraction *p* of recovered paper used in paper products was determined via the calculated consumption of wood pulp and recovered paper in Germany (cf. Chapter 6.10.5).

Along with the factors for industrial roundwood (fIRW) and wood pulp (fPULP), which were calculated using Equations 2.8.1 and 2.8.2 of the 2013 IPCC KP Supplement (IPCC et al. (2014a): 2.115), an additional factor for recovered paper was determined, using the same approach, with the help of UN FAO data (fRecP; Figure 75). That factor was used in the calculation of product fractions originating in the domestic harvest via Equation 2.8.4 of the 2013 IPCC KP Supplement (IPCC et al. (2014a): 2.118) for the HWP category paper and paperboard with fDP(i) = {(fIRW(i) • (1-p) • fPULP(i)} + p • fRecP(i).

Figure 75: Development of the domestic feedstock factor fDP(i) for the raw-material categories considered (FAO 2018}



In a second step (Chapter 2.8.1.2 IPCC et al. (2014a)), the carbon contained in the relevant products was allocated to the respective land-use classes from which the raw material originates. For Germany, the wood harvest can be broken down into wood harvested on Forest Land remaining Forest Land (category 4.A.1, Chapter 6.2.1), and wood harvested as a result of land-use changes from Forest Land (Table 447). In keeping with IPCC requirements, HWP from deforestation are taken into account on the basis of instantaneous oxidation (cf. Chapter 2.8.3 IPCC et al. (2014a)). Consequently, the annual wood-harvest fractions from managed forest areas can be calculated on the basis of the inventory information available for Germany and of Equation 2.8.3 (IPCC et al. (2014a): 2.116) $f_{FM}(i)$.

Table 447: Annual wood-harvest fraction from Forest Land remaining Forest Land

Time period	$f_{FM}(i)$
1990– 2002	0.98989
2003– 2007	0.99202
2008– 2012	0.98881

6.10.2.2 Emission factors

The carbon outflows from the carbon pool are calculated with the default values listed in Table 2.8.2 of the 2013 IPCC KP Supplement (IPCC et al., 2014a). Those values are based on the standard values given in Table 3a.1.3 of the 2003 IPCC GPG (IPCC, 2003).

6.10.2.3 Calculation method used

To calculate the contribution of HWP used, as material, to the delayed release of CO_2 emissions, on the basis of carbon-pool changes, Germany uses the exponential decay function described in the IPCC Guidelines, in combination with the product categories described in Table 2.8.1 of the 2013 IPCC KP Supplement. That approach is in keeping with the standard method described in the 2006 IPCC Guidelines (Equation 12.1 IPCC (2006): 12.11), as well as with the standard method, described in the 2013 IPCC KP Supplement, following a Tier 2 methodology (Equation 2.8.5). For the carbon conversion calculation, factors listed in Table 2.8.1 (IPCC et al., 2014a) are used. For the "wood materials" product categories, the detailed factors are used; for the "paper and paperboard" category, the aggregated factor is used. The carbon quantities in the product categories "non-coniferous and coniferous sawnwood" are calculated by means of the factors described in Rüter (2011) (cf. also UNFCCC (2011)), in order to take account of the wood types typically used in Germany for the production of sawnwood. For sawn softwood, the factor amounts to 0.225 t C/m^{-3}, while for hardwood lumber it is 0.335 t C/m^{-3}.

Time series, of adequate quality, for HWP and the relevant feedstock categories are available only for the period since German reunification in 1990. For that reason, and in order to reduce the uncertainties associated with the activity data, the initial value of the carbon stocks in HWP is calculated on the basis of Equation 2.8.6 (IPCC et al., 2014a), with $C(t_0)$ = 1990.

6.10.3 Uncertainties and time-series consistency (4.G)

The time series for HWP activity data from the UN FAO database are consistent and are available for the entire period covered by the report. Pursuant to the information provided in the relevant chapter of the 2013 IPCC KP Supplement (IPCC 2014a), the uncertainties for these time series amount to -25/+5 % (cf. also Chapter 11.3.1.5.3).

6.10.4 Category-specific quality assurance / control and verification (4.G)

Details regarding this year's reviews are provided in Chapter 6.1.3.

6.10.5 Category-specific recalculations (4.G)

In the current report year, the values for several product categories were corrected, with respect to the FAOSTAT 2017 statistical data that were used last year (cf. {FAO, 2018}). This is in keeping with the fact that the values given by production statistics, for the current reporting year (in the present case, for example, the values for 2017 as given in {FAOSTAT 2017}), are always provisional values. The relevant final values do not become available until the following year. The resulting changes in the determined net emissions time series, with respect to the previous year, are shown in Table 448.

Table 448: Comparison of changes, in the 2018 Submission and the 2019 Submission, with regard to net CO_2 emissions for HWP

	Net emissions [kt CO_2]	2015	2016
2018 Submission	From exported wood materials	-	-1,813
	From domestically used wood materials	-	2,206
	From exported paper and paperboard	-92	142
	From domestically used paper and paperboard	96	174
	From exported sawn lumber	-	-3,024
	From domestically used sawn lumber	-22	-14
2019 Submission	From exported wood materials	-	-1,777
	From domestically used wood materials	-	2260
	From exported paper and paperboard	-426	26
	From domestically used paper and paperboard	430	642
	From exported sawn lumber	-	-3,036
	From domestically used sawn lumber	21	126

6.10.6 Planned improvements, category-specific (4.G)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

6.11 Other sectors (4.H)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
-/-	4.H. Other	0	N_2O	IE	IE	IE	IE%	IE%

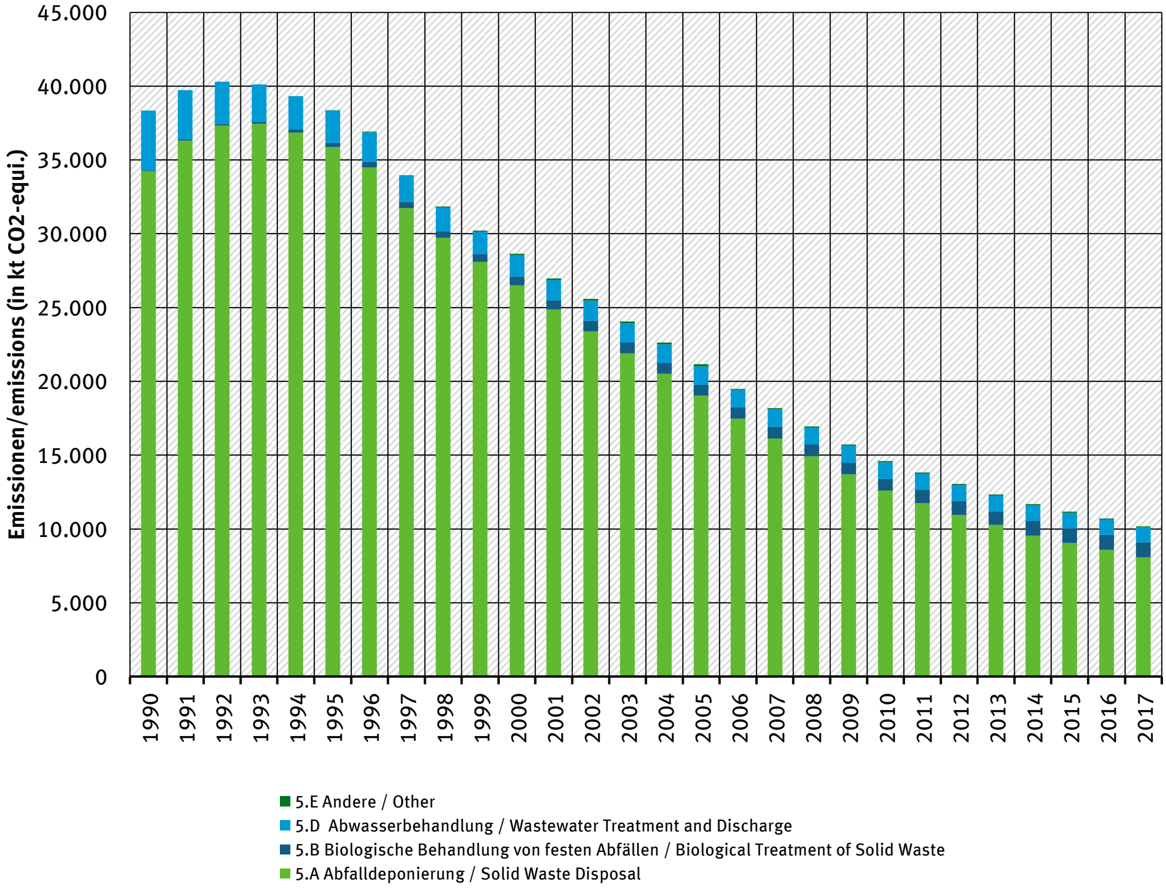
Gas	Method used	Source for the activity data	Emission factors used
-	-	-	-

In 4.H, N_2O emissions caused by cultivation of organic soils, and from the category *Settlements* (99.2 kt CO_2-eq.), for CRF Table 4 (II), are reported on a makeshift basis, because the CRF Tables of the CRF Reporter do not allow for such emissions. In the current NIR, the pertinent results are listed in the chapter on Settlements (Chapter 6.8.1).

7 Waste and Waste Water (CRF Sector 5)

7.1 Overview (CRF Sector 5)

Figure 76: Overview of greenhouse-gas emissions in CRF Sector 5



7.2 Solid waste disposal on land (5.A)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
L/T	5.A Solid Waste Disposal on Land	Managed Waste Disposal on Land	CH_4	34,250.00	2.80%	8,075.00	0.91%	-76.4%

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier 2	NS	CS

The category *Solid waste disposal on land* is a key category of CH_4 emissions in terms of emissions level and trend.

Only managed disposal in landfills (5.A.1) is relevant for purposes of German emissions reporting under CRF 5.A. "Wild" or illegal dumping of solid waste (CRF 5.A.2) is prohibited by law in Germany.

Since 2004, emissions from composting (Category 5.B.1) and from mechanical biological waste treatment (MBT; Category 5.E – Other areas – mechanical biological waste treatment) have been reported. As of the 2015 report, emissions from waste digestion (Category 5.B.2) are also reported. These changes reflect the growing importance of these additional treatment methods for biodegradable waste fractions.

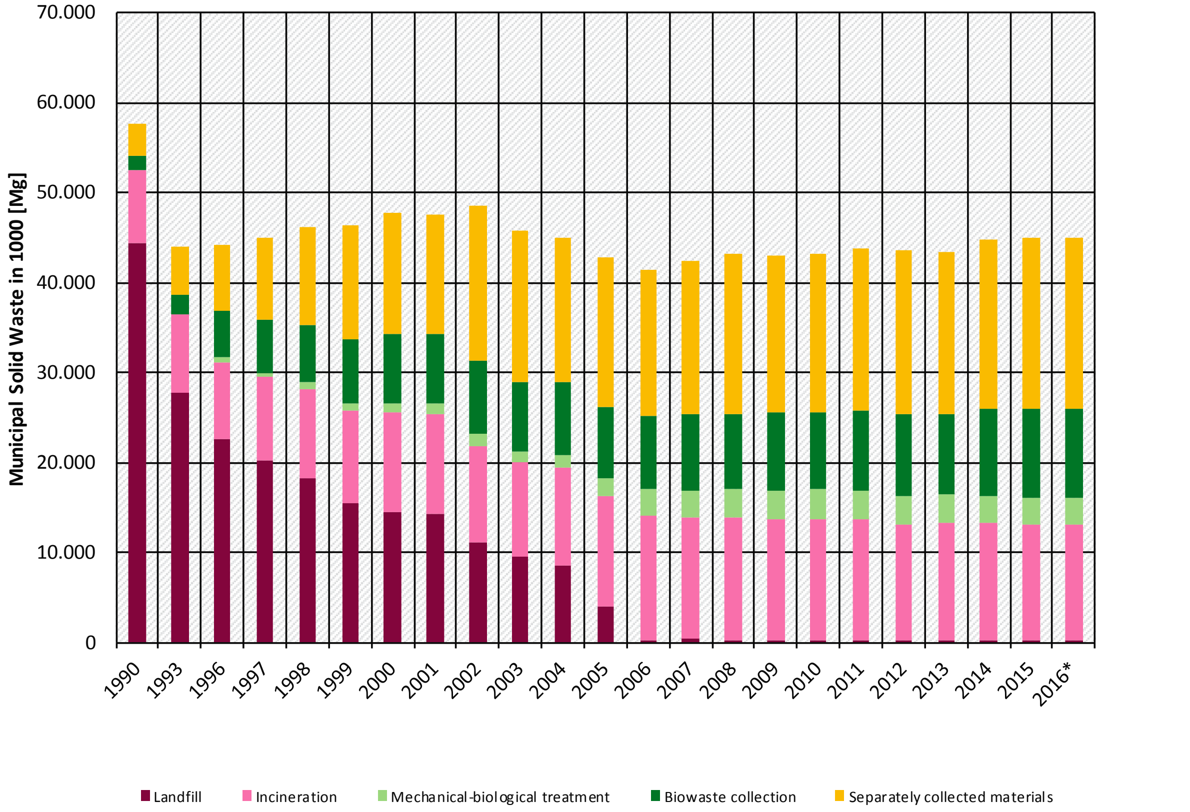
7.2.1 Managed disposal in landfills – landfilling of settlement waste (5.A.1)

7.2.1.1 Category description (5.A.1)

In the period since 1990 (and previously, to some extent), a number of legal provisions have been issued pertaining to Germany's waste-management sector, and a number of relevant organisational measures have been initiated. These moves have had a strong impact on trends in emissions from waste-landfilling. Relevant developments have included intensified collection of biodegradable waste from households and the commercial sector, intensified collection of other recyclable materials, such as glass, paper/cardboard, metals and plastics; separate collection of packaging; and recycling of packaging. In addition, incineration of settlement waste has been expanded, and mechanical biological treatment of residual waste has been introduced. As a result of such measures, amounts of landfilled settlement waste decreased very sharply from 1990 to 2006, and they have been stabilising at a low level since 2006 (cf. Figure 77). As the figure shows, over half of settlement waste produced in Germany today is collected separately and gleaned for recyclable materials (separate collection of recyclable materials and biodegradable waste), and is not incinerated or landfilled. Official statistical data in this area are collected and published annually by the Federal Statistical Office (Statistisches Bundesamt (FS 19, R 1b). The relevant surveys are exhaustive surveys. The activity data for the current report year have to be estimated, since official waste statistics are published with a one-year time lag. For purposes of estimation, the waste-quantity figure from the previous year is used, unchanged. In each case, such estimates are replaced in the following year with the relevant figures from survey statistics. Regular recalculations thus have to be carried out annually for the year prior to the past year. With regard to emissions from landfills, this procedure has only a very small impact on the total emissions in the relevant current report year, since those emissions are determined predominantly by the waste that has been landfilled in the past.

In 2004, about 330 landfills for settlement waste were in operation in the Federal Republic of Germany. By that year, strict legal regulations were already in place that require such landfills to have equipment for recovering and treating landfill gas. Those regulations have extensively reduced methane emissions from such facilities. In June 2005, in keeping with new, stricter requirements under the Ordinance on Environmentally Compatible Storage of Waste from Human Settlements (Abfallablagerungsverordnung) and the Landfill Ordinance (Deponieverordnung), over half of all landfills were closed. As a result, only about 150 landfills for settlement waste are now still in operation. In addition, landfilling of biologically degradable waste has been prohibited since June 2005. As a result, no landfilling of waste leading to significant methane formation has occurred since then. For conformance with pertinent requirements, settlement waste and other biodegradable waste must be pre-treated via thermal or mechanical biological processes. In waste landfilled after 2006, just a few waste components, with very small methane-formation potential (such as residues from treatment in MBT facilities; small wood fractions in processed construction rubble) have contributed to landfill-gas formation. As landfill-gas formation in older landfills drops off, methane emissions from landfills will again decrease extensively and will then, in the long term, stabilise at a very low level.

Figure 77: Changes in pathways for management of settlement waste, 1990 to 2016, with intermediate years



By reducing landfill methane emissions from about 1400 kt CH_4 in 1990 to about 330 kt in 2017, Germany's waste-management sector has made an important contribution to climate protection. Experience gained by Germany's waste-management sector shows that reductions of landfilled quantities of biodegradable waste can provide significantly higher contributions to climate protection than can recovery and treatment of landfill gas.

7.2.1.2 Methodological issues (5.A.1)

The method presented in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC (2006): *Chapter 3.2.1.1)* for calculation of CH_4 emissions from landfills is based on the "first order decay" method (FOD method). The relevant detailed method used in Germany lies between Tier 2 and Tier 3. The Tier 3 method requires national / country-specific key parameters for DOC, DOC_F and half-lives (k values). Germany uses country-specific DOC values, but it uses default values for DOC_F and k values.

The following section describes the FOD method, and the relevant parameters used, for determining methane formation in landfills. The FOD method uses the following equations:

Equation 52: (2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 3.2.1.1, Equation 3.6)

$$CH_4\ produced\ in\ year\ t\ \left(\frac{kt}{year}\right) = DDOCm\ decomp_t\ \times F \times 16/12$$

Where:

CH_4 produced in year t	*= Quantity of CH_4 produced by relevant biologically degradable waste*
DDOCm decomp$_T$	*= Mass of the biodegradable DOC that decomposes in year T*
F	*= Percentage share of CH_4 with respect to landfill gas*
16/12	*= Factor for conversion of C to CH_4*
t	*= Inventory year*

The following also holds:

Equation 53: (2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 3.2.1.1, Equation 3.2)

$$DDOC_m = W \times DOC \times DOC_f \times MCF$$

Where:

DDOCm	= Mass of biodegradable and landfilled DOC, (kt)
W	= Mass of landfilled waste (kt)
DOC	= Fraction of biodegradable organic carbon in the year in which landfilling takes place (Gg C / kt waste)
DOCf	= DOC fraction that is biodegradable under anaerobic conditions
MCF	= Methane-correction factor for the DOC fraction that is biodegradable under anaerobic conditions, for year x

Since 1972, only orderly landfilling has been permissible by law in western Germany. In 1989/90, in connection with German reunification, the relevant standards were extended to the new German Länder. The inventory calculations take account of all waste landfilled since 1950, regardless of whether the landfills in which the waste is now located have been decommissioned or are still in operation.

The emissions contributions from all waste landfilled between 1950 and 1972 are calculated with an MFC of 0.6. For the period 1973-1989, an MCF of 0.6 is used for the new German Länder, and an MCF of 1 is used for the old German Länder. For purposes of emissions calculation for the inventory, data from that period have been used to obtain a weighted MCF, for Germany as a whole, that reflects the various waste fractions' percentage contributions to the total for Germany as a whole. The emissions from waste landfilled since 1990 are calculated with an MFC of 1.

Germany uses the IPCC Waste Model, which was developed on the basis of Equations 3.4 and 3.5 of the 2006 IPCC Guidelines (IPCC, 2006). Under this approach, the total quantity of biodegradable DOC in landfills is calculated for each year, in order to calculate the quantity of DOC that is broken down, in each year, into CH_4 and CO_2:

Equation 54: (2006 IPCC Guidelines for National Greenhouse Gas Inventories, Equation 3.4)

$$DDOCma_t = DDOCmd_t + (DDOCma_{t-1} * e^{-k})$$

Where:

t	*= Inventory year*
DDOCma$_t$	*= DDOCm accumulated in the landfill at the end of year t (kt)*
DDOCma$_{t-1}$	*= DDOCm accumulated in the landfill at the end of year t-1 (kt)*
DDOCmd$_t$	*= DDOCm added to the landfill in year t (kt)*
k	*= Reaction constant – methane-formation rate (1/year) = ln(2)/$t_{1/2}$ (year^{-1})*
$t_{1/2}$	= half-life (years)

Equation 55: (2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 3.2.1.1, Equation 3.5)

$$DDOCm\,decomp_t = DDOCma_{t-1} \times (1 - e^{-k})$$

Where:

t = Inventory year

DDOC $decomp_t$ = DDOCm that decomposes in the landfill in year t (kt)

A multi-phase model was applied. In addition, the calculation was carried out with different half-lives for the different waste fractions involved, and the results so obtained were summed.

To obtain the final CH_4-emissions result, methane that is recovered and then flared, or then used for energy recovery, is deducted, and a correction factor is applied that accounts for methane oxidation in landfill covering layers, as shown by Equation :

Equation 56: ***(2006 IPCC Guidelines, Chapter 3.2.1.1, Equation 3.1)*****:**

CH_4 emitted in year t (kt/year) = (CH_4 produced in year t – R(t)) • (1- OX)

Where

R(t) = CH_4 recovered in year t

OX = Oxidation factor (fraction)

With the IPCC Waste Model, users may define a time period during which landfilled waste has not yet begun producing gas, i.e. a period of delay until gas formation begins. The 2006 IPCC Guidelines (IPCC, 2006) recommend 6 months as a standard value for this delay period. As a result of discussions with national waste experts, and on the basis of measurements of CH_4 formation following landfilling, a delay-period value of 3 months has been chosen. This change has only a slight effect on emission calculations.

For purposes of calculation, the relevant quantities of settlement waste (MSW_T), and the fraction of settlement waste that is landfilled (MSW_F), must be determined. For the FOD method, settlement-waste-production quantities have to be determined throughout the past few decades. Pursuant to the 2006 IPCC Guidelines (IPCC, 2006), estimates should be made of the different waste-type fractions contained in landfilled settlement waste, since the further emissions-calculation procedure is based on the fact that different waste types have different DOC values.

7.2.1.2.1 Quantities of landfilled waste

The FOD model calculates emissions from landfilled settlement waste, landfilled industrial waste and landfilled sewage sludge.

Pertinent quantities of landifilled settlement waste (household and commercial waste) are taken from relevant statistics of the Federal Statistical Office, which are based on annual surveys of waste types, origins and final destinations, as well as on surveys taken of waste-storage facilities, every two years, that focus on specific equipment of the facilities. The surveys of landfilled quantities of settlement waste in the old German Länder commenced in 1975, on the basis of the Environmental Statistics Act of 1974. Waste quantities for the period from 1950 to 1975 were extrapolated on the basis of population data.

For the new German Länder, data on landfilled quantities of settlement waste, differentiated by Länder, are available for the years 1990 and 1993. For the 1980s in the former GDR, Andreas (2000) has presented data that provide information about per-capita landfilled quantities of waste, waste composition, landfill types and types of waste storage involved. The per-capita quantities of landfilled waste in the former GDR, at 190 kg/person, were considerably lower than the corresponding quantities in the old German Länder (330 kg / person and year). The reason for this was that larger percentages of waste were recycled in the former GDR. In 1990, the year of German reunification, landfilled quantities of waste increased sharply in the new German Länder, to the extent that the relevant per-capita quantities even outstripped the corresponding quantities in the old German Länder. The reasons for this were that the former GDR's recycling systems collapsed in that year and that a flood of new products suddenly became available, leading to high levels of replacement purchases and to sharply increasing quantities of packaging waste. Since 1990, per-capita waste quantities in both parts of Germany have slowly been moving into alignment.

The inventory calculations include landfilled sewage-sludge quantities of the old and new German Länder (states), and of the former Federal Republic of Germany and the former GDR, for the entire period 1950 through 2015. No statistical data are available relative to landfilling in the new German Länder / the former GDR. The applicable waste compositions (including those of sewage sludge fractions) have been estimated on the basis of findings of a research project that in the 1990s studied waste inventories of GDR landfills.

In the former GDR, all non-recycled waste quantities were landfilled.

Since 1996, the Federal Statistical Office has published differentiated data on waste-landfilling by industry. The relevant inventory takes account of the landfilled waste quantities from industrial sectors as follows:

- Waste from agriculture, horticulture, forestry, fisheries and food processing
- Waste from wood processing
- Waste from production of pulp, paper and carton
- Waste from the textile industry
- Packaging waste, absorbent and filtration materials, wiping cloths and protective clothing
- Wood fractions in construction and demolition waste (data since 1975)

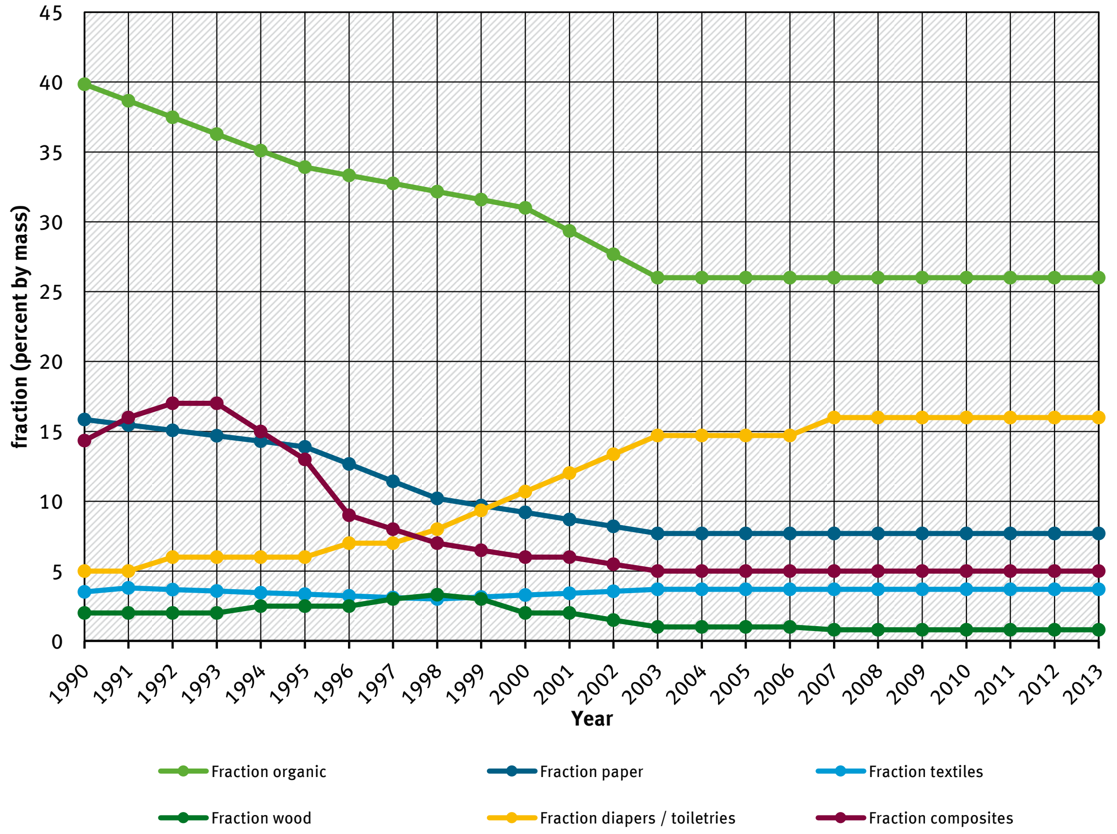
The quantities of industrial waste landfilled between 1975 and 1996 were derived on the basis of total quantities of landfilled waste. While the total quantities include industrial waste, the total-waste figures are not broken down to show industrial waste separately. Extrapolations between waste production and production data of relevant sectors, for the 1996-2002 period, produced no satisfactory statistical relationships. While production figures increased, waste-production figures decreased – considerably, in part – as a result of changes in production processes. Due to the lack of statistical relationships, the figures for landfilled waste quantities were kept constant for the period between 1950 and 1975. Changes in assumptions relative to industrial waste in the 1950-1970 period have only a very marginal effect on emissions in the base year.

For the entire period as of 1950, and for all relevant types of waste, including sewage sludges, complete and seamless data series are available that are based on the best-available sources for the sub-periods concerned.

7.2.1.2.2 Waste composition

For the inventory calculations, landfilled waste has to be divided into the landfill-waste fractions organic waste, garden and park waste, paper, wood, diapers and textiles, composite materials, sewage sludge and MBT output. To some extent, waste statistics include separate listings for these categories. On the other hand, such statistics also include landfilled quantities of mixed settlement waste that, for calculation purposes, have to be subdivided into the aforementioned fractions. To this end, numerous studies of the components of mixed settlement waste were evaluated, with a view to determining the historical development of waste fractions (organic waste, garden and park waste, paper, wood, diapers and textiles, composite materials). In the years 1980 and 1985, mixed-waste compositions were determined for the entire territory of the former Federal Republic of Germany (Barghorn et al., 1986; Greiner et al., 1983). For the subsequent period, a large number of individual studies exists – studies carried out by individual cities, administrative districts and Länder. Some of these had already been evaluated and combined within overarching studies. The pertinent figures were used to obtain time series for waste composition for the period between 1980 and 2013 (cf. Figure 78). Such evaluation of existing studies was carried out for household waste, household-like commercial waste and bulky waste, categories that are listed separately in national statistics. As to waste composition in the new German Länder, the figures provided by ANDREAS (2000) for the 1980s in the former GDR were adopted (composition of household waste: 28 % vegetable waste, 14 % paper/cardboard, 2.3 % wood, rubber, composites, 3 % textiles; household waste accounted for only 16 % of total landfilled waste quantities, however). Quantities of settlement waste landfilled in the former GDR contain smaller fractions of biodegradable materials and large inorganic fractions (primarily ash from household combustion systems). Food waste was collected and used as feed; feeds tended to be scarce during certain periods of time. Paper was collected; it was also a scarce resource. Wood and paper were often burned in ovens for purposes of heating and cooking. The "SERO" recycling system efficiently collected the country's relatively small fractions of plastic packaging. Deposit systems were operated for glass, and glass was also collected. All in all, the former GDR's economy was subject to scarcities of resources, and this led to efficient waste recycling. Ash from household combustion systems accounted for large fractions of landfilled quantities of household waste. In 2014, existing evaluations of waste-composition studies were reviewed, and more-recent studies of residual-waste composition in the period 2006 through 2013 were identified (6 studies) and evaluated. These more-recent studies confirmed existing assumptions regarding the composition of mixed-waste fractions, and thus the relevant data were carried forward without change. After 2005, landfilling of mixed settlement waste decreased dramatically, as a result of changes in applicable laws (from 5.8 million tonnes in 2004 to 2,000 tonnes in 2013). The need for precise determination of residual-waste fractions for the period as of 2005 has diminished correspondingly, and thus the Federal Government, and the country's Länder, administrative districts and municipalities, have commissioned fewer numbers of studies of waste composition since then.

Figure 78: Trends in household-waste composition between 1990 and 2013



The waste quantities stored in landfills are recorded by the Federal Statistical Office, in terms of separate fractions based on waste codes. For purposes of emission calculation, all waste types that can contribute to landfill-gas formation are taken into account, and each waste type is separately assessed in terms of its waste composition. Table 449 shows the waste types of relevance for landfill-gas formation (wood fractions of construction and demolition waste have been taken into account). The recovered quantities of landfill gas are based on official statistical data.

Since 1 June 2005 only waste with a total carbon content < 3 %, and mechanically and biologically treated settlement waste, may be landfilled in Germany. Since that time, landfilled waste quantities have decreased very sharply and now make only very small contributions to gas formation. Table 449 outlines the development of quantities of landfilled biodegradable waste. Biodegradable waste fractions have decreased further with respect to 2009. It is regularly the case that no figures for the current inventory year are available in time for the report. For this reason, the waste quantities and compositions reported for the year prior to the current inventory year are carried forward, unchanged, and then recalculated a year later (i.e. for the next year's report).

Table 449: Quantities of biodegradable waste landfilled between 2002 and 2015, broken down by waste fractions

Waste fraction	Units	2002	2003	2004	2005	2006	2007	2008	2009
Organic	kt	2.513	2.064	1.831	813	28	13	12	5
Garden and park waste	kt	43	43	49	26	19	25	23	1
Paper	kt	1.191	1.095	974	426	10	5	6	6
Diapers and textiles	kt	1.856	1.720	1.276	519	30	13	13	5
Wood	kt	860	709	529	238	10	11	5	1
Composite materials	kt	481	398	349	155	5	2	2	1
Sewage sludge	kt	369	308	624	634	130	129	133	31
Output from MBT facilities	kt	1.226	1.108	990	1.170	1.177	1.266	1.253	1.113

Waste fraction	Units	2010	2011	2012	2013	2014	2015	2016	2017
Organic	kt	6	5	0	0	0	0	0	0
Garden and park waste	kt	0	0	0	0	1	1	1	1
Paper	kt	7	6	2	4	1	1	4	4
Diapers and textiles	kt	5	5	2	2	2	2	3	3
Wood	kt	0	0	3	3	0	0	0	0
Composite materials	kt	1	1	0	0	0	0	0	0
Sewage sludge	kt DM	27	34	67	25	73	81	57	57
Output from MBT facilities	kt	991	934	764	692	702	714	618	618

During the 2010 inventory review, the review team requested that CH_4 emissions from landfilled MBT residues also be included in calculation of emissions from landfilling. While that fraction has now been included, there is no unambiguous method for that waste category, nor are there suitable national parameters for it. Furthermore, no results have yet been obtained with regard to the behaviour of landfilled waste from MBT facilities (i.e. behaviour in real landfills). Only laboratory data have been obtained to date, and thus the results in this area are subject to very high levels of uncertainty. The mechanical biological (waste) treatment (MBT) process is described in Chapter 7.6.1.

In 2011/12, the residual-gas emissions from landfill storage of mechanically and biologically treated waste were quantified in an expert judgement (Stegmann & Partner, 2012). The expert judgement confirms that emissions calculations to data have been correct in applying low emissions contributions from landfilling of MBT waste.

In keeping with the recommendations provided in the 2010 inventory review (paragraph 146, UNFCCC (2010)), additional information in this regard is provided as of the 2011 report. Table 450 shows the per-capita waste quantities landfilled, per day, between 1990 and 2013. These values do not represent the per-capita waste-production rate that is to be reported, as additional information, in the CRF tables. That figure comprises total waste consumption, taking all waste-management pathways into account. It will be calculated for the next report.

In Germany, landfilling of settlement waste has decreased very sharply since 2005, and that trend is also reflected in the per-capita rate of landfilled household waste.

Table 450: Per-capita quantities of landfilled household waste

	Units	1990	1991	1992	1993	1994
Per-capita quantities of landfilled waste	kg/capita/day	1.604	1.415	1.222	1.034	0.944
	Units	1995	1996	1997	1998	1999
Per-capita quantities of landfilled waste	kg/capita/day	0.855	0.765	0.614	0.543	0.568
	Units	2000	2001	2002	2003	2004
Per-capita quantities of landfilled waste	kg/capita/day	0.551	0.513	0.446	0.391	0.339
	Units	2005	2006	2007	2008	2009
Per-capita quantities of landfilled waste	kg/capita/day	0.181	0.051	0.053	0.053	0.044
	Units	2010	2011	2012	2013	2014
Per-capita quantities of landfilled waste	kg/capita/day	0.041	0.040	0.031	0.028	0.040
	Units	2015	2016	2017		
Per-capita quantities of landfilled waste	kg/capita/day	0.031	0.025	0.025		

Table 451: Per-capita quantities of settlement waste

	Units	1995	1996	1997	1998	1999
Production of settlement waste per capita	kg/capita/day	1.715	1.767	1.814	1.785	1.762
	Units	2000	2001	2002	2003	2004
Production of settlement waste per capita	kg/capita/day	1.776	1.750	1.772	1.667	1.629
	Units	2005	2006	2007	2008	2009
Production of settlement waste per capita	kg/capita/day	1.568	1.567	1.620	1.641	1.650
	Units	2010	2011	2012	2013	2014
Production of settlement waste per capita	kg/capita/day	1.680	1.715	1.693	1.681	1.715
	Units	2015	2016	2017		
Production of settlement waste per capita	kg/capita/day	1.693	1.731	1.725		

7.2.1.2.3 MCF (methane-correction factor)

Until 1972, when the first Waste Act was introduced, waste was usually stored in uncontrolled landfills; such landfills were closed after 1972. After 1972, waste was stored in managed landfills. In keeping with this history, a default MCF value of 0.6 was used for "unclassified landfills" ("nicht zugeordnete Deponien"), while an MCF of 1 was used after 1972.

Data are available from a 1989 survey of the territory of the former GDR that covered 120 managed landfills, some 1,000 controlled storage sites and some 10,000 uncontrolled dump sites (Institut für Umweltschutz (1990): p. 56, Table 12). Of the some 13,000 waste-storage sites, a total of 11,000 were for household waste and 2,000 were for industrial waste; most of the latter were plant-owned facilities (BMU (1990): p. 28). Consequently, an MCF of 0.6 (default value for unclassified landfills) was assumed for the territory of the former GDR for the period 1950 to 1990. Upon German reunification, the Federal Republic of Germany's waste laws were extended to the territory of the new German Länder, and transitional regulations were introduced to ensure that facilities – including both decommissioned facilities and still-operational facilities in which waste was (or is) produced or disposed of – were accounted for and that suitable clean-up measures were initiated (BMU (1990): p. 46). Uncontrolled landfills were closed in 1990, facilities permitted to remain open were secured, cleaned up and modernised/expanded in keeping with the standards of Federal German waste law, and sites for new facilities were sought. As of 1990, the Federal Statistical Office has collected statistics on both parts of Germany. For purposes of calculation for the period after 1990, an MCF of 1 is used for all of Germany's territory.

7.2.1.2.4 DOC

Both national data and IPCC default factors are used for DOC, the proportion of degradable organic carbon in waste. Table 452 below provides an overview of the DOC values used.

With regard to dry matter, the 2006 IPCC Guidelines (IPCC, 2006) give a default DOC of 50%, which is computationally equivalent to a dry-matter content of about 10%. From the 1980s until 2005, virtually all of the sewage sludge that was landfilled was mechanically dewatered sludge with a dry-matter content of about 30%. A weighted mean DOC of 15% has been derived on the basis of the dry-matter content of the total quantity of municipal and industrial sewage sludge landfilled over time. Since 1 June 2005, only waste with a total carbon content < 3 % may be landfilled in Germany. This also applies to sewage sludge. Computations use a DOC of 3% for the period as of 2006, because sewage sludge may be landfilled only if it has undergone proper pretreatment or if the relevant industrial wastewater has been proven to have suitably low carbon-content levels.

In keeping with the review results from the ARR 2015/2016 and 2018, Germany is making an intensive effort to discuss the sources for the data given in Table 452. This project is proving to be somewhat difficult, since the data, although derived in the framework of a research project for preparation of the ICR 2010, and presented within that review, were not adequately documented subsequently. The research contractor for that project is currently experiencing problems in accessing his archive. We are optimistic that the problems can be solved.

Table 452: DOC values used

Fraction	DOC		Source
	IPPC 2006 default value (wet waste)	DOC values used	
Organic	15 %	**18%**	Various national studies show DOC levels that are higher than the IPCC default value
Garden and park waste	20 %	**20%**	National value
Paper and cardboard	40 %	**40%**	IPCC default
Wood and straw	43 %	**43%**	The national value is somewhat higher than the IPCC default
Textiles	24 %	**24%**	National value
Diapers	24 %	**24%**	National value
Composite materials	N. e.	**10%**	National value
Sewage sludge	50 % (dry) 5 - 9 % (wet)	**15%**	Determined computationally from the IPCC default for sewage sludge, oriented to dry matter; after 2006, a DOC of 3% is assumed
Waste from MBT facilities	N. e.	**2.3%**	National value (10 % of the average DOC of landfilled fractions from the current year)

7.2.1.2.5 DOC_F

DOC_F, the DOC fraction that can be converted into landfill gas, is put at 50 % for settlement waste, on the basis of a national study (Rettenberger et al. (1997): p. 277). That value is in keeping with the IPCC default of 0.5.

7.2.1.2.6 F = Fraction of CH_4 in landfill gas

A value of 50%, the mean value in the IPCC default-value range, is assumed for F. That value has been confirmed by a national research project (Schön et al., 1993).

In recent years, the methane concentrations in recovered landfill gas (Table 453) have been decreasing. Presumably, this decrease in methane concentrations is to oxidation effects in the gas-recovery systems, effects that intensify as gas formation decreases.

Table 453: Fraction of CH_4 in landfill gas

Fraction of CH_4 in landfill gas	2004	2006	2008	2010	2012	2014	2016
Landfills in the operational and closure phases	49%	50%	49%	48%	48%	47 %	41 %
Landfills in the aftercare phase	N. e.	N. e.	N. e.	42 %	40 %	38 %	32 %

Source: Statistisches Bundesamt (FS 19, R 1b 1, 2012), Table 1.5

7.2.1.2.7 Half-life

The calculation model is a multi-phase model that takes account of the different half-lives of different waste fractions. Table 454 shows the half-lives and the methane-formation rate used for the pertinent waste fractions. In conformance with the recommendations provided in the 2010 inventory review (paragraph 146, FCCC/ARR/2010/DEU), additional information has been provided for reporting as of 2011. The constant methane-formation rate that appears in the FOD method corresponds to the time required for biodegradable organic carbon in waste to decompose to the point at which it has lost half of its original mass. It thus can be derived from the half-lives of the various relevant fractions, in keeping with Equation57.

The slight differences seen in the k values – between default and national values – are due to the following circumstances: The earlier versions of the IPCC tables (the versions distributed in connection with the publication of the 2006 IPCC Guidelines) for estimating methane emissions from landfilling of solid waste are based on half-lives. In later versions of the IPCC model table, this estimation basis was changed. In those earlier versions, the available selection of parameters included only half-lives – and no k values (unfortunately, the relevant file names did not include version numbers). The original version of the IPCC model table includes a "half-life" spreadsheet with embedded calculation of k values on the basis of half-lifes as well as calculation of half-lives on the basis of k values (i.e. the the vice-versa direction). Consquently, the standard half-life values shown in Table 454 are the standard parameters presented in the earlier version of the IPCC model table. The k values shown in this table have been obtained by calculating k on the basis of the standard half lives, using the embedded calculation tool in the model table. Until the ARR 2018, we assumed that the basic conversions provided by the IPCC's table tools were correct, and thus did not check the rounding that they involved. The ARR called attention to inconsistencies. Those inconsistencies are due to the differences between Table 3.3 and Table 3.4 of the 2006 IPCC Guidelines. For food waste, for example, we used the half-life given in Table 3.4, 4 years. That figure is equivalent to a value of 0.173 for k. Table 3.3 gives a value of 0.185 (not 0.173) for food waste, however, which is equivalent to a half-life of 3.747. As a result, Tables 3.3 and 3.4 are inconsistent with each other with regard to food waste (all other values are consistent, however). Since we began our calculation on the basis of the older model table, we have based our calculation on the temperate / wet climate-zone data given in Table 3.4. The discrepancies between our results and the specified values are minimal – and will cancel out when the announced improvement (cf. Chapter 7.2.1.6) is carried out.

Equation57: (2006 IPCC Guidelines)

$$k = \ln 2 / t_{1/2}$$

Table 454: Half-lives and constant methane-formation rates of waste fractions

Type of waste	Half-life (years)		CH4 formation rate (k value)	
	IPCC default value*	National value	IPCC default value*	National value
Food waste	4		0,185	0.173
Garden/park waste	7		0.1	0.099
Paper / cardboard	12		0.06	0.058
Wood	23		0.030	
Textiles / diapers	12		0.06	0.058
Composite materials	--	12	---	0.058
Sewage sludge	4		0,185	0.173
Waste from MBT facilities	--	12	--	0.058

* Wet temperate

7.2.1.2.8 Landfill-gas use

The "TA Siedlungsabfall" of 1993[167] made gas recovery one of the prerequisites for licensing of landfills for settlement waste. The amended version of the Environmental Statistics Act (UStatG) of 2005 mandates that in future the Federal Statistical Office, in its surveys, is to take account of, and publish, levels of landfill-gas recovery. For the years 2004, 2006 and 2008, and with regard to landfill-gas recovery and use, Fachserie 19 of 12 July 2012 includes only data for landfills in operation and closure phases. Collection of gas-recovery data for all landfills, i.e. including landfills in the aftercare phase, began for the first time for the year 2010 and has been reported to date for the years 2010 and 2012.

As a result of the above-described data gaps, in reporting in recent years (up to and including the 2012 NIR), total quantities of recovered landfill gas have been determined by combining data from the energy sector and from Fachserie 19. The data obtained for all landfills as a whole, for the years 2010 and 2012, show that the quantities of gas recovered at landfills in the aftercare phase have been considerably overestimated. For this reason, a recalculation had to be carried out to correct the amounts of gas recovered in landfills in recent years and, thus, to correct the relevant methane emissions. The quantities of methane listed in Table 455 include both the landfill-gas quantities used for energy generation and those flared off.

Since the greenhouse-gas emissions from the category landfill-gas flares in 5.A account for less than 0.05 % of the total inventory (not including LULUCF), and since they would not exceed 500 kt CO_2 equivalents (significance thresholds pursuant to FCCC/SBSTA/2013/L.29/Add.1), and since annual recording cannot be assured (in keeping with FCCC/SBSTA/2013/L.29/Add.1, para 37), we opt not to report on this area (IPCC, 2006). A one-time quantitative estimation of the emissions from landfill-gas flares that are thus not being included in the inventory yielded a figure of about 0.6 t CO_2 equivalent. In addition, a compilation of all sources listed as "not estimated" is presented in Annex 5 (Annex Chapter 21) of the present report.

[167] Technical instructions on recycling, treatment and other management of settlement waste (Third general administrative provision on the Waste Act (Abfallgesetz)) of 14 May 1993

Table 455: Methane collection in landfills

Year	2012 NIR			Current NIR				
					Recovered gas quantity, in Gg			
	Gas formation in Gg	Recovered gas quantity in Gg	Recovery rate in %	Gas formation in Gg	Operational and closure phases	Aftercare phase	Total quantity	Recovery rate in %
1990	2,169	126	5.8	1614			94	5.8
1991	2,228	136	6.1	1715			105	6.1
1992	2,246	146	6.5	1772			115	6.5
1993	2,223	156	7.0	1787			125	7.0
1994	2,167	166	7.7	1770			136	7.7
1995	2,095	176	8.4	1738			146	8.4
1996	2,008	190	9.5	1690			160	9.5
1997	1,906	260	13.6	1629			222	13.6
1998	1,801	280	15.5	1559			242	15.5
1999	1,703	349	20.5	1490			247	16.6
2000	1,611	352	21.8	1423			251	17.6
2001	1,520	356	23.4	1353			252	18.7
2002	1,441	360	25.0	1288			254	19.7
2003	1,355	363	26.8	1222			254	20.8
2004	1,280	425	33.2	1158	236	11	247	21.3
2005	1,202	447	37.2	1094			247	22.6
2006	1,120	460	41.1	1018	231	11	242	23.8
2007	1,026	445	43.4	937			220	23.5
2008	943	374	39.7	865	190	11	201	23.2
2009	874	358	41.0	800			191	23.8
2010	816	347	42.5	741	171	11	181	24.4
2011				689			167	24.2
2012				641	140	14	154	24.0
2013				598			143	24.0
2014				559	121	13	134	24.0
2015				523			120	23.0
2016				490	97	11	108	22.1
2017				460			102	22.1

Italics: Data of the Federal Statistical Office Statistisches Bundesamt (FS 19, R 1b) Fachserie 19, Reihe1, 2014 of 18 August 2016

The data include gaps, since official statistical data are available only for certain single years; such gasp were closed via -/ extrapolation and qualified estimates.

For the years through 1998, proportional gas-recovery rates (i.e. expressed as percentages) from earlier estimates continue to be used (cf. the 2012 NIR for the relevant sources and data derivation), and the recovered quantities of methane have been calculated from the methane formation and the pertinent methane-recovery rate (with the latter expressed as a percentage).

For the years 1999 through 2003, the proportional collection rates (expressed as percentages) have been interpolated from the values for 1998 (old method) and 2004. The recovered quantities of methane were calculated from the total methane formation and the relevant proportional recovery rate (expressed as a percentage).

For the years 2004, 2006 and 2008, Federal Statistical Office data are available only for landfills in operational and closure phases. The total quantities of methane recovered at all landfills were determined by adding a) the methane quantities determined for 2010, for landfills in the aftercare phase, and b) the pertinent annual figures for 2004, 2006 and 2008.

For the years 2010, 2012, 2014 and 2016, the Federal Statistical Office has provided complete data on landfill-gas recovery at all landfills. For odd years as of 2005, no data on quantities of recovered landfill gas are available, since the Federal Statistical Office collects such data only every second year. For those years, the proportional (percentage) rates of landfill-gas recovery were thus obtained via interpolation between the relevant previous and subsequent years, and the collected quantities of gas were then calculated from the gas formation and the applicable proportional (percentage) collection rate. For the relevant current year, the proportional (percentage) rate of landfill-gas recovery for the previous year is carried forward.

7.2.1.2.9 Oxidation factor

As to the factor determining the proportion of CH_4 that is oxidised in landfill covering layers, the IPCC default value of 0.1 was adopted for the entire time series. While in the early 1990s the former GDR probably had a higher percentage of uncontrolled landfills than did the old German Länder, a research project has found that the former GDR's landfills have a low CH_4-formation potential, and thus use of the factor 0.1 is also justified for that period (BMBF & UBA, 1998).

7.2.1.3 Uncertainties and time-series consistency (5.A.1)

The method's uncertainties were estimated for the first time for the 2006 NIR.

Over the long, 30-year period covered by the activity data, inconsistencies in the time series are unavoidable, since the pertinent waste categories and survey methods changed several times as a result of improvements in legislation and waste statistics. In Germany, special problems arise especially via German reunification and the resulting merging of two different economic and statistical systems. For this reason, considerable effort has to be invested in reviewing data consistency and allocations to the reported categories, in the interest of making time series as consistent as possible.

For some years now, there have been growing indications in Germany that the IPCC's FOD model for calculating landfill-gas formation, and the resulting methane emissions, produces significant overestimations with regard to actual landfill behaviour. The Federal Environment Agency has commissioned two research projects aimed at clarifying this situation. The inventory will be suitably revised, as necessary, as soon as those projects' results become available.

7.2.1.4 Category-specific quality assurance / control and verification (5.A.1)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The selected parameters were compared with relevant data for other countries.

In entry of data, the correctness of entries was checked via sum values – various waste categories were recorded solely for the purpose of checking correctness of data entry.

7.2.1.5 Category-specific recalculations (5.A.1)

Recalculations have to be carried out annually for the year prior to the previous year, since the waste statistics of the Federal Statistical Office appear with a one-year time lag, meaning that the current report-year data have to be estimated. In each case, such estimates are replaced in the following year with the relevant figures from survey statistics. Also in the present report, transfer errors in a) methane emissions from landfills and b) quantities of methane recovered were corrected for the years 2013 through 2016 (cf. Table Table 456). In addition, the figures in Table 450 and Table 451 have been revised in keeping with the 2011 census's updated population data for 1991-2011 and the now-available to-the-person population figures for 1990 and the period as of 2012. In addition, Table 455 has been adjusted in keeping with the latest available figures. The revisions of the last three tables are not discussed here in detail, since those tables simply provide supplementary information.

Table 456: Activity data, methane emissions and quantities of recovered methane

	Units	NIR	2013	2014	2015	2016
Settlement waste, total	[kg]	2018	-	839,000,000	-	823,900,000
		2019	-	839,300,000	-	751,600,000
Dissolved organic carbon (DOC)	[kg]	2018	-	558,519,729	-	490,065,639
		2019	-	558,519,619	-	490,052,029
CH_4 emissions	[kt]	2018	408	382	358	335
		2019	411	382	362	343
CH_4 recovery	[kt]	2018	145	-	125	117
		2019	142	-	120	108

7.2.1.6 Planned improvements, category-specific (5.A.1)

For some years now, there have been growing indications in Germany that the IPCC's FOD model for calculating landfill-gas formation, and the resulting methane emissions, produces significant overestimations with regard to actual landfill behaviour. To address this situation, the Federal Environment Agency has commissioned two research projects aimed at producing national values for the applicable half-lives, k values and DOC_f values.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

7.3 Anaerobic digestion (5.B)

In category 5.B, emissions from composting systems (5.B.1) and from digestion of biowaste in biogas plants (5.B.2) are reported. Both facility types in category 5.B treat separately collected biowaste and produce compost or digestates that are used in the agricultural or horticultural sectors. This is the difference with regard to the mechanical-biological treatment covered in category 5.E. Those facilities handle mixed settlement waste (residual waste). The residues from those facilities are either landfilled or incinerated.

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
-/-	5.B. Biological treatment of solid waste	0	CH_4	25.34	0.00%	708.56	0.08%	2696.2%
-/-	5.B. Biological treatment of solid waste	0	N_2O	15.97	0.00%	310.42	0.03%	1844.3%

The category *Other production* is not a key category.

7.3.1 Composting facilities (5.B.1)

7.3.1.1 Category description (5.B.1)

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier 2	NS	CS
N_2O	Tier 2	NS	CS

In Germany, annually increasing fractions of biodegradable waste are being separately collected and treated. The emissions reported under 5.B.1 originate in composting facilities that, primarily, compost biowaste separately collected from households, along with garden and park waste. The composts produced from such waste are used in the agricultural and horticultural sectors. The 2006 inventory report included a first report on CH_4 and N_2O emissions from treatment of biowaste in composting systems, along with a complete time series for those emissions. In the 2015 NIR, reporting in this area was brought into line with the 2006 IPCC Guidelines.

The area of composting includes centralised composting of separately collected biowaste as well as the composting that residents carry out in their own gardens (home composting). For this area, no reliable data are available to us on the relevant quantities involved and the emissions produced. For this reason, we do not report on these emissions.

7.3.1.2 Methodological issues (5.B.1)

Nitrous oxide and methane emissions from composting of kitchen and garden waste are reported in keeping with the 2006 IPCC Guidelines (IPCC, 2006). On the other hand, we use our own national emission factors, which were obtained via a research project (Cuhls et al., 2015). The methane and nitrous oxide emissions are calculated in accordance with the following formula:

$$E = M * EF$$

E = Emissions in kg

M = Mass of biowaste [kt]

EF = Emission factor [kg/kt]

Activity data

Since 1980, the Federal Statistical Office has regularly collected and published data on waste quantities managed in composting facilities (Statistisches Bundesamt, FS 19, R 1a, Tabelle 7). To this end, it carries out exhaustive surveys of waste treatment facilities.

The activity data for the current report year have to be estimated, since official waste statistics are published with a one-year time lag. For this reason, in each case the pertinent waste quantity from the previous year is carried forward, unchanged, and then, in the relevant subsequent year, is replaced with the applicable figure from waste-survey statistics. Recalculations are thus required annually.

Table 457: Waste quantities added to biowaste composting facilities

[in 1000 t]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Composting	724	1,515	1,956	2,397	3,783	5,168	6,554	7,214	7,431	8,186
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Composting	9,030	8,562	9,459	9,200	8,981	8,886	8,754	9,115	8,895	8,728
	2010	2011	2012	2013	2014	2015	2016	2017		
Composting	8,609	8,793	8,886	8,977	8,684	8,851	8,975	8,975		

Emission factors

Emission factors for composting of biowaste were determined in the framework of a research project (Cuhls et al., 2015). In that project, emissions measurements, covering methane, nitrous oxide and ammonia, were carried out at 19 composting facilities. From the results of those measurements, and from findings obtained via study of the literature, aggregated emission factors were extrapolated for the entire pool of such facilities in Germany. The factors take account both of the different facility technologies used in Germany and of the different types of biowaste used as input materials. In some cases, very high emissions measurements resulted, making the average value very high as well. For most of the facilities involved, the measurements were then repeated, to make it possible to take account of different atmospheric / meteorological conditions (summer/winter) and to be able to rule out differences in conditions as the cause of such measurements. In the framework of a peer review (with the research contractor, the UBA and experts taking part), the very high measurements were identified as outliers and classified as non-representative. For this reason, it was agreed, with the research contractor (Cuhls), to use the median values as the emission factors. All measured EF entered into the derivation of the median values. The EF themselves were derived from individual EF that had been developed for each different treatment technology. In the relevant procedure, weighted values were first developed, for each treatment technology, as a function of the quantities of waste treated in pertinent facilities in Germany (cf. Cuhls et al, Table 5-1, which lists the various technologies and their shares of treated biowaste). Then the various EF were combined into the EF currently used.

The following emission factors were obtained for composting of biowaste:

EF-CH_4 = 1,400 kg CH_4/ kt biowaste

EF-N_2O = 74 kg N_2O/ kt biowaste

These national emission factors, which comprise both emissions from the composting process itself and emissions from storage and application of compost, have been used for the inventory calculations. The nitrous oxide emissions following fertilisation with compost are very low. They can be neglected, since the nitrogen they include is organically bound and mineralises very slowly. Because nitrogen is released slowly under such conditions, it is largely absorbed by plants, and very little nitrogen is directly available (for example, in the form of nitrate) for conversion into nitrous oxide (Cuhls et al., 2015). Further information about this subject is provided in Category 3 D.

7.3.1.3 Uncertainties and time-series consistency (5.B.1)

Activity data

The uncertainties for the composted waste quantities (2 %) are considered to be very low, since the quantities are based on an exhaustive survey.

Emission factors

The uncertainties for the emission factors are high. They depend on the type of facility/plant in question, on waste composition and on the effectiveness of the biofilters used. The pertinent figures from the literature and from other countries vary so widely that uncertainties of +400 % to -69 % for CH_4, and of at least +177 % to -46 % for N_2O, are assumed. The uncertainties were determined in the framework of the aforementioned research project (Cuhls et al., 2015).

7.3.1.4 Source-specific quality assurance / control and verification (5.B.1)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The activity data are based on figures from federal waste statistics. No more-comprehensive or more-precise data are available.

The emission factors were determined on the basis of an evaluation of the relevant available literature, as well as on the basis of measurements. Furthermore, no more-recent data on emissions from biowaste treatment plants are known to have been published since the research project was carried out.

The emission factor used for methane, at 1.4 g CH_4/kg waste, is lower than the default value of 4 g. However, it does lie within the range for that value, 0.03 to 8 g CH_4/kg waste. In addition, the emission factor used for nitrous oxide, at 0.074 g N_2O/kg waste, is lower than the relevant default value, 0.3 g. It, too, lies within the range for its corresponding default value – which, in this case, is 0.06 to 0.6 g N_2O/kg waste. An important reason why the emission factor is so low is that the treatment plants have high technical standards (active ventilation, temperature monitoring and control, regular turning of compost heaps).

For the same reason, the IEF for CH_4 and N_2O lie well within the lower third of the ranges for reporting countries (GHG Locator 2018). The IEF for methane is of approximately the same magnitude as Italy's value, and it is much higher than the values of comparable countries, such as the Netherlands and France. The IEF for nitrous oxide lies within the lower part of the range, but it is of the same order of magnitude as the values of the Netherlands and Belgium.

7.3.1.5 Category-specific recalculations (5.B.1)

Recalculations have to be carried out annually for the year prior to the previous year, since the waste statistics of the Federal Statistical Office appear with a one-year time lag, meaning that the current report-year data have to be estimated. In each case, such estimates are replaced in the following year with the relevant figures from survey statistics.

Due to an error made in transferring the activity data for the years 1998 and 1999, the CH_4 and N_2O emissions had been slightly underestimated. They have now been corrected, as shown in the following table. Furthermore, the uncertainties for the nitrous oxide EF have been corrected, in the calculation database, from 205/-40 to the values listed in Chapter 7.3.1.3.

Table 458: Composted waste quantities, and the resulting emissions

		1998	1999
AD [t]	2018 NIR	7,320,000	7,964,000
	2019 NIR	7,430,799	8,185,797
Emissions [kg]	CH_4, 2018 NIR	10,248,000	11,149,600
	CH_4, 2019 NIR	10,403,118	11,460,116
	N_2O, 2018 NIR	541,680	589,336
	N_2O, 2019 NIR	549,879	605,749

In addition, rounding errors were corrected for the entire time series. Overall, the corrections were minor to the point of being negligible and thus are not listed here.

7.3.1.6 Category-specific planned improvements (5.B.1)

No improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

7.3.2 Digestion plants (5.B.2)

7.3.2.1 Category description (5.B.2)

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier 2	NS	CS
N_2O	Tier 2	NS	CS

In Germany, annually increasing fractions of biodegradable waste are being separately collected and treated. The emissions reported under 5.B.2 come from biowaste digestion plants that primarily digest separately collected biowaste from households, food waste from cafeterias and restaurants and biowaste from food production and processing. They do not include emissions from digestion of sewage sludge. In some biowaste digestion plants, manure (especially slurry) is also digested. The relevant quantities have been calculated out of the input waste, since their emissions are already included under CRF- category 3 B (cf. also Chapters 5.1.3.6.5 and 5.1.4).

Such digestion processes are operated specifically for the purpose of generating biogas – and, thus, for producing a fuel (unlike composting). For this reason, most of the so-generated biogas is collected and used for energy generation, and only a small fraction is flared off. Quantity data on the two types of gas quantities involved are recorded directly at the relevant plants, and the data are collected for statistical purposes at two year intervals. The results of such surveys are shown in annual waste statistics ((Statistisches Bundesamt, FS 19, R 1a), Table 1.5). Methane emissions from combustion of biogas for energy generation are reported in the section for the energy sector, in 1.A.1.a.

Digestates produced from such separately collected waste are used for agricultural and horticultural purposes. Statistics on digestion of biowaste in biogas plants have been kept only since 1998. In earlier years, such digestion played a negligible role. Since 1998, it has been growing in importance. As of the 2015 NIR, therefore, and in keeping with the 2006 IPCC Guidelines, the inventory now also reports on biowaste digestion in biogas plants.

7.3.2.2 Methodological issues (5.B.2)

Nitrous oxide and methane emissions from digestion of biowaste are reported in keeping with the 2006 IPCC Guidelines. On the other hand, we use our own national emission factors, which were obtained via a research project (Cuhls et al., 2015). The methane and nitrous oxide emissions are calculated in accordance with the following formula:

$$E = M * EF$$

E = emissions in kg

M = Mass of biowaste [kt]

EF = Emission factor [kg/kt]

The quantities of gas from biowaste digestion that are used for energy generation, and the gas quantities that are flared off, are also reported; since 2004, these data have been directly recorded in waste statistics at two-year intervals.

Activity data

The Federal Statistical Office regularly collects data on waste quantities managed in biowaste digestion plants, and it publishes such data annually ((Statistisches Bundesamt, FS 19, R 1a); Table 7). To this end, it carries out exhaustive surveys of waste treatment facilities. Any quantities of manure (especially slurry) present in the total quantities of waste managed in biowaste digestion plants are deducted from those total quantities, since such manure is already included in CRF-category 3B. This is achieved with the help of waste statistics as follows: the quantity listed under waste code 020106 is deducted from the total quantity. This approach, which is designed to prevent double-counting, has been coordinated with the experts responsible for category 3.

The activity data for the current report year have to be estimated, since official waste statistics are published with a one-year time lag. For purposes of estimation, the waste-quantity figure from the previous year is used, unchanged. In each case, such estimates are replaced in the following year with the relevant figures from survey statistics. Recalculations for the year prior to the past year thus have to be carried out on an annual basis.

Table 459: Waste quantities added to biowaste digestion plants

[in 1000 t]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Digestion	0	0	0	0	0	0	0	0	300	599
	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Digestion	916	1,323	2,032	2,254	2,546	2,521	2,744	3,082	3,088	3,402
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**		
Digestion	3,416	4,318	4,666	4,545	5,511	5,436	5,635	5,635		

Emission factors

Emission factors for digestion of biowaste were determined in the framework of a research project (Cuhls et al., 2015). In that project, emissions measurements, covering methane, nitrous oxide and ammonia, were carried out at 16 digesters. From the results of those measurements, and from findings obtained via study of the literature, aggregated emission factors were extrapolated for the entire pool of such facilities in Germany. The factors take account both of the different facility technologies used in Germany and of the diferent types of biowaste used as input materials. In some cases, very high emissions measurements resulted, making the average value very high as well. For most of the facilities involved, the measurements were then repeated, to make it possible to take account of different atmospheric / meteorological conditions (summer/winter) and to be able to rule out differences in conditions as the cause of such measurements. In the framework of a peer review (with the research contractor, the UBA and experts taking part), the very high measurements were identified as outliers and classified as non-representative. For this reason, it was agreed, with the research contractor (Cuhls), to use the median values as the emission factors. All measured EF entered into the derivation of the median values. The EF themselves were derived from individual EF that had been developed for each different treatment technology. In the relevant procedure, weighted values were first developed, for each treatment technology, as a function of the quantities of waste treated in pertinent facilities in Germany (cf. Cuhls et al, Table 5-1, which lists the various technologies and their shares of treated biowaste). Then the various EF were combined into the EF currently used.

The following emission factors were obtained for digestion of biowaste:

EF-CH_4 = 2,800 kg CH_4/ kt biowaste

EF-N_2O = 67 kg N_2O/ kt biowaste

These national emission factors, which comprise both emissions from the digestion process itself and emissions from storage and application of digestates, are used for the inventory calculations. The nitrous oxide emissions following fertilisation with digestates are very low. They can be neglected, since the nitrogen they include is organically bound and mineralises very slowly. Because nitrogen is released slowly under such conditions, it is largely absorbed by plants, and very little nitrogen is directly available (for example, in the form of nitrate) for conversion into nitrous oxide Cuhls et al., 2015). Further information about this subject is provided in Category 3 D.

7.3.2.3 Uncertainties and time-series consistency (5.B.2)

Activity data

The uncertainties for the waste quantities treated in digestion plants are considered to be very low (2 %), since the quantities are based on an exhaustive survey. This also applies to the statistical data collected on the gas quantities from biowaste digestion facilities that are used and on those that are flared off.

Emission factors

The uncertainties for the emission factors are high. They depend on the type of facility/plant in question, on waste composition and on the effectiveness of the biofilters used. The pertinent figures from the literature and from other countries vary so widely that uncertainties of +179 % to -77 % for CH_4, and of at least +320 % to -37 % for N_2O, are assumed. The uncertainties were determined in the framework of the aforementioned research project (Cuhls et al., 2015).

7.3.2.4 Source-specific quality assurance / control and verification (5.B.2)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The activity data consist of figures from federal waste statistics. No more-comprehensive or more-precise data are available.

The emission factors were determined on the basis of an evaluation of the relevant available literature, as well as on the basis of measurements. Furthermore, no more-recent data on emissions from biowaste treatment plants are known to have been published since the research project was carried out.

The emission factors for methane and nitrous oxide that were determined in the research project include both anaerobic treatment of biowaste and aerobic final composting of digestates. For this reason, the value used for methane, at 2.8 g CH_4/kg waste, is considerably higher than the default value of 1 g CH_4/kg waste. However, it does lie within the range for that value, 0 to 8 g CH_4/kg waste. The Guidelines provide no emission factor for nitrous oxide – presumably, because they consider only the relevant anaerobic process.

A comparison of the CH_4-IEF with the IPCC default values shows that the former is considerably larger than the latter. The reason for this is that the IEF is calculated as follows, in keeping with the calculation method given in the CRF: IEF = (CH_4 emissions + CH_4 recovered + CH_4 flared off) / annual quantity of waste in digestion plants.

The German CH_4-emissions figures, however, are based solely on the diffuse emissions that occur during treatment. They were calculated with an EF of 2.8 g CH_4/kg. The data on quantities of CH_4 that are recovered and flared off are obtained from national statistics. They are not of relevance for the emission calculation, since they are used for energy generation or are negligibly low. Consequently, the CRF method for IEF calculation is misleading – at least it is not useful for any comparison of the various countries, since countries that do not recover and flare off CH_4 achieve the IEF default values. Countries that recover CH_4 and use it for energy generation do not achieve the default values – in fact, they greatly exceed them, since the recovered and flared off quantities of CH_4 that are involved naturally greatly exceed the quantities of CH_4 that are diffusely emitted. This assessment is confirmed by a look at the IEF of the reporting countries (GHG Locator 2018). The values for those countries cover a very wide spectrum, and they do not lend themselves to any comparison. As described above, the Guidelines provide no EF for N_2O, because they classify those emissions as negligible. Apart from Germany, only the Netherlands reports these emissions (GHG Locator 2018). The countries IEF values are quite similar.

7.3.2.5 Category-specific recalculations (5.B.2)

Rounding errors were corrected for the entire time series. Overall, the corrections were minor to the point of being negligible and thus are not listed here. Furthermore, the uncertainties for the nitrous oxide EF have been corrected, in the calculation database, from 282/-42 to the values listed in Chapter 7.3.2.3.

Recalculations have to be carried out annually for the year prior to the previous year, since the waste statistics of the Federal Statistical Office appear with a one-year time lag, meaning that the current report-year data have to be estimated. In each case, such estimates are replaced in the following year with the relevant figures from survey statistics.

7.3.2.6 Planned improvements, category-specific (5.B.2)

No improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

7.4 Waste incineration (5.C)

In Germany, all plant(facility)-based waste incineration either is tied completely to energy generation or takes place in the crematorium sector. In order to prevent double-counting, the emissions that occur in connection with waste incineration with energy generation are reported in the energy section (CRF 1.A.1.a, Chapter 3.2.6). In 5.C, only emissions of NO_X, SO_2 and NMVOC from crematoriums (facilities) and NO_X, SO_2, CO and NMVOC from bonfires (open combustion carried out in connection with cultural customs) are reported.

7.4.1 Crematoriums

Gas	Method used	Source for the activity data	Emission factors used
NOX, SO2, NMVOC	Tier 1	AS	CS

The data on cremations are calculated from figures of the Federal association of German funeral homes (Bundesverband Deutscher Bestatter e.V.) and from the official death rates for Germany. Cremations have been accounting for a growing share of all funerals, and thus the absolute numbers of cremations have been growing as well (nearly 600,000 are now carried out per year). As a result, the listed pertinent emissions show an increasing trend. In the CRF Reporter, use of the units "kt" is fixed. Since this setting cannot be adjusted, in the CRF tables "NA" is entered for this category, along with explanatory remarks.

The following figures provide an overview, in lieu of any greater detail:

Cremations	(thousands)	1990	1995	2000	2005	2010	2015	2017
Number		169	316	328	365	427	574	583

No greenhouse-gas emissions are calculated, but the precursor substances NO_X, SO_2, CO and NMVOC are taken into account. Emissions of these substances are calculated using the EF default values in the EMEP/EEA Air Pollutant Emission Inventory Guidebook 2013.

Plans call for reviewing the suitability of the emission factors listed in the 2016 EMEP Guidebook and for taking the latest pertinent measurements into account. In addition, the possibility of listing cremations in mass unit (kt) form is to be reviewed.

7.4.2 Bonfires and similar open combustion

Gas	Method used	Source for the activity data	Emission factors used
NOX, SO2, CO, NMVOC	Tier 1	M, Q	C

For the first time, data on emissions from open combustion of wood and green waste, carried out in celebration of cultural traditions and customs – i.e. from fires such as Easter bonfires – are being reported. In addition to biogenic carbon dioxide, the data cover emissions of NO_X, SO_2, CO and NMVOC.

The applicable number of such culturally oriented bonfires was determined in the framework of a project carried out by experts (Wagner & Steinmetzer, 2018) and involving surveys of municipalities and statistical extrapolations for Germany for the year 2016. The project has shown a declining trend since 1990. On the basis of expert judgement, a further reduction of emissions in the future is expected.

Because the data in this category are being reported for the first time, no recalculations are required, and no improvements are planned.

7.5 Wastewater treatment (5.D)

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
-/T	**5.D.1 Wastewater handling**	**Domestic Wastewater**	**CH_4**	**2,629.71**	**0.21%**	**514.58**	**0.06%**	**-80.4%**
-/-	5.D.1 Wastewater handling	Domestic Wastewater	N_2O	1,389.87	0.11%	429.65	0.05%	-69.1%
-/-	5.D.2 Wastewater handling	Commercial Wastewater	N_2O	31.59	0.00%	25.11	0.00%	-20.5%
-/-	5.D.2 Wastewater handling	Commercial Wastewater	CH_4	9.25	0.00%	44.74	0.01%	383.6%

The category *Wastewater handling – municipal wastewater treatment* is a key category for CO_4 emissions in terms of trend. Because relevant emissions have been falling very sharply since 1990, and thus an extremely low emissions level has been attained, the Single National Entity has decided, as part of its resources prioritisation, not to apply the more stringent methods to this category that are required for key categories.

7.5.1 Municipal wastewater treatment (5.D.1)

7.5.1.1 Methane emissions from municipal wastewater treatment (5.D.1 municipal wastewater treatment)

7.5.1.1.1 Category description (5.D.1 municipal wastewater treatment)

Gas	Method used	Source for the activity data	Emission factors used
CH_4	D/CS	NS	D/CS
N_2O	D/CS	NS	D/CS

The category *Wastewater handling – municipal wastewater treatment* is a key category for CO_4 emissions in terms of trend.

A total of 99.4% of the wastewater produced in Germany is treated in wastewater treatment plants. In such treatment, methane is produced, although most wastewater treatment is aerobic. All process steps probably contribute to the emissions, although sludge digestion and stacking of digested sludge account for the largest shares. Sludge thickening, grit-chamber processes and denitrification account for considerably smaller shares. On the other hand, it is likely that these shares have changed throughout the period covered by the report.

The remaining 0.6 % of the total wastewater quantity (Statistisches Bundesamt, FS 19, R 2.1.3) consists of human sewage of inhabitants not connected to sewage networks or small wastewater-treatment facilities. Wastewater from such inhabitants is collected, for later transport to wastewater treatment plants, in cesspools or septic tanks with no drainage. In cesspools and septic tanks, uncontrolled processes (partly aerobic, partly anaerobic) can occur that lead to methane formation. Since 1990, the organic loads discharged into cesspools and septic tanks have been drastically reduced, however, because the percentages of inhabitants connected to wastewater treatment facilities have continually increased.

In addition, the open sludge digestion that was carried out, for purposes of sludge stabilisation, in the new German Länder until the early 1990s was gradually reduced and then completely discontinued as of 1994 (cf. Chapter 7.5.1.2.1). As a result, this sector's CH_4 emissions show a sharply decreasing trend.

7.5.1.1.2 Methodological issues (5.D.1 wastewater treatment)

Equation 6.1 (IPCC (2006): Vol. 5, Chapter 6.2.2.), which the IPCC has recommended for calculation of CH_4 emissions from municipal wastewater, cannot be applied to the situation in Germany. Two of the two population fractions (U_i) listed in Table 6.5 of the IPCC Guidelines (ibid.) – rural and urban-high – contribute to the emissions concerned. In addition, the pertinent primary and secondary sludges are used for generation of CH_4 in digestion towers. The resulting methane is recovered, and the total quantity of CH_4 produced in the process far exceeds the CH_4 emissions calculated via Equation 6.1. As a consequence, the pertinent value resulting from the IPCC equation would be negative. What is more, sewage sludge is used (for example, used for agricultural or landscaping purposes, or incinerated) only after the sewage gas from it has been recovered, i.e. after it has been fully digested. For this reason, the term "sludge removed" as used within the meaning of the Guidelines is not appropriate, since the sewage sludge is already fully digested and no longer has any BOD_5 (cf. also Chapter 7.5.1.2.1). Furthermore, the data available in Germany on numbers of persons connected to cesspools and septic tanks are much more precise than the values for U_i and $T_{i,j}$ (degree of utilisation of treatment system) that can be derived with Table 6.5 of the Guidelines. All in all, the 2006 Guidelines method is too limited to be suitable for the situation actually prevailing in Germany. For the above-described reasons, the calculations are carried out not with the 2006 IPCC equation, but in accordance with the 1996 IPCC method – with that method supplemented in accordance with the requirements set forth in the 2006 IPCC Guidelines.

The calculation of **methane emissions from wastewater treatment plants** is based on a limited number of measurements from Becker et al. (2012). An emission factor of 0.26 kg methane per year and inhabitant can be derived from the data given in that publication. The measurements were carried out at three installations. All in all, they comprise all potentially emissions-relevant mechanical and biological process steps in wastewater treatment (grit chamber, nitrification, denitrification, P elimination), including sludge treatment (primary and excess sludge, sludge digestion, sludge heaping). Due to the study's design, and the very limited number of measurements that were carried out, the EF must be seen more as the result of samples, and less as a truly representative emission factor. It is of limited reliability, both from a scientific standpoint and in light of the IPCC's quality standards for reference sources. During the 2016 In Country Review, Germany was informed that it is required to use the above EF, however. Furthermore, the uncertainty is also quite high, in light of the wide range covered by the measurements, and of the small number of measurements involved.

Because municipal wastewater treatment plants in Germany tend to have the same types of equipment, with regard to biological wastewater treatment, this emission factor is applied to all wastewater treatment plants.

A research project that is currently in progress is expected to provide data that will support more-precise determination of national emission factors, including factors for nitrous oxide emissions, and thereby considerably improve the precision of the pertinent figures overall. Since virtually all of Germany's inhabitants (about 97 %) are connected to one of the some 9,300 wastewater treatment plants in the country (Statistisches Bundesamt, FS 19, R 2.1.3), the country's total population is used as the activity data. Because the total-population figure is used in the calculations, and because small wastewater treatment plants and cesspools and septic tanks are taken into account, the result may safely be considered to be conservative. Any emission factor for small wastewater treatment plants would probably be lower, because such plants lack sludge treatment. While wastewater from cesspools and septic tanks is taken to municipal wastewater treatment plants – meaning that it also has to be considered here – such wastewater is already partly digested by the time it reaches such treatment plants. As a result, the emissions figures for wastewater treatment plants and those for cesspools and septic tanks overlap somewhat. Due to a lack of precise data, such overlapping cannot be precisely quantified. In any case, it is of very small magnitude and thus can be neglected. The development for the period as of 1990 that underlies the trend in the emission factor is based on a technical article (Grün et al., 2013). Its specific considerations applying to the catchment area of the "Emscher System" (North Rhine – Westphalia) have been generalised and, on the basis of expert judgements, taken as representative for Germany as a whole. This may be considered plausible in light of the highly consistent standards of wastewater treatment technology and plant management prevailing throughout the municipal wastewater treatment sector. The technical article assumes that emissions will be cut in half as a result of improvements in plant technology and plant management in the period 1990 through 2020. It must be noted that this development has been derived solely from the aforementioned improvements to wastewater treatment plants; it does not take account of the specific emissions reductions resulting from conversions of previously open sewer systems in the Emscher catchment basin. This means that the special aspects of the Emscher systems (in comparison to the average German wastewater treatment plants) have not entered into the trend as determined. For calculation of the individual emission factors for the years as of 1990, the above-described emission factor for the year 2014 is used as a fixed starting value. The emission factor for 1990 was determined via a linear equation, in combination with the assumption that the value for 2020 would be half as large as that for 1990. The emission factors for the other years can be determined via linear interpolation. Because the calculation method, described here, that is used to determine the emission factor for emissions from wastewater treatment plants makes use of real measurements, there is no point in applying a methane correction factor (MCF).

Organic loads from **cesspools and septic tanks** are calculated pursuant to the IPCC method, in which the number of persons connected to cesspools or septic tanks (P) is multiplied by the average organic load per person. The average organic load is assumed to be 60 g BOD_5 per inhabitant (Gujer, 2006). While that is the specific value for Germany, it is also used throughout Europe as a statistical average (91/271/EWG, 1991). The IPCC default value for Germany, at 62 g, is of the same order of magnitude (2006 IPCC Guidelines, (2006): Vol. 5, Chapter 6, Table 6.4).

Methane emissions from cesspools and septic tanks are also determined in keeping with the IPCC method. The IPCC default value for methane formation potential (0.6 kg CH_4 / kg BOD_5) has been used. Pursuant to IPCC (IPCC (2006): Chapter 6.1, page 6.7), the methane correction factor (MCF) depends on temperature. No significant methane production occurs at temperatures below 15°C.

In light of the long-term mean soil temperature in Germany (DWD, 2013) at a depth of 1 m, the average soil temperature in summer months ranges between 15 and 18°C. Methane thus can form during summer months, since the relevant cesspools and septic tanks are situated at depths averaging between about 0.5 m and 2.5m. In keeping with Gibbs and Woodbury (1993), the MCF for this period (about 3.5 months) is conservatively estimated to be 0.35. Throughout the rest of the year, the temperatures are below – significantly, in part – the IPCC's 15°C boundary. They drop to about 3.8 °C. In keeping with Gibbs and Woodbury (1993), the MCF for this period (about 8.5 months) is estimated to be 0.1. Furthermore, since the cesspools and septic tanks are regularly emptied, for transport of their wastewater to treatment plants, and thus no sedimentation or sludge concentration occurs, the values used are assumed to be realistic or even conservative. The figures given by Gibbs and Woodbury (1993) refer to studies on methane formation in animal manure. Since no similar data, either national or international, for human excretions are available, and since the pertinent IPCC default values are not applicable to the German situation, the MCF values determined in that study (ibid.) are assumed to be applicable to the task of determining a

national MCF. Since no data are available relative to the transferability of data from animal husbandry to human situations, an uncertainty of 20% (cf. Chapter 7.5.1.1.3) was estimated. A research project completed in 2018 (the project is still unpublished) explored whether any better data, either national or international, are available for derivation of a country-specific MCF. To this end, an extensive study of the pertinent literature was carried out. In addition, national manufacturers of cesspools and septic tanks, and national scientific and university institutions, were surveyed as whether any measurements on methane formation in cesspools and septic tanks are available. The study found that the very few measurements published in the international literature do not support any conclusions with regard to derivation of a national MCF. Furthermore, neither the manufacturers nor the surveyed institutions have any information regarding methane formation. For this reason, the MCF presented here will continue to be used in future, at least until suitable measurements become available.
The above-described conditions and temperature distribution in the soil yield a mathematically averaged MCF for Germany of 0.173.

The MCF is determined as follows:

$$MCF = (0.35 * 3.5 \text{ months} + 0.1 * 8.5 \text{ months}) / 12 \text{ months}$$

(Gibbs and Woodbury 1993) use an estimate of 0.35 for temperatures > 15° C and an estimate of 0.1 for temperatures < 15° C

The emissions are calculated as follows:

$$CH_4 = BOD_{5Y} \times B_o \times MCF$$

$$BOD_{5Y} = P_{cesspool,\ septic\ tanks} \times BOD_5 \times 365 \times 0.001$$

Where

MCF	= *Methane correction factor, 0.173*
B_o	= *Default value for max.* CH_4 *formation capacity, 0.6 kg* CH_4 */ kg* BOD_5
$P_{cesspools,\ septic\ tanks}$	= *Number of persons connected to cesspools or septic tanks*
BOD_{5Y}	= BOD_5 *in g / year*
BOD_5	= *60 g / day x persons*

Calculation pursuant to higher-Tier methods, as required for key categories, is not feasible, since the substance flows for cesspools and septic tanks are not separately recorded.

The following table presents inhabitant data for Germany as a whole and for inhabitants connected to cesspools and septic tanks. The values for the period 1990-2010 have been recorded at five-year intervals, while those for the period as of 2014, i.e. for the last five years, have been recorded on an annual basis. The values provide a framework for following the calculations described in this section.

Table 460: Inhabitants of Germany as a whole, and inhabitants connected to cesspools and septic tanks

Inhabitants [1000s of persons]	1990	1995	2000	2005	2010	2014	2015	2016	2017
Cesspools and septic tanks	8234.425	6434.800	1266.667	875.667	575.000	460.369	431.712	403.054	374.396
Germany as a whole	79753.227	81307.715	81456.617	81336.663	80284.071	81197.537	82175.684	82521.653	82792.351

The **total emissions of methane** from the area of municipal wastewater treatment are obtained as the sums of the emissions (as described in detail) from wastewater treatment plants, cesspools and septic tanks and open sludge digestion (cf. Chapter 7.5.1.2.2.3).

7.5.1.1.3 Uncertainties and time-series consistency (5.D.1 Wastewater treatment)

As described in section 7.5.1.1.2, the MCF value has been adjusted in keeping with the climatic conditions prevailing in Germany (long-term average soil temperature in Germany). The uncertainty for the value is ± 20 % (expert estimate).

In addition, the following uncertainties are also used (all are expert estimates):

- Emission factor for methane from wastewater treatment plants = ± 25 %
  The uncertainty is obtained from the range for CH_4 emissions (± 28.6%) given in the literature (Becker et al. (2012)) and the 95th percentile derived from it.
- Inhabitants with cesspools or septic tanks = ± 3 %
- BOD_5 = ± 30 %
- B_0 = ± 30 %

The activity data for organic loads in cesspools and septic tanks are based on figures of the Federal Statistical Office (Statistisches Bundesamt, FS 19, R 2.1.3). Every three years, the Federal Statistical Office conducts a survey – without determining the relevant uncertainties – of the numbers of inhabitants who are not connected to the public sewer system and whose wastewater is disposed of via cesspools and septic tanks. Data for interim years are linearly interpolated or extrapolated. No other data sources are available. The results of such surveys may be considered very precise, since the surveys are exhaustive.

Until 1995, data for the old and new Federal Länder were determined separately; since then, a single value for all of Germany has been determined in each case. This does not affect the consistency of the time series.

7.5.1.1.4 Category-specific quality assurance/ control and verification (5.D.1 Wastewater treatment)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

As noted above (Chapter 7.5.1.1.1), 0.6 % of the population in Germany are not connected to the sewage network and thus collect their wastewater in cesspools or septic tanks. This value agrees well with the values proposed by the IPCC (IPCC (2006): Vol. 5, Chapter 6.2.2.3; Table 6.5) for Germany, for the relevant fraction of the rural population and the associated degree of utilisation of septic systems. With the IPCC values, one obtains the result that about 1.2% of the population collects wastewater via septic systems. The two values are of the same order of magnitude and, additionally, lie quite close together.

7.5.1.1.5 Source-specific recalculations (5.D.1 Wastewater treatment)

Methane emissions from wastewater treatment plants

The data on CH_4 emissions (emissions from wastewater treatment plants, and total emissions) were corrected for the entire time series, to take account of adjustments in population figures for the period 1991-2011, on the basis of the 2011 census, and of the high-resolution (to the nearest person) population figures now available for 1990 and for the period as of 2012. The changes in the values are shown in the following table, for the years 1990-2010 (at five-year intervals) and for the period as of 2014 (for every year). As a result of the changes in the population figures, the values for the total organic load in wastewater (TOW) have also changed; for this reason, the new TOW values are listed as well. The values for inhabitants connected to cesspools and septic tanks are specific. Neither those values nor the calculation method applied to them have changed. As a result, the values for emissions from cesspools and septic tanks have also not changed.

Table 461: Recalculation of CH_4 emissions in keeping with adjustments of population figures

Population	Units		1990	1995	2000	2005	2010	2014	2015	2016
Inhabitants of Germany	[1000s of persons]	2019 NIR	79,753	81,308	81,457	81,337	80,284	81,198	82,176	82,522
		NIR 2018	79,753	81,817	82,260	82,438	81,752	81,198	82,176	82,800
Cesspools and septic tanks	**Units**		**1990**	**1995**	**2000**	**2005**	**2010**	**2014**	**2015**	**2016**
Organic load for Germany as a whole	[kt/a]	NIR 2019	2183.245	2225.799	2229.875	2226.591	2197.776	2222.783	2249.559	2259.030
		NIR 2018	2183.238	2239.740	2251.868	2256.740	2237.961	2222.795	2249.568	2266.650
Wastewater treatment plants	**Units**		**1990**	**1995**	**2000**	**2005**	**2010**	**2014**	**2015**	**2016**
CH_4 emissions	[kt]	NIR 2019	34.560	32.297	29.415	26.434	23.193	21.111	20.772	20.264
		NIR 2018	34.560	32.500	29.705	26.792	23.617	21.111	20.772	20.332
Wastewater treatment plants	**Units**		**1990**	**1995**	**2000**	**2005**	**2010**	**2014**	**2015**	**2016**
CH_4 emissions	[kt]	NIR 2019	105.188	46.925	32.294	28.425	24.500	22.158	21.754	21.180
		NIR 2018	105.188	47.127	32.584	28.783	24.924	22.158	21.754	21.248
CO_2 equivalents	[kt]	NIR 2019	2,629.71	1,173.12	807.36	710.62	612.51	553.95	543.84	529.50
		NIR 2018	2,629.71	1,178.18	814.61	719.57	623.11	553.95	543.84	531.21

7.5.1.1.6 Planned improvements, category-specific (5.D.1 Wastewater treatment)

No improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

7.5.1.2 Methane emissions from municipal sludge treatment (5.D.1 Sludge treatment)

7.5.1.2.1 Category description (5.D.1 Sludge treatment)

As a general rule, the treatment of municipal sewage sludge comprises two treatment stages:

- Water removal via mechanical processes (chamber-filter press, cyclone); evaporation in sludge-drying lagoons or sludge-drying beds
- Stabilisation: Aerobic stabilisation (open pool with oxygen input); or anaerobic stabilisation in digestion tower
- (until 1993: open sludge digestion)

With reference to population figures, mechanical *dehydration* + treatment in a digestion tower (with dehydration before or after the digestion-tower treatment) currently represents the main treatment method (some treatment is also carried out in small, rural sewage treatment plants). Moreover, sewage sludge is generally stabilised prior to subsequent use.

The purpose of sludge stabilisation is to prevent uncontrolled sludge digestion. In facilities for fewer than 10,000 inhabitants, such stabilisation is usually carried out aerobically, with energy consumption, while in facilities for more than 30,000 inhabitants it normally is carried out anaerobically, with production of methane gas [168]. The amount of digester gas produced depends especially on the composition of the sewage sludge, the temperature and the reaction conditions. Gas so produced is usually recovered for energy generation in combined heat/power generating systems (CHP). It is reported under 1.A.1.

Until the early 1990s, in eastern Germany sludge was still stabilised via open digestion, a process that produced methane emissions. Open sludge digestion is no longer practiced. It was phased out gradually, and was then completely discontinued in 1994. Emissions from open sludge digestion continue to be the reason, however, why NO is reported for this point in the CRF, instead of IE (for the energy-related use under 1.A.1 – see above), since this technique, with its related emissions, was used through 1993.

The secondary sludge (excess sludge) occurring in wastewater treatment, and the pertinent primary sludge, are anaerobically treated, together, in digestion towers and thus anaerobically stablised. That process produces digested sludge. That sludge, in turn, undergoes further treatment in wastewater treatment facilities and leaves such facilities as sewage sludge. Use of this process ensures that the sewage sludge is completely free of readily biodegradable substances.

The sewage sludge and the treated wastewater are the final products of wastewater treatment.

In Germany, sewage sludge remaining after biological wastewater treatment is managed in the following ways (where applicable, after dehydration and stabilisation):

- Thermal utilisation: no methane emissions occur. Thermal utilisation requires energy inputs and thus is allocated to CRF 1.
- Recycling for substance recovery: the most important procedures for recycling sewage sludge for substance recovery include recycling in agriculture, pursuant to the Ordinance on Sewage Sludge (Klärschlammverordnung), and use in landscaping and other measures.

Table 462: Use of sewage sludge

Sewage sludge Dry matter DM [t]	2012	2013	2014	2015	2016
Total quantity	1,846,441	1,787,871	1,809,166	1,803,087	1,773,186
Thermal utilisation	*1,008,830*	*1,034,771*	*1,084,108*	*1,148,679*	*1,142,893*
- Mono-incineration		*230,581*	*431,286*	*432,516*	*460,411*
- Co-incineration		*250,326*	*400,115*	*446,871*	*615,928*
- Unknown		*553,864*	*252,707*	*269,292*	*66,554*
Landfill	0	0	0	0	0
Recycling for substance recovery	*837,611*	*748,868*	*722,416*	*651,410*	*624,000*
- Agriculture	*544,065*	*484,464*	*470,882*	*427,736*	*423,497*
- Landscaping-related measures	235,439	203,712	216,148	190,127	169,439
- Composting	0	0	0	0	0
- Other	58,107	60,692	35,386	33,547	31,064
Other direct utilisation		4,232	2,642	2,998	6,293

The activity data for sewage-sludge utilisation are based on data of the Federal Statistical Office (Statistisches Bundesamt, ab 2010). The relevant report appears every 3 years. The figures for interim years are taken from the publication "Wasserwirtschaft Öffentliche Abwasserentsorgung Klärschlammverwertung aus der biologischen Abwasserbehandlung“ ("Water resources sector, public wastewater management, use of sewage sludge from biological wastewater treatment" (Statistisches Bundesamt, ab 2013). No data are available for the period prior to 1998 and for the

[168] In 2016, digester gas was recovered in a total of 1,258 wastewater treatment facilities (Statistisches Bundesamt, 2017).

years 1999-2000, 2002-2003 and 2005. No interpolation is possible, because a statistical conversion for the period as of 2007 makes it impossible to form a 100% sum(Wiechmann et al., 2013). No data are available for the current inventory year; for this reason, only the data of the previous years can be presented here. For 2013, the Federal Statistical Office reported for the first time in this regard, under "substance recovery" ("Stofflicher Verwertung")[169].

The activity data for sewage-sludge utilisation, for the years prior to 2011, are available in the 2015 NIR.

7.5.1.2.2 Methodological issues (5.D.1 Sludge treatment)

7.5.1.2.2.1 Digester gas

As described above, the digester gas that is produced by the digestion process is recovered and used for energy generation. The methane content in digester gas is nearly 65 % (Schön et al., 1993). The relevant quantity of methane per raw-gas volume (Statistisches Bundesamt, ab 2012) is determined as follows:

$$M_{methane} = V_{raw\ gas} \times 0.65 \times \sigma \times 0.000001$$

Where

$M_{methane}$ = Mass of methane produced via digestion (kt)

$V_{raw\ gas}$ = Volume of digester gas produced (m^3)

0.65 = Conversion factor for determination of the methane contained in the digester gas

σ = Density of methane (0.717 kg/m^3) (v.Vogel & Synowietz, 1974)

7.5.1.2.2.2 Digester-gas losses

Operators report data on digester-gas collection and sewage-sludge utilisation annually to the Federal Statistical Office, on the basis of the Act on Energy Statistics. Enquiries to several wastewater treatment facilities with digester-gas collection revealed that the gas losses at such facilities amount to 5 %. This confirms the relevant figures of the Federal Statistical Office (Statistisches Bundesamt, ab 2012). It is assumed that most of the gas lost is burned in flares. Such flaring losses in connection with gas collection result via technical difficulties, damage and maintenance measures. When such factors arise, flaring is carried out for safety reasons. Such gas flares are designed to be able, in emergencies, to burn all of the gas being collected. In addition, they are equipped with automatic ignition. The reported losses can also be due to discrepancies between the accuracy of measurements made at gas-production sites and the accuracy of measurements made at consumption sites. Normally, gas routed to flares is not separately measured. As a result, no details on the nature of such losses can be provided here.

Any leakages that occur in such facilities are taken into account by the calculations described under 7.5.1.1.2, since the area of sludge treatment has been included in determination of the emission factor.

7.5.1.2.2.3 Open sludge digestion

An emission factor of 210 kg CH_4/t TS is used for open sludge digestion in the new German Länder, in keeping with the results of the study Schön et al. (1993).[170] The activity rates for the years 1990 to 1992 were communicated personally to the Federal Environment Agency by the then Chief Inspector of the former GDR's water-processing plants.

[169] This includes provision to drying facilities in cases in which further disposal steps are not known.

170 The emission factor was determined via the difference between methane emissions from psychrophilic sludge stabilisation in the new German Länder and the total amount of sewage sludge produced.

In keeping with the fact that open sludge digestion is prohibited in the Federal Republic of Germany, use of that treatment method was gradually reduced in the new German Länder until 1994 and then was completely discontinued as of 1994.

The above-described data for the years 1990-1994 were most recently provided, in tabular form, in the 2015 NIR.

7.5.1.2.3 Uncertainties and time-series consistency (5.D.1 Sludge treatment)

7.5.1.2.3.1 Digester gas

The uncertainties in determination and calculation of the applicable quantities of methane are assessed as follows (expert assessment):

Volume of digester gas produced = ± 5 %

The uncertainties originate in the measurement inaccuracies of the measuring devices used

Methane content in digester gas = ± 15 %

Varies in keeping with the composition of the wastewater – and, thus, of the composition of the sludge

Density = ± 30 %

The literature gives a range of different densities for methane (depending on temperature, etc.)

The figure for the quantity of digester gas produced is based on data of the Federal Statistical Office. The time series are thus internally consistent. The relevant surveys are carried out annually. The results of the surveys are considered accurate.

7.5.1.2.3.2 Open sludge digestion

Since the uncertainties connected with open sludge digestion have not yet been estimated, the default values (conservative factors) given in UNFCCC Decision 20/CMP.1 (p. 39ff) (UNFCCC, 2006) are used. The activity rates between 1990 and 1992 are based on a personal communication; those for 1993 are based on estimates of the Federal Environment Agency. As a result, a high degree of time-series consistency is not assured.

7.5.1.2.4 Category-specific quality assurance / control and verification (5.D.1 Sludge treatment)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The methane content in sewage gas was determined with an average-methane-content figure (65 %) (Schön et al., 1993) that has been checked with data of the Federal Statistical Office (Statistisches Bundesamt, ab 2012). For 2015, the Federal Statistical Office obtained a figure of 63.17 % as the average methane content of sewage gas. The value used is thus considered verified.

No comparable emissions data for Germany, or other data on methane collection from wastewater treatment plants, are known.

7.5.1.2.5 Source-specific recalculations (5.D.1 Sludge treatment)

No recalculations are required.

7.5.1.2.6 Category-specific planned improvements (5.D.1 Sludge treatment)

At present, improvements seem neither necessary nor possible, since no further activity data are available.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

7.5.1.3 Nitrous oxide emissions from municipal wastewater (5.D.1 Nitrous oxide emissions from municipal wastewater)

7.5.1.3.1 Category description (5.D.1 Nitrous oxide emissions from municipal wastewater)

Municipal wastewater contains numerous nitrogen compounds. In bacterial decomposition processes, part of the available organic nitrogen is converted back into biomass.

Direct emissions: So that they can eliminate virtually all of the nitrogen remaining in wastewater, nearly all of the municipal wastewater-treatment plants in Germany are operated with an additional nitrification and denitrification stage that complements the plants' biological wastewater treatment. In nitrification, the nitrogen compounds in the wastewater are converted into nitrate, under aerobic conditions. In denitrification, the nitrogen bound in the nitrate is converted into molecular nitrogen and nitrogen oxides. Under unfavourable conditions (cf. also Chapter 7.5.2.2.1), nitrous oxide (N_2O) can occur as a by-product / intermediate product in both processes, although denitrification is the predominate source in this regard (IPCC (2006): Vol. 5, Chapter 6.1, p. 6.8).

Indirect emissions: The nitrogen that remains in wastewater following wastewater treatment enters into water bodies. There, microbial decomposition processes also take place in which nitrous oxide can be formed and emitted.

The total emissions of nitrous oxide that are produced via municipal wastewater are determined as a combination of the direct nitrous oxide emissions (N_2O_{Plants}) and indirect nitrous oxide emissions ($N_2O_{Effluent}$). The total emissions are obtained as follows:

$$N_2O_{Total} = N_2O_{Plants} + N_2O_{Effluent}$$

The emissions show a strongly decreasing trend, as a result of extensive additions of denitrification systems to wastewater treatment facilities in the period 1990 through about 2001. This is due to implementation of the Waste Water Ordinance (Abwasserverordnung) (91/271/EWG, 1991) which, in the early 1990s, made nutrient removal in wastewater treatment plants part of the state of the art. Nutrient removal technology has since reached high technological standards, and a slightly decreasing emissions trend became established in about 2005.

7.5.1.3.2 Methodological issues (5.D.1 Nitrous oxide emissions from municipal wastewater)

Direct emissions

Pursuant to the 2006 IPCC Guidelines, only countries with modern, centralised wastewater treatment facilities are required to report direct emissions. According to the IPCC, "modern" facilities in this context are facilities with nitrification and denitrification phases. As described above, nitrous oxide emissions occur, pursuant to IPCC (ibid.), primarily in denitrification. For this reason, in the following the fraction of German wastewater treatment plants with denitrification equipment (T_{Plant}) – and not the fraction of plants with nitrification equipment – is used for the calculations. 97 % of wastewater treatment plants are equipped with nitrification, while 96 % have denitrification (Statistisches Bundesamt, FS 19, R 2.1.3). Calculation of the nitrous oxide emissions takes account of central wastewater treatment plants that are equipped with denitrification.

Pursuant to the 2006 IPCC Guidelines (IPCC (2006): Vol. 5, Chapter 6.3.1.3, Equation 6.9), nitrous oxide emissions as calculated as follows:

$$N_2O_{PLANTS} = P \bullet T_{PLANT\ DENI} \bullet F_{IND-COM} \bullet EF_{PLANT}$$

Where

N_2O_{PLANTS}	=	Total annual N_2O emissions of plants, in kg N_2O/year)
P	=	Population
$T_{PLANT\ DENI}$	=	Degree of utilisation of modern centralised wastewater treatment plants with denitrification, %/100 (i.e. with respect to the entire wastewater load in Germany)
$F_{IND-COMM}$	=	Fraction of protein of industrial / commercial origin that is managed via wastewater; default = 1.25
EF_{PLANT}	=	Emission factor; 3.2 g N_2O/person x year

While IPCC default values are used for the emission factor for nitrous oxide, and for the fraction of the protein of industrial and commercial origin ($F_{IND-COMM}$) that is managed via municipal plants, the population figure (P) and the degree of utilisation of modern, centralised wastewater treatment plants with denitrification ($T_{Plant\ deni}$) are country-specific values.

Indirect emissions

In keeping with the method proposed by the 2006 IPCC Guidelines, first the total annual quantity of nitrogen in wastewater effluent is determined. For countries with modern, centralised wastewater treatment plants, and taking N_{WWT} into account, this is to be determined as follows:

$$N_{Effluent} = (P \times Protein \times F_{NPR} \times F_{Non-con} \times F_{Ind-comm}) - N_{Sludge} - N_{WWT}$$

(IPCC (2006): Vol. 5, Chapter 6.3.1.3. Equation: 6.8).

Where

$N_{EFFLUENT}$	=	Total annual quantity of nitrogen in wastewater effluent, in kg N/year
P	=	Population
Protein	=	Per-capital protein consumption, in kg/person/year
F_{NPR}	=	Nitrogen fraction in protein; default = 0.16 kg N / kg protein
$F_{NON-CON}$	=	Fraction of non-consumed protein in wastewater; default = 1.1
$F_{IND-COMM}$	=	Fraction of protein of industrial / commercial origin that is managed via wastewater; default = 1.25
N_{SLUDGE}	=	Nitrogen removed with sludge; default = 0 in kg N / year
N_{WWT}	=	Nitrogen fraction in the nitrous oxide occurring in connection with wastewater treatment
	=	N_2O_{PLANTS} x 28/44 in kg N/year
28/44	=	Factor for conversion of N_2O to N_2

According to experts, this formula is erroneous, however, and ineffective by itself, since it does not take account of the N-removal performance of wastewater treatment plants' denitrification phases. To obtain realistic results, one must thus adapt the above equation, as shown below. For the years 2006-2013, data on the average N content of the wastewater flowing into ($N_{influent}$) and out of ($N_{effluent}$) German wastewater treatment plants are available(DWA, ab 1988 - jährlich). From those data, biological wastewater-treatment plants in Germany were determined to have an average N-removal efficiency of 81.2 % in the years mentioned. In the interest of data comparability, $T_{Plant\ deni}$ was determined, via selection of wastewater treatment plants with denitrification. In the following, the factors to be taken into account include a) the removal efficiency of wastewater treatment plants with denitrification[171] and b) the N load of all plants

[171] Only installations with denitrification are considered, since nitrous oxide formation is more likely in such installations.
In its surveys, DWA does not break the data down in accordance with individual treatment stages.

without biological wastewater treatment. The factor N_{WWT} does not suffice for this purpose, since it includes only the nitrogen fraction in the nitrous oxide that is produced (direct emissions); it does not include the N fraction in the molecular nitrogen produced via denitrification. The factor N_{WWT} is thus removed from the equation. In addition, the factor N_{SLUDGE} is also removed, since N_{SLUDGE} value used by Germany is equal to 0, and since nitrogen elimination from the sludge is already taken into account via $F_{ELIMINATION}$:

$$N_{EFFLUENT} = (P \times Protein \times F_{NPR} \times F_{NON-CON} \times F_{IND-COM})$$

That formula applies for plants without nitrogen elimination.

For calculation of the N load ($N_{Effluent\ with}$) in the effluent of plants with nitrogen elimination, the elimination factor $F_{ELIMINATION}$ is introduced. The formula is thus as follows:

$$N_{EFFLUENT\ with} = (P \times Protein \times F_{NPR} \times F_{NON-CON} \times F_{IND-COM}) \times (1 - F_{ELIMINATION}) \times T_{PLANT\ Deni}$$

Where

$F_{ELIMINATION}$ = Factor for nitrogen-elimination performance in wastewater treatment plants = N effluent / N influent = 81.2 / 100 (DWA, ab 1988 - jährlich)

$T_{PLANT\ Deni}$ = Degree of utilisation of modern centralised wastewater-treatment plants with denitrification, %/100 (i.e. with respect to the entire wastewater load in Germany)

$N_{EFFLUENT\ with}$ = N load in the effluent of wastewater treatment plants

$N_{EFFLUENT\ without}$ = N load in the effluent of wastewater treatment plants

The N load ($N_{Effluent\ without}$) in the effluent of wastewater treatment plants without biological wastewater treatment is calculated as follows:

$$N_{EFFLUENT\ without} = (P \times Protein \times F_{NPR} \times F_{NON-CON} \times F_{IND-COMM}) \times (1 - T_{PLANT\ Deni.})$$

Then, the nitrogen loads in the effluent of wastewater treatment plants with denitrification and in the effluent of wastewater treatment plants without biological wastewater treatment are added, to yield the total N load in the effluent of all wastewater treatment plants:

$$N_{Effluent} = N_{Effluent\ with} + N_{Effluent\ without}$$

$$= (P \times Protein \times F_{NPR} \times F_{NON-CON} \times F_{IND-COMM}) \times (1 - F_{ELIMINATION}) \times T_{PLANT\ Deni.} + (P \times Protein \times F_{NPR} \times F_{NON-CON} \times F_{IND-COMM}) \times (1 - T_{PLANT\ Deni.})$$

The result obtained with the above-described procedure has been verified via comparison with alternative data (DWA, 2007-2015; UBA, 2014) (UBA, 2016a) and it thus seems to be correct (cf. Chapter 7.5.1.3.6).

The relevant IPCC default values have been used for the emission factor for nitrous oxide, the nitrogen fraction in protein and the fraction of protein of industrial and commercial origin that is managed via municipal plants ($F_{IND-COMM}$). Country-specific values are used for the average per-capita protein intake and the population size (number of persons). The value for non-consumed protein ($F_{NON-CON}$) is so low, because waste disposal via wastewater (garbage disposal units) is not widespread in Germany.[172]

[172] While Germany does not prohibit garbage disposal units at the national level, some municipalities' wastewater ordinances prohibit addition of waste, including ground or shredded waste, to wastewater. https://de.wikipedia.org/wiki/K%C3%BCchenabfallzerkleinerer 28 July 2016

As of 2015, the average protein intake per person and day, throughout the entire reporting period, has been determined only on the basis of the data in the FAOSTAT database (FAOSTAT, ab 2015). The FAOSTAT data differ only marginally from the data in the FAO Statistical Yearbook.

The nitrous oxide emissions are determined as follows, in keeping with the IPCC method:

$$N_2O_{\text{Emissions}} = N_{\text{EFFLUENT}} \times EF_{\text{EFFLUENT}} \times 44/28$$

Where

$N_2O_{\text{Emissions}}$ = N_2O emissions, in kg N_2O/year

N_{EFFLUENT} = Nitrogen discharged into the aquatic environment, in kg N/year

EF_{EFFLUENT} = Emission factor for N_2O emissions released into wastewater, in kg N_2O-N/kg N (default = 0.005)

44/28 = Factor for conversion of N_2O-N to N_2O

Due to the great many plants concerned, calculation with higher-Tier methods is not feasible. What is more, the Federal Statistical Office does not list the substance flows of wastewater-treatment plants separately.

The **total emissions of nitrous oxide** from the area of municipal wastewater treatment are obtained as the sum of the relevant direct and indirect emissions described in detail.

7.5.1.3.3 Uncertainties and time-series consistency (5.D.1 Nitrous oxide emissions from municipal wastewater)

The following uncertainties are used (all are expert estimates):

P (population)	=	± 5 %
$T_{\text{Plant deni}}$ (wastewater treatment plants with denitrification)	=	± 5 %
$F_{\text{Ind-comm}}$	=	± 25 %
Protein	=	± 15 %

The activity data are based on data of the Federal Statistical Office. The population of Germany is determined on an annual basis, while the quantity of wastewater treated in wastewater-treatment facilities with denitrification is determined every three years (without determination of pertinent uncertainties). The results of the latter surveys may be considered very precise, since the surveys are exhaustive. The figures for the years prior to 1998 have been extrapolated. They are plausible, since inclusion of nitrogen elimination processes in wastewater treatment began to be expanded in Germany as of the beginning of the 1990s. The figures for the years after 2013 have been carried forward from earlier years. All other lacking data have been linearly interpolated.

The uncertainties for the EF_{Plant} have been taken from (IPCC (2006):, Vol. 5, Table 6.11); they are -37.5 % and + 150 % . Experts consider those values plausible.

The uncertainty for the average N-removal efficiency of German wastewater-treatment plants is estimated at ± 5 %.

The average daily protein requirement for 1990 – 2013 has been obtained from the database (FAOSTAT, ab 2015). For the subsequent years, the value for 2013 has been carried forward. An uncertainty of ± 20 % (expert estimate) is assumed.

The average nitrogen fraction in protein (F_{NPR}) is 16 % ± 1%. In obtaining this value, it was assumed that Bovine serum albumin is the standard protein. In light solely of the aforementioned standard deviation (± 1%), the uncertainty would be about ± 6 % (with respect to the 16% fraction). It is estimated to total ± 7 %, however, since the relevant wastewater contains a broader spectrum of protein (expert estimate).

In addition, the following uncertainties have also been used (all are expert estimates):

$F_{NON-CON}$, = ± 30 %

$F_{IND-COMM}$ = ± 25 %

The uncertainties for the $EF_{EFFLUENT}$ have been obtained from (IPCC (2006): Vol. 5, Table 6.11).

7.5.1.3.4 Category-specific quality assurance / control and verification (5.D.1 Nitrous oxide from municipal wastewater)

General and category-specific quality control and quality assurance have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The formula adapted via $F_{ELIMINATION}$, for determination of the N effluent into water bodies, was verified with the average values, as published in the comparison of the performance of municipal wastewater treatment plants (Leistungsvergleich Kommunaler Kläranlagen), for N discharges into water bodies(DWA, ab 1988 - jährlich). Currently, verification is being carried out with data for the years 2006-2015. Data provided under the Urban Waste Water Treatment Directive (reporting by the Federal Government to the EU pursuant to 91/271/EEC (UBA, 2016a)) are used as an additional data source for verification. The data in both data sources are completely independent of the data used with the above-described calculation method. The following table presents the results of calculation of $N_{Effluent}$ (indirect emissions) on the basis of the 2006 IPCC method; of the modified IPCC method (nitrogen elimination factor $F_{Elimination}$); of the measurements obtained by the German Association for Water, Wastewater and Waste (DWA); of a mixed method using DWA data and data of the Federal Statistical Office; and of data provided under the the Urban Waste Water Treatment Directive.

Table 463: Comparison of NEFFLUENT as determined on the basis of various sources; (kt N/year)

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
With the IPCC 2006 method										
$N_{EFFLUENT}$	654.8	675.9	666.2	673.8	669.4	665.4	658.6	658.7	662.2	670.2
With the modified IPCC 2006 method										
$N_{EFFLUENT}$	159.3	156.3	152.9	153.4	151.1	148.9	146.0	141.8	144.1	144.4
With DWA data on N inputs & wastewater quantities										
$N_{EFFLUENT}$	71.5	86.1	86.5	82.7	87.0	77.9	79.1	81.7	72.8	72.3
With DWA data on N inputs & wastewater-quantity data of the Federal Statistical Office										
$N_{EFFLUENT}$	80.8	90.6	95.4	95.1	92.9	90.4	88.9	87.4	85.0	84.5
With data provided under the Urban Waste Water Treatment Directive										
$N_{EFFLUENT}$			87.3	-	82.6	-	83.1	-	75.1	-

The above-described modified method yields significantly lower values for the N load in the effluent ($N_{Effluent}$) than does the IPCC method. The values calculated with the modified method are confirmed by the data sources used for verification. The various results are all of the same order of magnitude. The modified method yields the highest values overall, and thus may be considered a conservative method. The rather considerable discrepancy seen with the modified IPCC method can be ascribed to the IPCC default emission factor used. In light of this verification, it must be considered too high. Nonetheless, in spite of its probable overestimation of the real N load in the effluent, and of the related possible N_2O emissions, it lies within the range allowed by the uncertainties.

Alternative data sources for the average protein intake per person and day include:

- The 1991 food table for practical applications (Senser & Scherz, 1991) gives an average protein intake of 94 g/inhabitant and day.

- The nutrition report of the German Nutrition Association (Deutsche Gesellschaft für Ernährung) (DGE, 2008)[173] used estimated food-consumption data for 2005/2006 to estimate average daily protein intake. From that data, an average value of about 79 g protein / person and day[174] was derived.

As of the 2017 NIR, the FAOSTAT database (FAOSTAT, ab 2015) is used for determination of N_2O emissions in wastewater, since it contains a consistent time series. It is internationally comparable, and it is regularly updated. The Federal Environment Agency has no information to the effect that the country-specific values in the food table and in the 2008 nutrition report are more precise or enjoy greater national acceptance. In addition, many countries use the FAO database; as a result, the emissions-determination process used by Germany is internationally comparable. A European comparison shows that the daily protein intake assumed for Germany lies within the middle of the overall range. The FAO data do not take account of the protein fractions that are not consumed – and that are disposed of instead upon utilisation ($_{FNON-CON}$). The WWF (2015) assumes consumption waste of up to 16 % for meat, eggs and milk.

The protein-consumption data used by the FAO are derived on the basis of production data (supplied by the Federal Statistical Office) and trade data (EUROSTAT). The relevant work considers and studies five different, successive losses along the value chain, including harvest, post-harvest, process, distribution and consumption losses (WWF, 2015).

7.5.1.3.5 Category-specific recalculations (5.D.1 Nitrous oxide from municipal wastewater)

The N_2O-emissions data (direct, indirect and total emissions) were corrected for the entire time series, to take account of adjustments of population figures (cf. 7.5.1.1.5). In addition, the data on protein intake for the years 1990-2010 were updated by FAOSTAT. The changes in the values are shown in the following table, for the years 1990-2010 (at five-year intervals) and for the period as of 2014 (for every year).

[173] The nutrition report is published every four years.
[174] This value was obtained with the help of the rough estimate that each population group in Germany consists of 50 % men (90.8 g/day) and 50% women (66.7 g/day).

Table 464: Recalculation of N_2O emissions in keeping with adjustments of population figures

+	Units		1990	1995	2000	2005	2010	2014	2015	2016
Inhabitants of Germany	[1000s of persons]	2019 NIR	79,753	81,308	81,457	81,337	80,284	81,198	82,176	82,522
		NIR 2018	79,753	81,817	82,260	82,438	81,752	81,198	82,176	82,800
Protein intake	**Units**		**1990**	**1995**	**2000**	**2005**	**2010**	**2014**	**2015**	**2016**
	[g/capita/d]	NIR 2019	96.66	91.89	94.46	96.96	101.89			
		NIR 2018	96.80	92.00	94.50	97.00	102.00			
Direct emissions	**Units**		**1990**	**1995**	**2000**	**2005**	**2010**	**2014**	**2015**	**2016**
N_2O emissions	[kt]	NIR 2019	0.0176	0.1410	0.2582	0.2982	0.3062	0.3130	0.3176	0.3198
		NIR 2018	0.0176	0.1419	0.2607	0.3022	0.3118	0.3130	0.3176	0.3209
kt CO_2-eq.	[kt]	NIR 2019	5.23	42.02	76.93	88.86	91.25	93.27	94.65	95.31
		NIR 2018	5.23	42.28	77.69	90.06	92.92	93.27	94.65	95.63
Indirect emissions			**1990**	**1995**	**2000**	**2005**	**2010**	**2014**	**2015**	**2016**
$N_{EFFLUENT\ Real}$	[kt]	NIR 2019	591.37	388.75	220.34	161.98	148.28	144.06	144.37	143.54
		NIR 2018	592.22	391.65	222.61	164.24	151.15	144.06	144.38	144.02
N_2O emissions	[kt]	NIR 2019	4.65	3.05	1.73	1.27	1.17	1.13	1.13	1.13
		NIR 2018	4.65	3.08	1.75	1.29	1.19	1.13	1.13	1.13
kt CO_2-eq.	[kt]	NIR 2019	1384.64	910.22	515.92	379.27	347.18	337.31	338.04	336.09
		NIR 2018	1386.64	917.02	521.23	384.57	353.91	337.31	338.05	337.22
Emissions, total			**1990**	**1995**	**2000**	**2005**	**2010**	**2014**	**2015**	**2016**
N_2O emissions	[kt]	NIR 2019	4.66	3.20	1.99	1.57	1.47	1.44	1.45	1.45
		NIR 2018	4.67	3.22	2.01	1.59	1.50	1.44	1.45	1.45
kt CO_2-eq.	[kt]	NIR 2019	1389.87	952.24	592.85	468.13	438.43	430.58	432.70	431.40
		NIR 2018	1391.88	959.30	598.92	474.63	446.83	430.58	432.70	432.85

7.5.1.3.6 Planned improvements, category-specific (5.D.1 Nitrous oxide from municipal wastewater)

No improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

7.5.2 Methane emissions from industrial wastewater treatment (5.D.2)

7.5.2.1.1 Category description (5.D.2 CH_4)

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier2/CS	NS	CS
N_2O	Tier 2/CS	NS	CS

Emissions from industrial wastewater treatment are not a key category.

The CH_4 emissions reported here relate only, in keeping with IPCC (2006), to that wastewater fraction that is treated in industrial wastewater treatment facilities. The industrial wastewater fraction that is sent to municipal facilities is included under 5.D.1 (municipal wastewater treatment), via an added share of 25 percent.

The foundations for calculation of CH_4 emissions from industrial wastewater treatment are described in detail in the underlying research report Austermann-Haun and Witte (2014).

In Germany, the biological stage of industrial wastewater treatment is partly aerobic and partly anaerobic. In aerobic treatment of industrial wastewater, as in aerobic treatment of municipal wastewater, no methane emissions occur. On the other hand, digester gas, consisting largely of CO_2 und CH_4, occurs when organic substances in wastewater are broken down anaerobically.

In Germany today, industrial wastewater is treated anaerobically in many sectors. Such treatment is especially prevalent in the food industry. Data on the relevant plant equipment and systems used in this area are not systematically collected in Germany. On the other hand, an evaluation of (Austermann-Haun and Witte (2014)) shows that 184 anaerobically operating facilities are currently in service in Germany, at a total of 136 plants. The plants involved cover a total of 26 industrial sectors, throughout a spectrum that includes such diverse areas as vegetable processing, sugar production, paper production and production of cleansers. The largest COD loads that are treated anaerobically occur in pulp and paper production, sugar production and the breweries sector.

The systems used for anaerobic industrial wastewater treatment especially include sludge-bed reactors (upflow anaerobic sludge blanket (UASB) and expanded granular sludge bed (EGSB) reactors). Anaerobic activated sludge processes are also used. All relevant facilities are equipped with gas flares with automatic ignition, as required by law. Only one plant, a relatively small sugar plant, treats its wastewater in anaerobic ponds.

Almost all of the resulting digester gas is recovered and combusted either to provide process heat (where it replaces town gas) or to generate electricity. Use for energy recovery is reported under CRF 1.A.1. The sewage-gas-quantity data published by the Federal Statistical Office include both the digester gas occurring in this category and the gas occurring at municipal plants.

The only CH_4 emissions that are relevant for Germany, therefore, are those that occur via unintended releases. Such unintended releases can include:

- CH_4 in the liquid-phase effluent of methane reactors (the relevant quantities are temperature-dependent),
- Losses from gas-storage systems,
- Losses via sludge removed from systems for storage of anaerobically granulated sludge,
- Gas that forms in non-aerated pond systems,
- Gas that forms in acidification reactors,
- Gas that forms in wastewater ponds of the sugar industry,
- Losses via leaks/malfunctions/flaring losses.

All of the gas flares used with relevant gas-collection systems are emergency/shutdown flares; i.e. they also come into play when systems (such as combined heat-and-power (CHP) generating systems) have to be shut down for maintenance purposes. Such gas flares are designed to be able, in emergencies, to burn all of the gas being collected. The gas quantities routed through gas flares are not recorded. The flares are used as emergency flares, meaning that the quantities of combusted gas in this area of application are near zero. Gas flares are equipped with automatic ignition systems that assure reliable burning of collected gas during disruptions of normal system operation. During the start-up and shut-down phases of digesters, the methane that is produced may be burned via gas flares, if methane concentrations are too low for other use. In seasonally operating plants, this occurs at the beginning and end of the operational season. The methane emissions from gas flares are assessed by experts as "zero".

According to experts (Austermann-Haun & Witte, 2014), in the area of anaerobic industrial wastewater treatment, two malfunctions involving gas losses have occurred in Germany in recent decades as a release of leakage from methane reactors' gas-containment vessels. As a result of the odour emissions that accompany them, such leaks are quickly discovered, located and eliminated. In 1992, odour emissions at a wastewater treatment plant led to the discovery of a leak in a methane reactor's glass-fibre reinforced plastic (GRP) roof. A second case of leakage occurred in 2013, in the steel roof of a methane reactor. As a result of the small number of such malfunctions (2 in a total of 30 years of operation of a pool of methane reactors that now numbers 184), the methane emissions from malfunctions involving leakage are classified as negligible.

Other types of malfunctions – for example, malfunctions that inhibit the methane bacteria – do not result in any methane emissions.

7.5.2.1.2 Methodological issues (5.D.2 CH_4)

The calculation method selected is in keeping with Tier 2.

For 20 of the 26 relevant industrial sectors, the annual COD load was calculated via the equation (IPCC (2006): Vol. 5, Chapter 6.2.3.3, Equation 6.6). To that end, the applicable production quantities for 2013, and the applicable specific wastewater production as given in federal statistics (Statistisches Bundesamt, FS 4, R 3.1), were determined for each industrial sector and then combined with the relevant specific COD concentrations in the raw wastewater given in the research report. For 6 industrial sectors (Manufacture of grain mill products (industrial sector (Wirtschaftszweig) code WZ 10.61), Manufacture of prepared meals and dishes (WZ 10.85), Manufacture of other organic basic chemicals (WZ 20.14), Manufacture of fertilisers and nitrogen compounds (WZ 20.15), Manufacture of plastics (WZ 20.16) and Manufacture of soap, detergents and cleaning and polishing preparations (WZ 20.41)) the literature provided no data on specific wastewater production. As a result, it was not possible to calculate the annual COD load for those sectors.

$$TOW_i = P_i \cdot W_i \cdot COD_i$$

Where

TOW_i	= Total organically degradable material in the wastewater of industrial sector i (annual COD load), in kg COD / year
i	= Industrial sector
P_i	= Total industrial product for industrial sector i, in t / year
W_i	= Wastewater generated in industrial sector i, in $m^3/t_{product}$
COD_i	= Chemical oxygen demand (degradable organic components in industrial wastewater), in kg COD/m^3

Since it is good practice to calculate with country-specific data, and since country-specific data area available for Germany, we use our own method for calculation of total methane emissions, rather than the IPCC method (IPCC (2006): Vol. 5, Chapter 6.2.3.1, Equation 6.4). The total methane emissions from industrial wastewater treatment are calculated with the following formula:

$$CH_4\ Emissions = \sum_i \left[\left(TOW_i \cdot \omega_{ANR,i} \cdot \omega_{CSB,i} \cdot EF_{CH4,gelöst,i}\right) + E_{CH4,GS,i} + E_{CH4,PS,i} + E_{CH4,AT,i}\right]$$

Where:

$CH_4\ Emissions$	= CH_4 emissions in the inventory year, in kg CH_4/a
TOW_i	= Total organically degradable material in the wastewater of industrial sector i (annual COD load), in kg COD/a
i	= Industrial sector
$\omega_{ANR,i}$	= Percentage share for anaerobic treatment, for industrial sector i
$\omega_{CSB,i}$	= Degree of COD degradation in anaerobic treatment, for industrial sector i
$EF_{CH4,gelöst,i}$	= Emission factor for CH_4 dissolved in water, in industrial sector i, in kg CH_4 / kg $COD_{eliminated}$
$E_{CH4,GS,i}$	= CH_4 emissions from gas-storage systems in industrial sector i, in kg CH_4/a
$E_{CH4,PS,i}$	= CH_4 emissions from systems for storage of anaerobically granulated sludge in industrial sector i, in kg CH_4/a
$E_{CH4,AT,i}$	= CH_4 emissions from wastewater ponds in industrial sector i, in kg CH_4/a

It is not usefully feasible to compare the results with results obtained with the method described in IPCC (2006), since only the approach chosen is feasible in light of the technical realities (cf. "Category description") and the prevailing data situation.

The specific emission factors $EF_{CH4,gelöst,i}$ for methane dissolved in the water phase have been calculated on the basis of Henry's law, and they are listed in the research report. A pressure of

1.043 bar is used as a basis. The temperature, which is always sector-specific, varies between 32°C and 37°C.

The emissions from gas-storage systems are based on the permissible rates of leakage from such storage systems. On this basis, the CH_4 emissions per gas-storage system have been calculated as 20 m^3 CH_4 / year.

The emissions from systems for storage of anaerobically granulated sludge have been set at 0 kg CH_{4b} / year, since the emissions from this area are considered to be negligible (expert assessment). Similarly, the CH_4 emissions from malfunctions have been set at 0 kg CH_4 / year.

The methane emissions from acidification reactors are negligible, as a result of such reactors' unfavourable conditions for methane formation, and have been set at 0 kg CH_4 / year.

The emission factor for wastewater ponds was determined using Equation 6.5 and Table 6.8 from (IPCC (2006): Vol. 5, Chapter 6). For Bo, the IPCC default value has been used; for the MCF, 0.2 has been used, for a pond depth of no more than 2 metres.

The time series for the period as of 1990 was obtained on the basis of trends in anaerobic industrial wastewater treatment – especially with regard to capacities for treatment of COD loads. The entire time series for the period from 1990 to 2013 has been published in the 2015 NIR. Until the next updating of the database, the data as of 2014 will be carried forward with growth of 2 percent per year, under the assumption that moderate additions of anaerobically operating facilities will take place (expert assessment). All in all, with the formula given above, methane emissions of about **1.79 Gg CH_4 / year** from industrial wastewater treatment have been calculated **for the year 2017**. The following table provides an overview of the time series. The percent values given show the changes in comparison to the reference year 2013. The table also shows the annual COD loads upon which the calculation is based. The calculations produce an implied emission factor of 1.86 kg CH_4/t COD.

Table 465: Time series for CH_4 emissions from industrial wastewater treatment

Year	Anaerobically treated annual COD loads [t/a]	Percentage with respect to the CH_4 emissions of 2013	CH_4 emissions [kg CH_4 / year]
1990	198,477	22 %	370,087
1995	332,950	37 %	620,829
2000	493,357	56 %	919,931
2005	744,371	84 %	1,387,979
2010	854,374	96 %	1,593,094
2011	881,360	99 %	1,643,412
2012	886,829	100 %	1,653,610
2013	888,757	100 %	1,657,206
2014	906,532	102 %	1,690,350
2015	924,307	104 %	1,723,494
2016	942,083	106 %	1,756,638
2017	959,857	108 %	1,789,782

The TOW figures for the individually considered sub-sectors are shown in Table 9 in Austermann-Haun and Witte (2014). For the chemical industry, the food industry, and the paper and pulp industry, the total TOW was determined on the basis of an average COD concentration and the absolute wastewater quantity (Table 467). . This total-TOW figure from the formula $TOW_i = P_i \cdot W_i \cdot COD_i$ has not been used for calculation of CH_4 emissions, because those emissions, as described above, were calculated using a country-specific method, and on the basis of sub-sector-specific TWO_i values. In the country-specific method, and in keeping with the formula term $TOW_i \cdot \omega_{ANR,i} \cdot \omega_{CSB,i} \cdot EF_{CH4,gelöst,i}$ given above, the fraction of anaerobically treated wastewater for each sector or sub-sector $\omega_{ANR,i}$ was taken into account, and the sector-specific maximum degree of degradation $\omega_{CSB,i}$, and the applicable temperature-dependent and sector-dependent fraction of dissolved methane $EF_{CH4,gelöst,i}$, were applied to each sector-specific TWO_i. The sector-specific parameters are listed in the following Table 466 (cf. also Table 12 in Austermann-Haun and Witte (2014)).

The various sub-sectors differ in terms of the fractions of wastewater (cf. $\omega_{ANR,i}$ in Table 466) and, thus, of total TOW, that they treat in anaerobic installations. Only treated quantities of TOW can lead to methane emissions. In derivation of the IEF, the total TOW quantity for the source category involved, and not only the TOW quantity treated anaerobically, is the reference value. This approach leads to comparatively very low IEF.

Table 466: Parameters used to determine emissions of dissolved methane from anaerobic treatment of industrial wastewater (for reference year 2013)

WZ code	TOWi [t CSB/a] (rounded)	$\omega_{ANR,i}$ [%]	$\omega_{CSB,i}$ [$EF_{CH4,dissolved,i}$]	[kg CH_4/kg CSB_{eli}]%]
10.20 Fish processing	12,000	9.0	77.5	0.00455
10.31 Potato processing	47,000	35.6	85	0.00244
10.32 Manufacture of fruit and vegetable juices	12,000	96.3	80	0.00838
10.39 Other processing of fruit and vegetables	80,000	8.7	85	0.00097
10.51 Milk processing	109,000	7.3	77.5	0.00615
10.52 Production of ice cream	17,000	8.2	80	0.00196
10.61 Manufacture of grain mill products	NN	NN	80	NN
10.62 Manufacture of starches and starch products:				
– potato starch	1,000	94.0	75	0.00087
– wheat starch	18,000	36.0	75	0.00087
10.71 Production of baked goods	268,000	0.2	80	0.00093
10.81 Production of sugar	64,000	95.1	95	0.00085
10.82 Confectionary production	43,000	10.1	95	0.00165
10.83 Processing of coffee and tea, production of coffee substitutes	49,000	2.1	75	0.00067
10.84 Manufacture of condiments and seasonings	12,000	0.2	80	0.00395
10.85 Manufacture of prepared meals and dishes	NN	NN	80	NN
10.89 Manufacture of other food products				
– Baking yeasts	2,000	86.2	90	0.00223
– Other yeasts	7,000	32.1	90	0.00223
10.9 Production of animal feed	24,000	3.5	70	0.00258
11.02 Manufacture of wine from grapes	18,000	1.0	90	0.00177
11.05 Production of beer	88,000	28.0	85	0.00748
11.06 Production of malt	4,000	1.1	80	0.01236
11.07 Manufacture of soft drinks; production of mineral waters	21,000	5.2	80	0.00656
17.1 Manufacture of pulp, paper and paperboard	759,000	39.1	70	0.00578

20.14 Manufacture of other organic basic chemicals	NN	NN	80	NN
20.15 Manufacture of fertilisers and nitrogen compounds	NN	NN	80	NN
20.16 Manufacture of plastics	NN	NN	72	NN
20.41 Manufacture of soap, detergents and cleaning and polishing preparations	NN	NN	80	NN
Total (rounded)	**1,653,000**			

It was not possible to determine average COD quantities for other sectors. In addition to the sectors previously included, the 2006 IPCC Guidelines also provide default values for "Organic Chemicals," "Plastic & Resins" and "Soap & Detergents." Under the heading "Chemische Erzeugnisse" ("chemical products"), wastewater statistics combine products with WZ 2008 Code 20. This group include organic chemistry (WZ 2008 Code 20.14), plastics and resins (Code 20.1) and soap and cleansers (Code 20.4). Code 22 lists end products – plastic and rubber products. In this regard, it differs from Code 20.4, in which precursors are reported. The default value reported in 2006 IPCC (IPCC (2006): Vol. 5, Chapter 6) refers to precursors. The reporting to date thus already includes the required additional product categories. (IPCC, 2006) notes that the default values have to be used with care, since they are industry-specific, process-specific and country-specific.

Table 467: Calculation of the TOW for 2016, direct discharges

Industrial sector	Average COD [kg/m³]	Wastewater quantity (2016) [m³]	TOW (2016) [t COD/year]
Chemical industry	3[1)]	265,739,763	797,219
Food industry	3[2)]	64,298,076	192,894
Paper and pulp industry	2[2)]	203,527,590	407,055
			1,397,168

1) Expert judgement, based on 2006 IPCC Guidelines, IPCC (2006): Vol. 5, Chapter 6, Table 6.9.

2) Expert judgement

7.5.2.1.3 Uncertainties and time-series consistency (5.D.2 CH_4)

Experts put the uncertainty for the total methane emissions at ± 50 %. The reasons for this include a lack of data for some industrial sectors, differences between methane reactors' operational pressures, differences between the membranes used in gas-storage systems and the fact that it is not known how many gas-storage systems are in service.

7.5.2.1.4 Category-specific quality assurance / control and verification (5.D.2, CH4)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

The data cannot be cross-checked against ETS data, since the described installations are not subject to emissions trading requirements. To this end, countries with relevant parameters (climate, installed equipment) that are similar to those in Germany were selected.

In Austria, methane emissions from industrial wastewater treatment are considered negligible, since the resulting methane is recovered and either used for energy generation or burned in flares.

In the Netherlands, methane emissions are reported on the basis of the IPCC default values, in conjunction with country-specific data on TOW and with other specific adjustments. No current information about the COD quantities treated in industrial wastewater treatment plants is available. Here as well, therefore, data availability is the limiting factor. The data cannot be compared directly.

In Denmark, no distinction is made between industrial and municipal installations. The method is in keeping with the IPCC Guidelines.

A comparison of the IEF for methane with the figures published in other countries' reports shows that the IEF described here is lower – in some cases, considerably so – than the other countries' figures. The reasons for this are that a) the methane emissions have been determined via a country-specific method, and b) as described above, only the TOW treated anaerobically can lead to methane emissions.

Further verification is not feasible, since no additional specific data on this category are available for Germany.

7.5.2.1.5 Category-specific recalculations (5.D.2 CH_4)

No recalculations are required.

7.5.2.1.6 Planned improvements, category-specific (5.D.2 CH_4,)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

7.5.2.2 Nitrous oxide emissions from industrial wastewater treatment (5.D.2 N_2O)

7.5.2.2.1 Category description (5.D.2 N_2O)

Nitrous oxide emissions can occur as a by-product of biological wastewater treatment with added nitrogen elimination. They occur mainly in connection with denitrification, although they are presumed to occur also in connection with nitrification. (Cf. IPCC (2006), Vol. 5, Chapter 6.1, page 6.8.) Presumably, in such treatment, reduction from N_2O to N_2 is hindered by various influencing factors, such as free oxygen, high concentrations of nitrite, ammonium and/or sulphides, and such hindrance leads to the formation of N_2O (Austermann-Haun and Carozzi (2011): page 2-12 ff).

The majority of industrial wastewater is treated in municipal wastewater-treatment plants. Consequently, that majority is covered in 5.D.1 (as an added share of 25 percent). For this reason, only industrial direct discharges are considered under 5.D.2.

7.5.2.2.2 Methodological issues (5.D.2 N_2O, industrial)

The 2006 IPCC Guidelines do not mandate, or provide regulations for, calculation of N_2O emissions from industrial sectors (IPCC (2006): Vol. 5, Chapter 6.3.4). Neither a relevant decision tree nor any higher-Tier calculation methods are available. The calculation methods presented in the following are thus seen in the context of the decision tree and the Tier classification for CH_4 (industrial). The approach used here is thus in keeping with a Tier 2 calculation method.

Since no calculation obligations apply, the relevant contribution to the overall inventory is negligible and the fluctuations between the individual reporting years are minimal, and since resource limitations apply, nitrous oxide emissions are being carried forward at constant levels for the time being. Updating of this approach is planned for the 2020 inventory report.

For determination of nitrous oxide emissions from industrial wastewater treatment, a research project collected data on product-specific wastewater production, on nitrogen concentrations and on COD (chemical oxygen demand) for all industrial areas and then, on the basis of annual production figures, determined annual nitrogen loads. The underlying data on nitrogen loads have been obtained from information sheets of the DWA (Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e. V.). They reflect the current, recognised state of scientific research. The relevant procedure is set forth in detail in UBA 2011b. A COD:N ratio < 40 served as the threshold criterion for assuming that the wastewater of a given sector had a nitrogen surplus that would be able to cause nitrous oxide emissions in subsequent biological wastewater treatment. A possibility that nitrous oxide could be emitted in biological wastewater treatment can be assumed only if the wastewater contains so much nitrogen that, after conversion into biomass, a residual amount of nitrogen remains that has to be removed via biological nitrogen elimination. The value used has been verified by the document ATV-DVKK-Arbeitsblatt A 131 which, as a simplification, considers the nitrogen load to amount to 2 to 2.5 % of the COD concentration (2.5 % is equivalent to a COD:N ratio of 40:1). The data compilation made it possible to identify the 6 industrial sectors that are most important in this regard. Together, those sectors account for some 75 % of the nitrogen load from industrial wastewater treatment (Austermann-Haun & Carozzi, 2011). They are as follows:

- Slaughterhouse and meat-processing operations,
- Milk processing,
- Processing of animal by-products,
- Beer production,
- Sugar production,
- Wheat starch production.

Data for the textile industry (7.5 % of the total nitrogen load) and for potato processing (2.6 % of the total nitrogen load) have not been included, since the wastewater from those areas has a COD:N ratio greater than 40 and thus, according to the findings of the research report, does not lead to formation of nitrous oxide. Production of potato starch is not considered relevant with regard to formation of nitrous oxide – that area accounts for less than 0.4 % of the total nitrogen load in wastewater. The remaining some 20 % of the total nitrogen load are spread over many individual sectors with unclear data situations (especially the ratio COD:N). Most of these sectors discharge their nitrogen loads into municipal wastewater-treatment plants, as indirect dischargers; this is covered by the emissions reporting under 5.D.1.

The annual nitrogen load that is discharged into raw wastewater is determined on the basis of the mean product-specific nitrogen loads for the 6 aforementioned industrial sectors, as well as of the pertinent annual production figures. In the process, it is assumed that, as a result of organisational and technical measures, such discharges were gradually reduced to the level seen in 2010, and that the nitrogen quantity discharged into wastewater in 1990 was 30 % higher than that level (expert estimate). For the years 1990 through 2000, annual nitrogen-load reductions of 2 percentage points are assumed, while one-percent reductions are assumed for the period 2000 through 2010 (expert estimate). As of 2010, the nitrogen load per cubic metre of wastewater is assumed to be constant (expert estimate).

The activity-data calculation was carried out as follows:

$$AD = \sum_B [NF_B \times PZ_B \times 10^{-6}]$$

Where

AD	= Total activity data [t N_Z/a] = average N load in the inflow = N_Z
NF_B	= Average specific N load for the relevent sector [g N per unit]
PZ_B	= Production figures for the year 2010, for the relevant sector [number of units / a]
10^{-6}	= Factor for conversion of g into t

The N_2O emission factor was determined, in the aforementioned research project, by analysing various data from the literature. From those data, a weighted mean value was formed. As a result, it was found that 1 % of the nitrogen load in a wastewater treatment plant is emitted as N_2O-N (cf. also Chapter 7.5.2.2.4).

$$N_2O = EF \times AD \times 44/28$$

Where

N_2O	= N_2O emissions in t N_2O / a
EF	= Emission factor of 0.01 t N_2O-N / t N
44/28	= Stoichiometric factor for conversion of N_2O-N to N_2O

In addition, the shares of direct dischargers in the various individual sectors were determined and taken into account in the calculation.

The nitrous-oxide-formation rate in the sectors considered differs significantly from the corresponding formation rate in municipal wastewater-treatment plants; the rate for industrial wastewater-treatment plants is higher, by a factor of 100, than that for municipal plants. This is due to the above-described COD:N ratio and to the resulting better conditions, in industrial plants, for N_2O formation.

7.5.2.2.3 Uncertainties and time-series consistency (5.D.2 N_2O)

The uncertainties in the production figures originate in the relevant Federal statistics, and other statistics, all of which are based on exhaustive surveys. The uncertainties for the data are thus likely to be very low. The production statistics are updated annually, and the wastewater statistics are updated at three-year intervals. The wastewater statistics will be updated for the next time in 2019.

In the aforementioned research project, the N_2O emission factor was determined (by expert estimate) to have a very high uncertainty of - 99.9 % / + 300 %.

The mean specific nitrogen loads in the various relevant sectors have the uncertainties shown in (Table 468). The uncertainties were determined via expert estimates. In a conservative estimate, the uncertainty for the total nitrogen load (activity data) is assumed to be -50 % / +50 % (expert estimate)

Table 468: Uncertainties for the mean specific nitrogen loads for the 4 industrial sectors that are most important in this regard

Mean spec. N load of the industrial sector	Uncertainty, upper bound	Uncertainty, lower bound
Slaughtering of swine	40	40
Slaughtering of sheep	50	50
Slaughtering of goats	50	50
Slaughtering of cattle	40	40
Slaughtering of horses	50	50
Slaughtering of poultry	40	40
Meat processing	40	40
Processing of animal by-products	20	20
Milk processing	15	15
Beer production	30	30
Sugar production	30	30
Wheat-starch production	30	30

7.5.2.2.4 Category-specific quality assurance / control and verification (5.D.2, N_2O)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

As reported above, an update is planned for the 2020 inventory report. At that time, the next regular-interval comparison with other countries' inventory reports will be carried out.

The data cannot be cross-checked against ETS data, since the described installations are not subject to emissions trading requirements. The described activity data have been obtained from the public statistics of the Federal Statistical Office, with the exception of the data for processing of animal by-products; those data have been taken from the report of the "Servicegesellschaft tierische Nebenprodukte". No further activity data of relevance for plausibility checking are available at present.

For purposes of plausibility checking, an attempt was made to consult comparable data from the inventory reports of other countries. In 2017, to this end, countries with relevant parameters (climate, installed equipment) that are similar to those in Germany were selected.

In Austria, N_2O emissions from industrial wastewater treatment are considered only in the framework of co-treatment in municipal wastewater treatment facilities. It is assumed that N_2O emissions from industrial wastewater treatment amount to 30 % of the emissions from municipal wastewater treatment. In German emissions reporting, reporting on municipal wastewater treatment includes an added 25 % for co-treated industrial wastewater. On the other hand, specific emissions from industrial wastewater-treatment installations are additionally determined for the above-described sectors. While it is not possible to compare the two methods precisely, the difference between the two methods may be assumed to be small.

In the Netherlands, N_2O emissions from industrial wastewater treatment are classified as irrelevant in comparison to N_2O emissions from municipal wastewater treatment, and they are not reported. For this reason, no comparison was possible.

In Denmark, industrial wastewater treatment is not considered separately.

Austermann-Haun and Carozzi (2011) lists a study, in the pertinent literature, on nitrous oxide emissions from wastewater treatment. The emission factors used in the present context have been derived from that study.

Further verification is not feasible, since no additional specific data on this category are available for Germany.

The approach used differs from the IPCC default method given in IPCC (2006), Vol. 5, Chapter 6.3.1.2, page 6.25. In that source, the IPCC gives a value range of 0.0005 – 0.25 kg N_2O-N/kg –N (default: 0.005 kg N_2O-N/kg –N). In the above-described research project, a country-specific emission factor of 0.01 kg N_2O-N/kg –N was determined; that value is being used for the emissions reporting. The emission factor used is thus larger, by a factor of two, than the default value. It still falls within the given range, however.

7.5.2.2.5 Category-specific recalculations (5.D.2 N_2O)

No recalculations are required.

7.5.2.2.6 Planned improvements, category-specific (5.D.2 N_2O)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

7.6 Other sectors (5.E)

At present, only emissions from mechanical-biological waste treatment are reported in category 5.E.

KC	Category	Activity	EM of	1990 (kt CO_2-eq.)	(fraction)	2017 (kt CO_2-eq.)	(fraction)	Trend 1990-2017
-/-	5.E. Other	Other	CH_4	0.00	0.00%	4.04	0.00%	---
-/-	5.E. Other	Other	N_2O	0.00	0.00%	69.41	0.01%	---

The category 5.E – Other is not a key category.

Furthermore, emissions from unintentional fires in buildings and vehicles are assigned to this category; this does not mean that pertinent greenhouse gases or precursor substances are included. The the inventory report for the CLRTAP[175] contains descriptions of methods for addressing such emissions, however. The non-biogenic greenhouse-gas emissions from unintentional fires in buildings and vehicles amount to less than 0.05 % of the total inventory (not including LULUCF), and they are less than 500 kt CO_2-equivalents. What is more, relevant annual surveys cannot be assured (UNFCCC, 2013a). The theoretically resulting time series would show less than 100 kt per year, under the assumption than less than 20 percent of the material burned in such fires is of fossil origin (expert judgement made without access to suitable activity data).

7.6.1 Other areas – mechanical biological waste treatment (MBT) (5.E Other MBT)

7.6.1.1 Category description (5.E Other MBT)

Gas	Method used	Source for the activity data	Emission factors used
CH_4	Tier 1	NS	CS
N_2O	Tier 1	NS	CS

As of 1 June 2005, direct landfilling of organic and biodegradable waste is no longer permitted in Germany. Miscellaneous settlement waste, and other waste of similar composition, may thus be landfilled only following pre-treatment. In addition to thermal waste-treatment processes (waste incineration), mechanical biological processes are increasingly being used for this purpose.

In Germany, a distinction is made between a) biological treatment of separately collected biowaste and b) biological treatment of residual waste. The purpose of biowaste treatment is to produce compost or digestates that can be used as fertiliser. The purpose of biological treatment of residual waste is to pre-treat organic waste so that it can be landfilled or used for energy generation. The emissions-control requirements pertaining to treatment of residual waste are stricter than those pertaining to biowaste treatment. For this reason, the emission factors for MBT are considerably lower than those for composting and digestion of biowaste. The relevant waste streams are separately recorded in federal statistics.

For MBT installations, the 30th Ordinance on the Execution of the Federal Immission Control Act (30. Verordnung zum Bundesimissionsschutzgesetz – BImSchV) limits emissions loads for organic substances to 55 g per tonne of treated waste and, for N_2O, to 100 g per tonne of treated waste. A number of reviews have found that all German installations reliably meet the emissions limits, and that many installations even remain considerably below them. The emissions limits and the emission factors are oriented to wet substance; waste quantities are recorded in those terms when delivered to the installations.

Since the 1990s, mechanical biological processes have been used extensively in Germany for managing miscellaneous waste. Initially, relevant plants had relatively simple designs and were not fitted for waste-gas collection and treatment. As processes have improved, however, closed systems, with "biofilters" for waste-gas scrubbing, have gradually become the norm. While the

[175] directly in the Informative Inventory Report (IIR): www.iir.umweltbundesamt.de

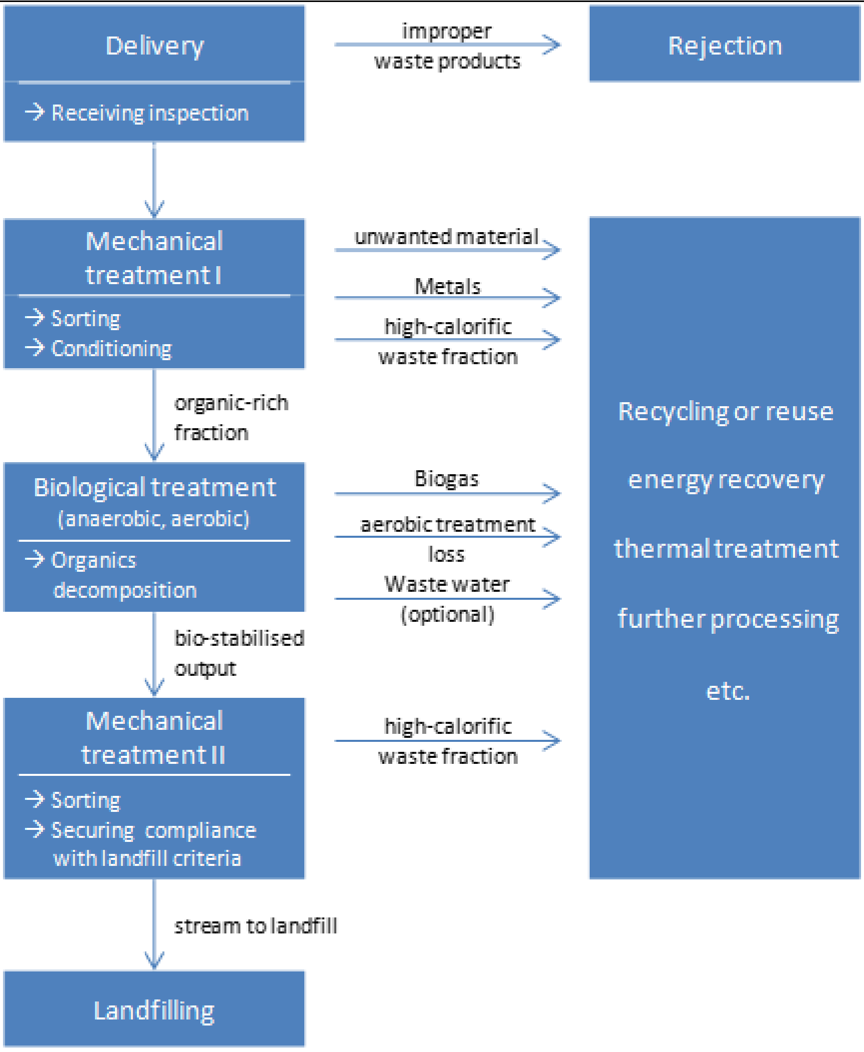
waste-gas-scrubbing processes used by such plants have significantly reduced the plants' odour emissions, they have not reduced greenhouse-gas emissions.

In 2005, when all landfilling of untreated waste was terminated, capacities for mechanical biological waste treatment were considerably expanded. The 30th Ordinance on the Execution of the Federal Immission Control Act (Verordnung zum Bundesimmissionsschutzgesetz) (30. BImSchV, 2017) mandates strict technical requirements and maximum permitted levels for new MBT plants as of 1 March 2001. The transitional provisions for old plants called for such plants to be retroffited by no later than 1 March 2006. The emission standards mandated by the 30th Ordinance on the Execution of the Federal Immission Control Act can be reliably achieved, under the current state of the art, only with thermal waste-gas treatment (such as regenerative thermal oxidation – RTO).

Nearly all recently constructed new facilities were commissioned in 2005. Via expansions and operational upgrades, nearly all old facilities were brought into conformance with the 30th BImSchV by 2005. The transitional situation prevailing in 2005 can hardly be described with existing calculation models, since the relevant waste quantities cannot be correlated with the various relevant facility technologies. For the sake of simplicity, emissions through the year 2005 are calculated with the higher emission factors applying to the older-facility systems. For 2006, emissions are being calculated using the lower emission factors for the new facilities.

Currently, about 4 million Mg of waste are treated annually in mechanical biological waste treatment plants in Germany. This produces about 0.5 million Mg of treatment residues that have to be landfilled. In addition, about 2.5 million Mg of waste fractions with high calorific values are separated out and then used as substitute fuels in industrial combustion systems. The metals contained in the waste are separated out and used as secondary raw materials. The remainder of 1.5 million Mg consists of mass losses, in the treatment process, occurring via biodegradation of organic fractions and evaporation or drainage (wastewater) of the water in the waste.

Figure 79: Substance-flow scheme for mechanical biological waste treatment (MBT)[176]



7.6.1.2 Methodological aspects (5.E Other MBT)

Since 1995, the Federal Statistical Office has regularly collected and published data on waste quantities managed in MBT systems. For the period 2007 through 2010, recent reports have used data from the research project "Facilities for mechanical and biological treatment of residual waste" ("Anlagen zur mechanisch-biologischen Restabfallbehandlung") (Kühle-Weidemeier et al., 2007). In connection with those earlier reports, there was doubt as to whether the data of the *Federal Statistical Office* cover all types of facilities that, in terms of their emissions behaviour, must be grouped with MBT facilities. As a conservative approach therefore, emissions calculation was carried out using the higher waste quantities determined by the research project. Via a number of discussions with the Federal Statistical Office, those doubts have since been eliminated. For the years 2007 through 2010, the 2014 NIR included a recalculation carried out with data of the Federal Statistical Office (Statistisches Bundesamt (FS 19, R 1b) of 12 July 2012). For further reporting, the current data of the Federal Statistical Office are used.

[176] Source: VDI 3475 Blatt 3, Emisssionsminderung - Anlagen zur mechanisch-biologischen Behandlung von Siedlungsabfällen, 2006-12 (amended)

Activity data

MBT have been operated in Germany only since 1995. For reporting purposes, the current data of the Federal Statistical Office are used (Statistisches Bundesamt, FS 19, R 1b). The Federal Statistical Office has regularly collected and published pertinent data since 1995.

Emission factors

In the 1990s, emissions from mechanical biological waste treatment were studied in a major collaborative research project supported by the Federal Ministry of Education and Research (BMBF). In a project carried out in 2003, the Institute for Energy and Environmental Research (IFEU) used the collaborative research project's findings to develop emission factors. In doing so, it differentiated between mechanical biological waste-treatment processes that were open (with no waste-gas collection and treatment) and processes that were closed (with waste-gas collection and treatment in biofilters). For methane, the emission factors for both types of processes were considered to be the same, since that substance is hardly broken down at all in biofilters. The N_2O emission factor for closed systems was considered to be higher than that for open systems, since N_2O also forms in biofilters, via oxidation of ammoniacal nitrogen.

Since June 2005, as a result of new legal provisions (30th BImSchV), all mechanical biological waste-treatment facilities are closed facilities, which have the more effective waste-gas-scrubbing processes. For the period 2006 through 2014, therefore, the emissions standards of the 30th Ordinance on the Execution of the Federal Immission Control Act have been used as the applicable emission factors.

For open mechanical biological waste-treatment facilities, the following emission factors resulted:

EF-N_2O = 190 g N_2O/Mg waste
EF-CH_4 = 150 g CH_4/Mg waste

For closed mechanical biological waste-treatment facilities with biofilters, the same study obtained the following emission factors:

EF-N_2O = 375 g N_2O/Mg waste
EF-CH_4 = 150 g CH_4/Mg waste

For the period as of 2006, for inventory reports through the 2015 inventory report, the emissions-load limits set forth by the 30th BImSchV have been used as the applicable emission factors:

EF-N_2O = 100 g N_2O/Mg waste
EF-CH_4 = 55 g CH_4/Mg waste

Since in 2005 most MBT systems were equipped with waste-gas-treatment systems for minimising N_2O emissions, the emission factor for 2005 was estimated to be 169 g.

In 2013, in the framework of data collection for revision of the Best Available Techniques Reference Document "Waste Treatment", the Federal Environment Agency, in cooperation with the Arbeitsgemeinschaft stoffstromspezifische Abfallbehandlung ((ASA); Working group for substance-stream-specific waste treatment (association of MBT operators), collected emissions data on MBT. The emissions data for the parameters methane and N_2O proved to be considerably below the maximum permitted levels (Table 469).

Table 469: Emissions of MBT

Emissions parameter (exhaust gas)	Framework conditions (normal conditions)	Emissions range 16 installations		Maximum permitted levels 30. BImSchV
Total carbon ($C_{ges.}$)	Half-hour averages	min.	0– 1.53	**40**
		Median	**1.2– 11.6**	
	Concentration in mg/m³ Continuous measurement	max.	1.5– 38.7	
	Daily averages	min.	0– 2.68	**20**
	Concentration in mg/ m³	**Median**	**1.3– 15.9**	
	Continuous measurement	max.	4.58– 23.9	
	Monthly averages	min.	2.3– 21.8	**55**
	Load in g C_{total}/Mg waste	**Median**	**8.36– 30.7**	
	Calculated from half-hour averages	max.	10.6– 44.0	
Nitrous oxide (N_2O)	Monthly averages	min.	0.01– 33.3	**100**
	Load in g N_2O/Mg waste	**Median**	**1.54– 59.0**	
	Calculated from half-hour averages	max.	6.23 – 108	

The emissions data reported in the survey are representative for existing German installations and take all MBT types used in Germany into account. For the data survey, each installation reported its emissions ranges in terms of the highest and lowest measurements for the relevant parameters. Table 469 lists the installations with the lowest and highest emissions, along with the installation that fell into the middle of the emission range in each case (the median).

On the basis of this survey, and as of the 2016 submission, the emission factors for years as of 2006 have been brought into line with the actual installation emissions. In the process, the maximum emissions loads of the median installations were taken as the emission factors.

$EF\text{-}N_2O$ = 59.0 g N_2O/Mg waste

$EF\text{-}CH_4$ = 40.9 g CH_4/Mg waste (30.7 g $C_{ges.}$ are equivalent to 40.9 g CH_4)

These national emission factors were used for inventory calculations for the first time, in the present context, in the 2016 Submission.

7.6.1.3 Uncertainties and time-series consistency (5.E Other MBT)

The uncertainties for the mechanically-biologically treated waste quantities are considered to be very small (2 %) theoretically, since the relevant data were obtained via a complete-coverage survey, the reporting quality is good and operators have an interest in quality reporting. The uncertainties for the emission factors are high for the period before 2005. They depend on the type of facility/plant in question, on the type of process used at the relevant time and on the effectiveness of the biofilters used. The pertinent figures from the literature vary widely. .

7.6.1.4 Category-specific quality assurance / control and verification (5.E Other MBT)

General quality control, and quality assurance, have been carried out, in conformance with the requirements of the QSE manual and its associated applicable documents, by the relevant involved experts and the Single National Entity.

7.6.1.5 Category-specific recalculations (5.E Other MBT)

As the NIR 2019 was being prepared, statistical data on landfilled waste quantities were available only up to 2016. The quantities of waste treated were thus considered to have remained constant in 2016 and 2017. Therefore, the emissions of the year 2016 were recalculated with the current data published in (Statistisches Bundesamt, FS 19, R 1a). In addition, the transmitted emissions data contained minor rounding errors, in the time series, for the period as of 2007. Because the errors are insignificant, no need was seen to present an overview of these changes here.

7.6.1.6 Planned improvements, category-specific (5.E Other MBT)

No further improvements are planned at present.

Chapter 10.4, Inventory Improvements (Table 480), presents an overview of the improvements that previous reports have listed in this chapter. Improvements that have been completed are listed in Table 479 in the same chapter.

8 Other (CRF Sector 6)

In keeping with recommendations made by the UNFCCC Expert Team in the 2016 In Country Review, no greenhouse gases are reported in CRF Category 6. Because certain relevant categories of the CRF Reporter do not support data entry, the non-greenhouse gases NO_X, CO and NH_3 are subsumed under CRF 6. The actual allocation involved is shown in the following table:

Table 470: Actual allocation of the non-greenhouse gases listed under CRF 6

Gas	Quantity in kt	Actual allocation
CO	0.17	1.B
NO_X	0.04	1.B
NH_3	629.24	3

9 Indirect CO_2 & N_2O

In general, indirect CO_2 emissions from CO, CH_4 and NMVOC, and indirect N_2O emissions from NO_X and NH_3, are not recorded and reported for purposes of the national inventory.

The following exceptions apply:

- CRF 1: Since the emissions are calculated on the basis of a carbon mass balance, indirect CO_2 is taken into account via the calculation method.
- CRF 2.D.1 & 3: The NMVOC emissions from lubricants (cf. also Chapter 4.5.1) and from solvent use (cf. also Chapter 4.5.3) are converted into indirect CO_2 and reported in CRF Table2(I).A-Hs2.
- CRF 3: In CRF Tables 3.B(b) and 3.D, indirect N_2O emissions from atmospheric deposition and leaching / surface runoff are reported.
- CRF 4: Indirect N_2O emissions from leaching / surface runoff are reported in CRF Table 4(IV).

10 Recalculations and improvements

10.1 Explanation and justification of the recalculations

10.1.1 Greenhouse-gas inventory

10.1.1.1 General procedure

There are a number of other reasons, in addition to the need for corrections, why recalculations and improvements can be necessary:

- Additional data become available that make it possible to close gaps in the inventory.
- A data source has changed.
- The method used for the source category has been adapted to provisions of the *Good Practice Guidance*.
- The source category has become a key category, thus necessitating a change of methods.
- New country-specific calculation procedures need to be used.
- Recommendations and results provided by reviews have been implemented.

In good practice, when methods change, the entire relevant time series should be consistently recalculated with the same method, to ensure that the same method is used each year and old values can be suitably replaced. Where the same method cannot be used for all relevant years, one of the following four recalculation procedures (pursuant to the *IPCC Good Practice Guidance, 2000*: *Chapter 7*) should be used:

- *Overlap* – For this method, the data for calculation pursuant to the old and new methods should be jointly available for at least one year.
- *Surrogate method* – For this method, the EF and/or AD used to date should be highly similar to the newly available data.
- *Interpolation* – The data previously used for recalculation cover only a few years of the time series, and the lacking data are interpolated.
- *Trend extrapolation* – The data for the new method are not available for the beginning and/or end of the time series.

The QSE manual contains a guide to the above-outlined recalculation procedures. It also presents relevant examples.

10.1.1.2 Recalculations in the 2019 inventory, by source categories

This year's recalculations were necessitated by a range of methodological adjustments, some of which led to significant changes in the affected source categories, as well as by further improvements in details.

The inventories contain improvements in the following areas (unless otherwise indicated, in each case the changes refer to the entire pertinent time series):

Energy

With regard to reporting year 2016, the most important recalculations have been necessitated by the appearance of the *final* 2016 Energy Balance.

For stationary combustion systems, the following changes in fuel quantities have resulted from the finalization: Pursuant to the final Energy Balance, 4.1 million t less gaseous fuel, but 2.3 million t more liquid fuel and 0.8 million t more solid fuel, were used in 2016, with respect to the provisional values reported in the 2018 Submission.

The same source has updated the data on waste incineration, and this has led to recalculations for the period as of 2008. The quantity of waste incinerated, on average throughout the time series as a whole, is now about 0.5 million t smaller. The quantity of waste incinerated in 2016 is about 0.8 million t greater, however.

(Additional, on an excerpt basis)

- Replacement of the provisional Energy Balance by the final Energy Balance, for 2016 (1.A)
- Updating of the data for waste incineration, for the period as of 2008, on the basis of final waste statistics
- Revision of the EF(CO_2) for natural gas, as of 2015 (1.A.)
- Revision of specific LTO-consumption data (1.A.3.a, 1.D.1.a)
- Revision of TREMOD (1.A.3.b, 1.A.3.c, 1.A.3.d)
- Revision of TREMOD MM (1.A.2.g vii, 1.A.4.a ii, b ii, c ii)
- Revision of the BSH model (1.A.3.d, 1.A.4. c iii,1.D.1.b and 1.A.5.b)
- Revision of statistical input data for 2016 and 2017 that, until recently, was still provisional (1.B)
- Change in the statistics on distribution of petroleum products (1.B.2.a)
- Revision of the lengths of the pipelines operated by transport-network operators, for the period as of 2015 (1.B.2.b)

Industrial processes & product use

- Changes in the activity data for lime kiln dust (LKD) in the lime industry, 2015 & 2016 (2.A.2)
- Updating of activity data for the glass industry, 2016 (2.A.3)
- Correction of a calculation on soda-ash use, 2016 (2.A.4.b)
- Correction of an erroneous emission calculation relative to carbon black, 2005 through 2015 (2.B.8)
- Change of method with respect to CO_2 from stationary lubricant uses (2.D.1)
- Correction of the AD for paraffin wax use, 2016 (2.D.2)
- Correction of the AD for charcoal use, 2016 (2.G.4)
- Correction of the EM(HFKW134a) from magnesium production, 2001-2016 (2.C.4)
- Supplementation of the data on C_6F_{14} charging and disposal emissions from the semiconductor industry (2.E.4).
- Correction of the unit-number figures for plug-in units and condensing units, for the period as of 2005 (2.F.1.a – commercial refrigeration)
- First-time inclusion of data for ice cream machines, for the period as of 1997 (2.F.1.b – residential refrigeration)
- Updating of statistical input data for industrial refrigeration, 2016 (2.F.1.c)
- Updating of the numbers of refrigerated containers, 2016 (2.F.1.d)
- Reassessment of the size classes, charges and applicable refrigerant shares for refrigerated vehicles, for the period as of 1993 (2.F.1.d)
- Correction of the numbers of utility vehicles for the period as of 2013, and of the numbers of automobiles and ships for 2016 (2.F.1.e – mobile air conditioning systems)
- First-time inclusion of commercial dishwashers with heat pumps, for the period as of 2005 (2.F.1.f - stationary air-conditioning systems)
- Changes in the applicable numbers for chillers and turbo-compressor systems, 2015 & 2016 (2.F.1.f – stationary air-conditioning systems: chillers))

Agriculture

- Updating of the applicable numbers of cattle for several years (3.A, 3.B, 3.D)
- Updating of the animal-population data for weaners and fattening pigs, 2016 (3.A, 3.B, 3.D)

- Correction of the energy-requirements calculation for heifers (3.A, 3.B, 3.D)
- Updating of the milk production data for dairy cows, and of the weight data for dairy cows, heifers and male beef cattle, for several years (3.A, 3.B, 3.D)
- Updating of feeding data for dairy cows, heifers and male beef cattle (3.A, 3.B, 3.D)
- Updating of weight data for weaners and fattening pigs, 2016 (3.A, 3.B, 3.D)
- Updating of data on VS excretions of sheep and horses (3B)
- Updating of the data on "total gross meat quantity obtained at slaughter" for broilers, 2016 (3B, 3D)
- Updating of the data on quantities of straw bedding, for cattle (3.B, 3.D)
- Updating of the N_2O emission factor for solid manure (3.B, 3.D)
- Updating of the activity data for manure digestion (3.B, 3.D)
- Updating of the activity data on digestion of energy crops, 2015 and 2016 (3.D, 3.J, 3.s2)
- Updating of the N quantities applied with sewage sludge, 2016 (3.D)
- Updating of the N quantities in crop residues (3.D)

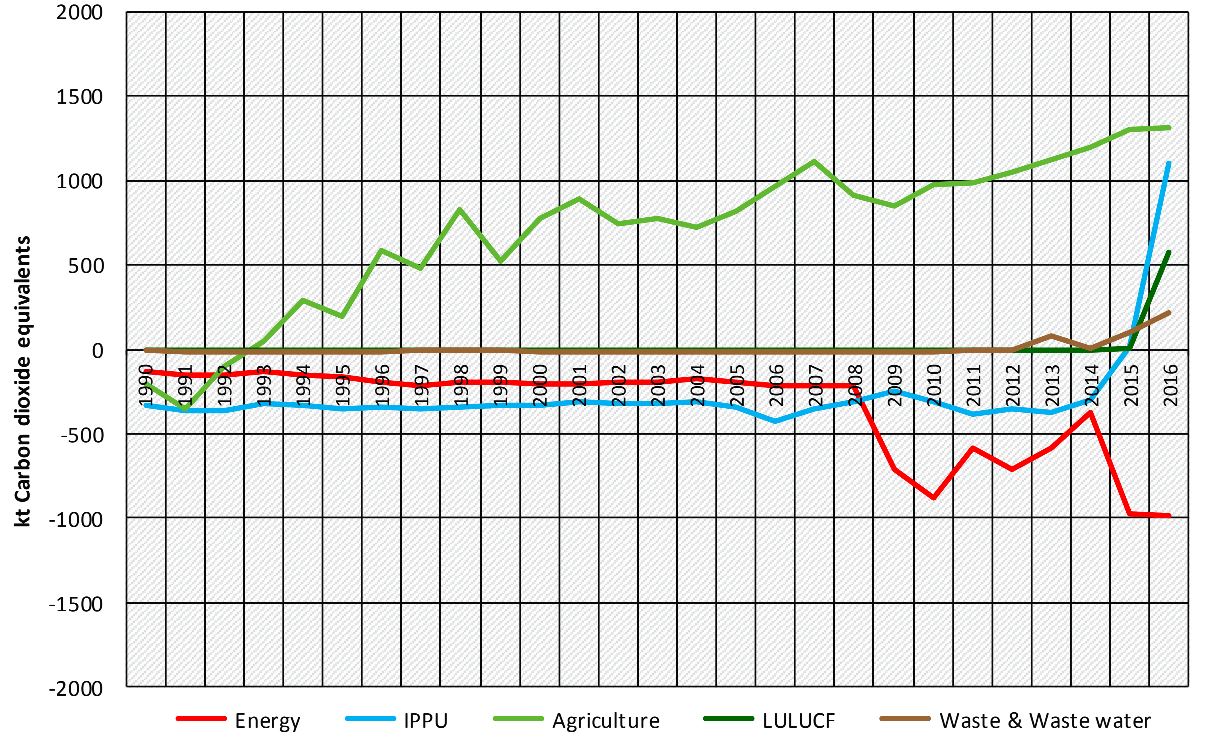
Land use, land-use change and forestry:

- Updating of the FAO database for HWP data in the product categories a) paper and paperboard and b) sawn lumber, 2015 and 2016 (4.G)

Waste and wastewater:

- Correction of activity data, 2016 (5.A, 5.B, 5.E.1)
- Correction of typing errors made in CH_4-emissions data, 2013- 2016 (5.A)
- Correction of population data to take account of census data (5.A, 5.D.1)
- Correction of typing errors made in CH_4 and N_2O emissions data, 1998 + 1999 (5.B.1)
- Correction of rounding errors (5.B.1+5.B.2)
- Correction of rounding errors in emissions data, for the period as of 2007 (5.E.1)

Figure 80: Change in total emissions, throughout all categories, with respect to the 2018 Submission



10.1.1.3 Recalculations in the 2019 inventory, by substances

Recalculations were carried out in the following source categories (cf. also the specifications in 10.1.1.2):

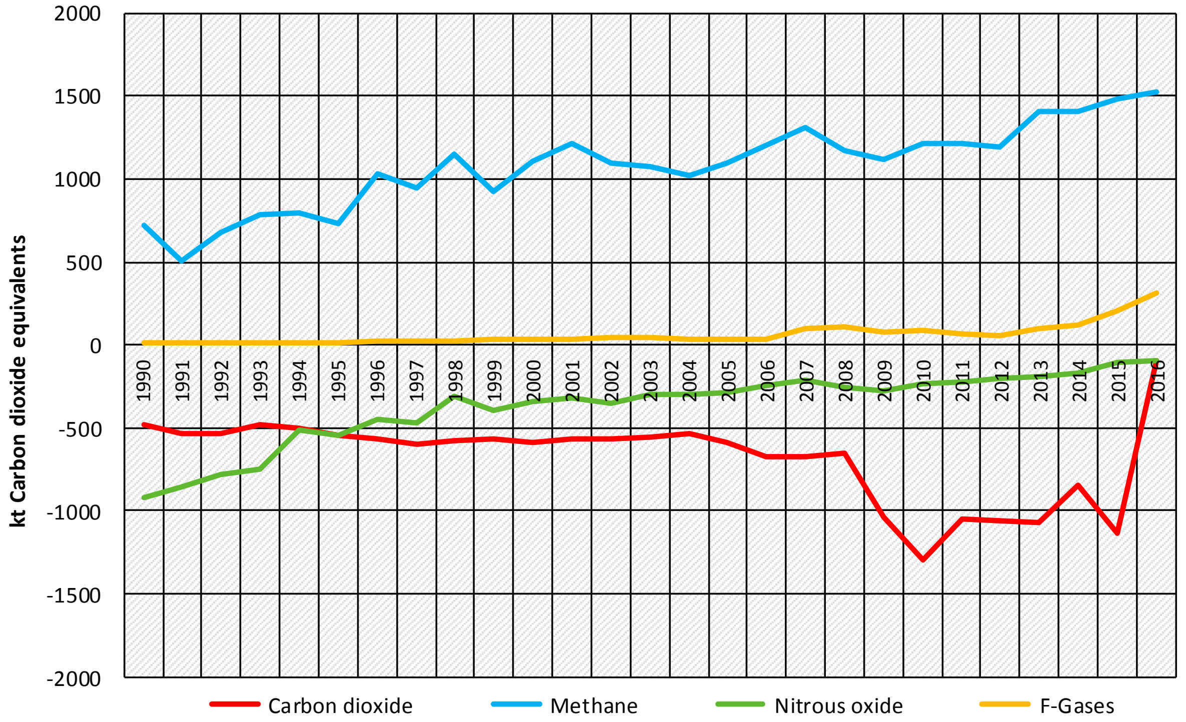
Table 471: Overview of the CRF main categories affected by recalculations

CRF	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NF_3
1 – Energy	x	x	x				
2 – IPPU	x	x	x	x	x		
3 – Agriculture	x	x	x				
4 – LULUCF	x						
5 – Waste & wastewater		x	x				

Table 472: Percentage changes with respect to last year's report

		Base year	2016
Total (CO_2 equiv.)		-0.05%	0.18%
CO_2	1990:	-0.05%	-0.01%
CH_4		0.60%	2.80%
N_2O		-1.41%	-0.24%
F gases	1995:	0.10%	2.04%
HFCs		0.07%	2.87%
PFCs		0.57%	-3.27%
SF_6		0.00%	0.00%
NF_3		0.00%	0.00%

Figure 81: Recalculation of total emissions of individual greenhouse gases, throughout all source categories, with respect to the 2018 Submission



10.1.1.4 Recalculations carried out to implement results of the review process

No recalculations were carried out, with respect to the 2018 Submission, that were derived on the basis of information or recommendations provided in reviews.

10.1.2 KP-LULUCF inventory

10.1.2.1 General procedure

The methods used for recalculations under the Kyoto Protocol are the same as those used under the Convention. Detailed information on the general procedure is provided in Chapter 10.1.1.1.

10.1.2.2 Recalculations in the 2019 inventory, by categories

For *Harvested Wood Products (HWPs)*, the FAO database for export data, in the product categories a) paper and paperboard and b) sawn lumber, was updated for the years 2015 and 2016 (cf. Chapter 6.10.5).

10.1.2.3 Recalculations in the 2019 inventory, by gases

The described changes only affect the reported CO_2 emissions.

10.1.2.4 Recalculations carried out to implement results of the review process

10.2 Impact on emissions levels

10.2.1 Greenhouse-gas inventory

The changes with respect to the 2018 Submission, at -0.05 % for 1990 and +0.18 % for 2016, are very small.

Table 475 and Table 476 show the changes in emissions as reported for 1990 and for 2015, for the various CRF sectors.

The inventory has been improved with regard to completeness and accuracy.

Table 473: Recalculation of total national GHG emissions (without LULUCF)

	2018 Submission	2019 Submission	Change with respect to 2018 Submission	
1990	1,251,659	1,250,993	-667	-0.05%
1995	1,123,367	1,123,035	-333	-0.03%
2000	1,044,966	1,045,187	221	0.02%
2005	993,088	993,344	255	0.03%
2006	1,000,323	1,000,638	315	0.03%
2007	973,427	973,942	515	0.05%
2008	975,279	975,646	367	0.04%
2009	908,182	908,054	-128	-0.01%
2010	942,783	942,542	-241	-0.03%
2011	920,305	920,306	1	0.00%
2012	924,628	924,611	-16	0.00%
2013	942,004	942,250	246	0.03%
2014	902,676	903,196	521	0.06%
2015	906,752	907,190	439	0.05%
2016	909,404	911,049	1,645	0.18%

Source: Own calculations

Table 474: Recalculation of inventory data that are reported as memo items

	1990	2016
Emissions reported as memo items:	**11.44%**	**1.31%**
From international transports	0.73%	0.56%
of which: international civil air transport	1.13%	0.78%
of which: international maritime navigation	0.00%	-0.14%
From multilateral military missions	NE	NE
CO_2 from combustion of biomass	2.87%	0.75%

Source: Own calculations

10.2.1.1 Impacts on emissions levels of categories in 1990

Total emissions (not including LULUCF) for 1990 were downwardly corrected, by a total of about 0.05 %, or 667 kt CO_2 equivalents (cf. Table 475).

The most important inventory-affecting corrections were made in the categories *Industrial processes and product use* (-334 kt, -0.34 %), *Energy* (-128 kt, -0.01 %) and *Agriculture* (-203 kt or -0.26 %).

By contrast, emissions in the *Waste & wastewater* sector remained nearly unchanged, with a reduction of 2 kt CO_2-eq.

The emissions reported for 1990 for the *LULUCF* sector (*Land Use, Land Use Change and Forestry*) also remained nearly unchanged.

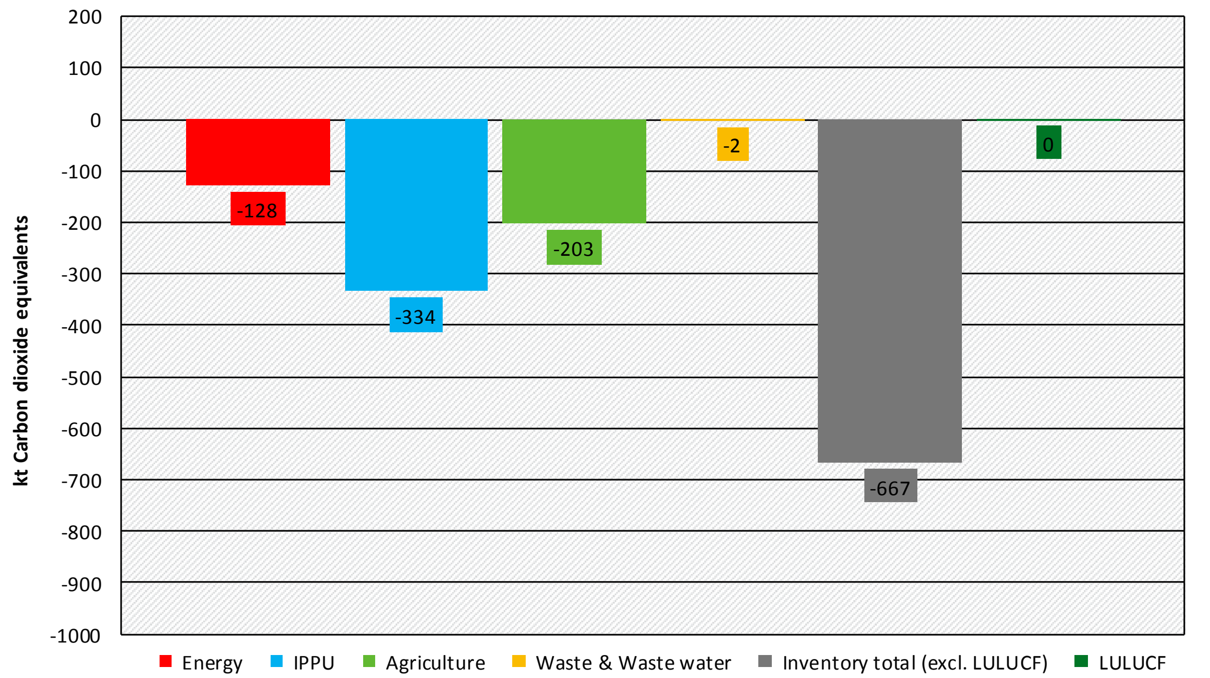
More-detailed pertinent information, in addition to that provided in the following table, is available in CRF tables 8(a)s1 through 8(a)s4.

Table 475: Recalculation of CRF-specific total greenhouse emissions, 1990

	2018 Submission	2019 Submission	Change with respect to 2018 Submission	
Total national emissions (without LULUCF)	**1,251,659**	**1,250,993**	**-667**	**-0.05%**
1. Energy	1,036,736	1,036,608	-128	-0.01%
2. IPPU	97,172	96,838	-334	-0.34%
3. Agriculture	79,398	79,195	-203	-0.26%
4. Land-use changes and forestry	-31,312	-31,312	0	0.00%
CO_2 (net emissions / removals)	*-33,018*	*-33,018*	*0*	*0.00%*
N_2O + CH_4 (emissions)	*1,706*	*1,706*	*0*	*0.00%*
5. Waste & wastewater	38,354	38,352	-2	-0.01%

Source: Own calculations

Figure 82: Absolute changes in CRF sectors and the inventory as a whole, for the year 1990



10.2.1.2 Impacts on emissions levels of categories in 2016

The total emissions reported for the year 2016, without LULUCF, increased, by comparison to the 2017 Submission, by 1,645 kt CO_2 equivalents, or 0.18 % (cf. Table 476).

The most important inventory-affecting corrections were made in the categories *Agriculture* (+1,308 kt, or +2 %), *Industrial processes and product use* (+1,106 kt, or +1.79 %) and – in the opposite direction – *Energy* (-988 kt, or -0.13 %).

Emissions in the *Waste and wastewater* sector were also upwardly corrected markedly – by 219 kt CO_2 equivalents (+2.09 %).

In the *LULUCF* sector, CO_2 sink performance decreased by 570 kt in 2016. The methane and nitrous oxide emissions for both that year and 1990 remained unchanged, however.

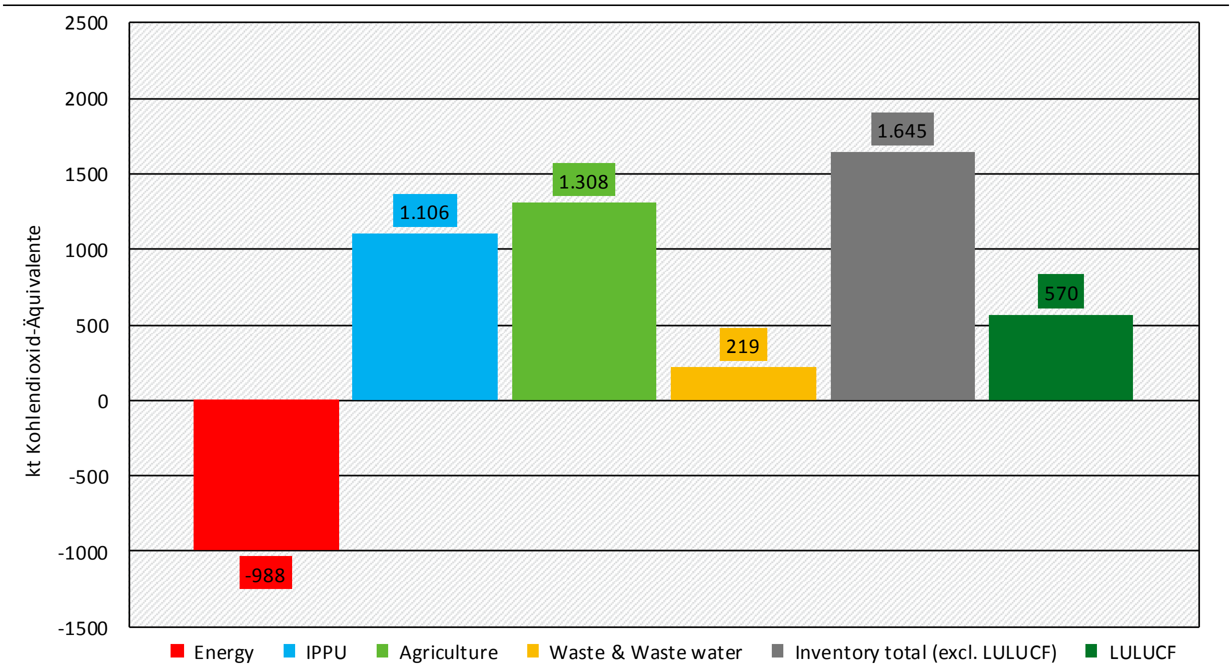
More-detailed pertinent information, in addition to that provided in the following table, is available in CRF tables 8(a)s1 through 8(a)s4.

Table 476: Recalculation of CRF-specific total greenhouse emissions, 2016

	2018 Submission	2019 Submission	Change with respect to 2018	
Total national emissions (without LULUCF)	**909,404**	**911,049**	**1,645**	**0.18%**
1. Energy	771,901	770,912	-988	-0.13%
2. IPPU	61,797	62,903	1,106	1.79%
3. Agriculture	65,228	66,536	1,308	2.00%
4. Land-use changes and forestry	-14,479	-13,909	570	3.93%
CO_2 (net emissions / removals)	*-16,204*	*-15,634*	*570*	*3.52%*
N_2O + CH_4 (emissions)	*1,725*	*1,725*	*0*	*0.00%*
5. Waste & wastewater	10,478	10,697	219	2.09%

Source: Own calculations

Figure 83: Absolute changes in CRF sectors and the inventory as a whole, for the year 2016



10.2.2 KP-LULUCF inventory

10.2.2.1 Impacts on emissions levels of categories in 1990

Since no recalculations were carried out, the total sink performance for 1990 was not changed from the figure reported in the 2018 Submission (cf. Table 477).

Table 477: Recalculation of total emissions for 1990, in kt CO_2 equivalents

Land-use category	2018 Submission	2019 Submission	Change with respect to 2018	
Afforestation (KP 3.3)	582	582	0.00	0.00 %
Deforestation (KP 3.3)	1,768	1,768	0.00	0.00 %
Forest management (KP 3.4)	-74,806	-74,806	0.00	0.00 %
Cropland management (KP 3.4)	12,669	12,669	0.00	0.00 %
Grassland management (KP 3.4)	25,722	25,772	0.00	0.00 %
Total	<-34,015	-34,015	0.00	0.00 %

Source: Own calculations

10.2.2.2 Impacts on emissions levels of categories in 2016

As a result of changes in the harvested wood products category, the total sink performance for the year 2016 has decreased by 2.49 % with respect to the 2018 Submission.

Table 478: Recalculation of total emissions for 2016, in kt CO_2 equivalents

Land-use category	2018 Submission	2019 Submission	Change with respect to 2018	
Afforestation (KP 3.3)	-6,918	-6,918	0.00	0.00 %
Deforestation (KP 3.3)	2,124	2,124	0.00	0.00 %
Forest management (KP 3.4)	-55,024	-54,454	570	1.04 %
Cropland management (KP 3.4)	14,875	14,875	0.00	0.00 %
Grassland management (KP 3.4)	22,043	22,043	0.00	0.00 %
Total	-22,900	-22,330	570	2.49 %

Source: Own calculations

10.3 Impacts on emissions trends and on time-series consistency

10.3.1 Greenhouse-gas inventory

The time-series consistency has improved as a result of the recalculations.

As a result, the trend for total national emissions (not including LULUCF) shows a reduction of nearly 28 % with respect to the current base year. This reduction is virtually unchanged from the corresponding figure in the 2018 Submission.

Following a recent considerable increase, the 2017 figures for pure CO_2 emissions are now only 0.3 % below the corresponding values for the previous year. A similar statement can be made for methane, which shows a decrease of 0.7 %. By contrast, nitrous oxide emissions increased by 1.3 %.

The trends for HFC, PFC and SF_6 and NF_3 emissions have continued to diverge: With respect to 2016, HFC emissions are up by 1.5 %, while PFC emissions are up by a full 8.1 %. The emitted quantities of SF_6 increased by 4.9 %, while NF_3 emissions decreased considerably, by -41.4 %.

10.3.2 KP LULUCF inventory

The consistency of the time series is maintained, in spite of the recalculations that have been carried out. The emission calculation has been significantly improved, thanks especially to an improved method for differentiating perennial and annual crops.

10.4 Inventory improvements

10.4.1 Greenhouse-gas inventory

The following table summarises the improvements made in GHG-emissions reporting on the basis of the ERT's references and remarks in past reviews under the UNFCCC and the Kyoto Protocol. The table lists only aspects that were not already successfully addressed during the Review.

Table 479: Compilation of the Review recommendations successfully addressed as of the current report

CRF	Review Findings	Improvement	Report [year]	Source	Reference	Resolved in …
0.	Germany described in the NIR that it determines uncertainties with a tier 2 analysis every three years. The latest tier 2 uncertainty analysis was carried out in 2010, and it should have been carried out again in 2013. However, according to the NIR, Germany extensively revised the calculation algorithms, and integrated uncertainty calculation within CSE in 2012. Although initial results have already been obtained with the new approach, neither they nor the basic change in methods have yet been verified. The necessary review for verification will be carried out in 2013 and the results of the tier 2 uncertainty analysis will be reported as part of the 2014 annual submission. The ERT welcomes the plan	Resolved. All calculations have been verified and full dataset is available as part of the NIR 2019	2013	ARR	§ 13, Table 4	NIR, chapter 1.7 and Annex 7 Tab 550+551
0.	For Table 1A.D, the TERT noted that there are several inconsistencies between the emissions reported here to be allocated to the IPPU sector and the actual IPPU emission, e.g. for natural gas 4 862 kt CO_2 is excluded from the reference approach and 884 kt CO_2 is said to be reported under 'Non-energy Products from Fuels and Solvent Use' while the amount of CO_2 reported for ammonia production is 6.739. Germany indicated that they are aware of the problem, that they will correct the erroneous data for submission 2016 and put additional effort in improving both consistency and transparency of the entire NEU reporting in CRF Table 1.A(d). The ERT accepts Germany's response and recommends that as indicated by Germany, it improves the reporting in table 1Ad in the next submission. The TERT notes that this issue is outside the agreed scope for the 2015 ESD trial review.	Resolved	2015	ESD	DE-1AB-2015-0003	CRF Table 1.A(d)
0.	The ERT noted that table 542 of the NIR (annex 7) does not follow the outline of table 3.2 provided in the 2006 IPCC Guidelines (volume 1, chapter 3). In particular, the ERT noted that the uncertainty estimates for the AD and EFs, as well as the trend uncertainty, were reported as "0" for several categories in the energy sector (e.g. CH4 and N2O emissions from category 1.A.1.a (public electricity and heat production)). During the review, Germany explained that the uncertainty estimates for the AD and EFs were included in the combined uncertainty of the emissions, without providing supporting documentation, and provided no clarification on whether the trend uncertainty was correctly estimated. ERT: Finding is an issue and/or a problem: Yes	Germany assumes that the uncertainties are correlated across years for these categories. According to the 2006 IPCC Guidelines (see Chapter 3, Table 3.2, Note A), this results in zero ("0") values for the AD uncertainties in column E. For other categories, uncertainty information is only available at the emission level, not for activity data and emission factors. In this case and to make the table calculate, column E is also set to zero and the emission uncertainty is given in both column F and G. This is also according to the Guidelines, chapter 3.2.3.1. Please note that Germany provides much better uncertainty data resulting from the Monte-Carlo simulation for all these categories and with each submission, which should be used instead.	2015, 2016	ARR	G.2, Table 5	-

CRF	Review Findings	Improvement	Report [year]	Source	Reference	Resolved in …
0.	The ERT noted that the total national emissions excluding LULUCF (901 914 kt CO2 eq) reported in NIR table 516 (which presents sources and sinks for which emissions have not been estimated), were not the same as the emissions reported in the original submission of CRF summary table 2 for 2014 (900 202.15 kt CO2 eq). Consequently, the estimates of the national thresholds of 0.05% and 0.1% of the total national emissions reported in the NIR were incorrect. The ERT notes that these latest estimates from 2014 were also included for the purposes of the analysis of the significance threshold for the 2015 NIR. During the review, Germany confirmed that the calculation of the thresholds for emissions reported as "NE" was related to the total national GHG emissions including CH4 and N2O emissions from LULUCF, instead of the total national emissions excluding LULUCF. The ERT noted that Germany's use of an incorrect amount of total national emissions for the estimation of the national threshold did not change the outcome of its analysis of categories reported as "NE". ERT: Finding is an issue and/or a problem: Yes	Resolved	2015, 2016	ARR	G.3, Table 5	NIR 2019, chapter 21, table 552
0.	In the NIR (page 768) Germany calculates its commitment period reserve (CPR) to be 4 381 287 024 t CO2 eq. This value has not been updated from the 2014 NIR (page 721) and is not calculated based on the current calculated assigned amount for Germany (3 592 699 888 t CO2 eq). Based on the assigned amount for the second commitment period of the Kyoto Protocol, the ERT calculates the CPR to be 3 233 429 900 t CO2 eq.. ERT: Finding is an issue and/or a problem: Yes	Resolved	2015, 2016	ARR	G.5, Table 5	NIR 2019, chapter 12.5
1.A.1.b.	All fuels: During the review, Germany provided the ERT with additional information regarding its activities related to the use of EU ETS data in the preparation of the inventory for the energy sector (see ID# E.5 in table 3). ERT: Finding is an issue and/or a problem: Yes	Resolved	2015, 2016	ARR	E.12, Table 5	
1.A.2	For category 1A2 Manufacturing industries and construction, the TERT noted that Germany reports for a number of subcategories "IE" or "C" (e.g. 1A2b, 1A2c, 1A2d). This hampers transparency. Eurostat provides activity data at a more detailed level on their website than what is included in CRF. This issue has been raised several times before. In response to a question raised during the review, Germany provided an extensive explanation, which mainly come downs to the complexity of the database used for monitoring air pollution and greenhouse gases. Regarding the suggestion to use the inclusion of the SNAP code in the database, Germany replied that it would not solve the problem. Many additional statistical data and calculation steps would be necessary in order to provide a more differentiated structure in 1.A.2 Manufacturing industries and construction. The creation of time series back to 1990 is extremely difficult because of the reunification in Germany. The TERT understands the difficulties. However, other member states have faced similar difficulties and try to provide a more detailed inventory for this sector. The fact that the aggregation is very high in the manufacturing industries makes it very difficult to review the inventory. The TERT would recommend Germany to look for a solution of this problem to enhance transparency of the sector 1A2 Manufacturing industries and construction.	Resolved	2016	ESD	DE-1A2-2016-0001	
1.A.3.e.	All fuels: During the review, Germany provided the ERT with additional information regarding its activities related to the use of EU ETS data in the preparation of the inventory for the energy sector (see ID# E.5 in table 3). ERT: Finding is an issue and/or a problem: Yes	Resolved	2015, 2016	ARR	E.12, Table 5	
1.B.1.b.	All fuels: During the review, Germany provided the ERT with additional information regarding its activities related to the use of EU ETS data in the preparation of the inventory for the energy sector (see ID# E.5 in table 3). ERT: Finding is an issue and/or a problem: Yes	Resolved. Information regarding the use ETS data have been provided.	2015, 2016	ARR	E.12, Table 5	NIR, chapter 1.4.1.1.1

CRF	Review Findings	Improvement	Report [year]	Source	Reference	Resolved in ...
1.B.2.	Liquid and gaseous fuels: Fugitive CH4 emissions from oil and natural gas for 2013 declined significantly as a result of recalculations (–2 564.38 kt CO2 eq), but the information provided in the NIR to explain the decrease was not sufficient. During the review, Germany explained that there are three reasons for the decrease: (i) the length of the gas distribution system was revised; (ii) new information from a study about the pipeline's material was adopted; and (iii) a correction to a double counting of emissions from compressor stations between subcategories 1.B.2.b.4 (natural gas transmission and storage) and 1.B.2.b.5 (natural gas distribution) was applied ERT: Finding is an issue and/or a problem: Yes	Resolved. All information regarding recalculations for category 1.B.2.b+c are provided	2015, 2016	ARR	E.17, Table 5	NIR, chapter 3.3.2.5
1.B.2.a.	All fuels: During the review, Germany provided the ERT with additional information regarding its activities related to the use of EU ETS data in the preparation of the inventory for the energy sector (see ID# E.5 in table 3). ERT: Finding is an issue and/or a problem: Yes	Resolved	2015, 2016	ARR	E.12, Table 5	NIR, chapter 1.4.1.1.1
1.B.2.b.	For CRF category 1B2b, Other leakage fugitive emissions from natural gas and gases, CH_4 for the year 2013 the TERT noted that that there is the same emission value for 2013 as the previous year. In response to a question raised during the review, Germany explained that the activity data of the industry's energy consumption is taken from industry association statistics released each April containing the numbers from three years ago. The number of gas meters is considered very constant and therefore not updated yearly by the association. Due to the delay in the statistics the same activity data were taken for 2012, and 2013. The TERT noted that this is not in accordance with 2006 IPCC Guidelines methods and that the full time series should be estimated using appropriate splicing and extrapolation techniques (see Section 5.3.3 of 2006 IPCC Guidelines data collection). The TERT notes that the issue is below the threshold of significance for a technical correction. The TERT recommends that Germany should apply appropriate extrapolation and splicing techniques and include a summary of this information in the NIR category description for 1B2b Other leakage fugitive emissions from natural gas, in its next submission.	Resolved. Information regarding the extrapolation of values are provided in chapter 3.3.2.2.6.1	2016	ESD	DE-1B2b-2016-0003	see NIR, section 3.3.2.2.6.1
1.D	Gaseous fuels: In CRF table 1s2, the cells for reporting CO2 captured for domestic storage and for storage in other countries were left blank. During the review, Germany clarified that this should be reported as "NO" ERT: Finding is an issue and/or a problem: Yes	Issue has been resolved, by adding the aproprlate notation key	2015, 2016	ARR	E.18, Table 5	CRF table 1.C
2.B.3.	The 2014 review report contained a recommendation on the methodology used to estimate N2O emissions from adipic acid production (see table 3, ID# I.2). In the 2016 submission, Germany improved the transparency of its reporting on the methodology used to estimate N2O emissions from the three plants in operation (page 318). It is reported that one of the three plants, which started operation in 2002, has been conducting measurements continuously since 2013. However, Germany did not report how the emissions for that plant were estimated during the period 2002–2012, prior to when the measurements started ERT: Finding is an issue and/or a problem: Yes	Resolved	2015, 2016	ARR	I.9, Table 5	NIR 2019, chapter 4.3.3.2
2.B.4.	In the 2016 annual submission, Germany reported N2O emissions under category 2.B.2 (nitric acid production) from one plant that was first identified in 2015. During the review, Germany explained that the plant is classified as nitric acid production under the EU ETS and that the data became available to the GHG inventory team for the 2016 submission. Furthermore, Germany explained that the identification of the additional plant was the result of the QA/QC system and that the plant is producing nitric acid as an intermediate, but the final product is caprolactam. The ERT considers that as the plant is producing caprolactam as final product, emissions from the plant should be reported under category 2.B.4 (caprolactam, glyoxal and glyoxylic acid production) in order to be in line with the 2006 IPCC Guidelines. Germany explained that reporting the emissions under category 2.B.4 is not possible at the moment for data confidentiality reasons ERT: Finding is an issue and/or a problem: Yes	Resolved	2015, 2016	ARR	I.10, Table 5	NIR 2019, chapter 4.3.4.2

CRF	Review Findings	Improvement	Report [year]	Source	Reference	Resolved in …
2.B.4.	In the NIR (section 4.3.4.1, page 319), Germany reported N2O emissions from caprolactam acid as zero, assuming a 100% efficiency of the abatement system (the ERT notes that these N2O emissions are reported as “NA” and the AD are reported as “C” in CRF table 2(I)A-H)). According to the NIR (page 320), there are two plants producing caprolactam in Germany, but the N2O emissions are assumed to be negligible. However, the 2006 IPCC Guidelines (volume 3, chapter 3.5.2) provide methods and EFs for the estimation of these emissions (see the EFs in table 3.5 for caprolactam production). Germany provided additional information to the ERT during the review explaining that the two plants operating in Germany are equipped with redundant high thermal destruction systems. It was the Party’s view that this destruction process results in no N2O emissions. The ERT noted that the 2006 IPCC Guidelines provide default destruction and utilization factors for a thermal destruction system of up to 99% (chapter 3, volume 3, page 3.30, table 3.4). The ERT further noted that Germany did not provide any documentation to justify the assumption of 100% destruction of N2O emissions (including information on the abatement efficiency and system utilization), in line with good practice as provided in section 3.5.2.3 of the 2006 IPCC Guidelines. The ERT concluded that this represented a possible underestimation of N2O emissions from caprolactam production for the 2016 submission and included this issue in the list of potential problems and further questions raised. In response to this list, Germany decided to report these emissions as insignificant, in accordance with paragraph 37(b) of the UNFCCC Annex I inventory reporting guidelines. Germany provided data demonstrating that the maximum emissions for this category for 2014 were 17.90 kt CO2 eq and that the total of all excluded emissions remained below 0.1% of the total national GHG emissions. ERT: Finding is an issue and/or a problem: Yes	Resolved	2015, 2016	ARR	I.11, Table 5	NIR 2019, chapter 4.3.4.2
2.B.4.	Germany reported in its 2016 submission N2O emissions from caprolactam acid as zero for 2013 and 2014 (NIR page 319), assuming a 100% efficiency of the abatement system (the ERT notes that these N2O emissions are reported as “NA” and the AD are reported as “C” in CRF table 2(I)A-H)). According to the NIR (page 320), there are two plants producing caprolactam in Germany but N2O emissions are assumed to be negligible. However, the 2006 IPCC Guidelines (volume 3, chapter 3.5.2) provides methods and emission factors for the estimation of these emissions (referring to the emission factors shown in table 3.5 for caprolactam production). Germany provided additional information to the ERT through bilateral discussions during the review week that the two plants operating in Germany are equipped with two-stage destruction systems, one stage of which is a thermal-destruction system under very high temperature. It is the Party’s view that this two stage process results in no N2O emissions. The ERT notes that the 2006 IPCC Guidelines provide default destruction and utilization factors for a thermal destruction system of up to 99% (table 3.4, chapter 3, volume 3, page 3.30). The ERT further notes that Germany did not provide any documentation to justify the assumption of 100% destruction of N2O emissions (including information on the abatement efficiency and system utilization), in line with good practice as provided in section 3.5.2.3 of the 2006 IPCC Guidelines. The ERT considers that the Party has not met the requirements in paragraph 50 (a) of the annex to decision 24/CP.19, which reads that the NIR shall include “descriptions, references and sources of information for the specific methodologies… assumptions, EFs and AD, as well as the rationale for their selection.” The ERT concludes that this represents a possible underestimate of N2O emissions from caprolactam production for the 2015 and 2016 submissions.	Resolved	2015, 2016	ARR	SP- 1	NIR 2019, chapter 4.3.4.2

CRF	Review Findings	Improvement	Report [year]	Source	Reference	Resolved in …
3.A.	In the NIR (page 457), Germany reported a methodological change in the calculation of the dry matter intake for calves. However, no information on the new value of dry matter intake or on how this value is calculated is provided in the NIR. During the review, the Party provided additional information and a reference (Dämmgen et al., 2013j), explaining that the dry matter intake value is calculated using the data and information on typical diet composition and dry matter feed content provided in Dämmgen et al ERT: Finding is an issue and/or a problem: Yes	Resolved	2015, 2016	ARR	A.5, Table 5	NIR 2019, chapter 5.1.3.3, Table 239
3.A.2	The Party applies the IPCC tier 1 method for the estimation of CH4 emissions from enteric fermentation for sheep, goats and horses. For lambs, 40% of the default value for sheep is assumed, based on the ratio of N excretion by lambs and adult sheep. However, no information to support the appropriateness of the assumption used is provided in the NIR. In response to questions raised by the ERT on the Party's assessment of the value used for lambs (3.2 kg CH4/head/year), the Party provided, informally, a revised estimate of the EF for lambs (3.57 kg CH4/head/year) using the approach provided in the 2006 IPCC Guidelines, taking into account the performance difference for lambs. This revised estimate was higher than the official estimate provided in the annual submission. As the Party was underestimating CH4 emissions from sheep, the ERT included this issue in the list of potential problems and further questions raised by the ERT. In response to this list, the Party provided revised estimates for the category enteric fermentation for the entire time series using a new CH4 EF for lambs (3.6 kg CH4/head) and documentation on the method used to derive the new EF. ERT: Finding is an issue and/or a problem: Yes	Resolved. Elevation of Tier 1 emission factor for CH4 from digestion in lambs	2015, 2016	ARR	A.4, Table 5	NIR 2018, chapter 5.1.7.4
3.D.a.6.	The NIR states that N2O emissions from cultivation of organic soils are calculated using country-specific EFs: 10.7 kg N2O-N/ha/year for cropland and 2.7 kg N2O-N/ha/year for grassland. The ERT noted that the EF for grassland is lower than the default value for temperate organic crop and grassland soils provided in the 2006 IPCC Guidelines of 8 kg N2O-N ha-1 year-1 (volume 4, chapter 11, table 11.1), and the default values for drained grassland provided in the Wetlands Supplement of 1.6–9.5 kg N2O-N ha-1 year-1 (table 2.5, page 2.34). However, the NIR does not provide information to support the appropriateness of the value used for drained grassland, such as drainage depth and the nutrient status of the drained grassland. During the review, the Party explained that the EF of 2.7 kg N2O-N ha-1 year-1 is applied for drained grassland only and represents the mean value of all known German measurements (with a mean annual water table of 0.1 m below surface) used in a European study by Leppelt et al. (2014).k The Party also provided additional information on the value used for drained grassland including national N2O measurements (Tiemeyer et al., 2016)l to support the appropriateness of the EF used. ERT: Finding is an issue and/or a problem: Yes	Resolved A German emission factor of 2.3 kg N2O-N per hectare and year was derived for drained grassland. The arable and grassland areas, which vary from year to year, lead to a time-varying mean emission factor.	2015, 2016	ARR	A.7, Table 5	NIR, chapter 5.5.2.1.1; Table 323
5.	There are a number of instances where Germany uses the notation key "IE" in the CRF tables (e.g. flaring of CH4 from municipal solid waste, N in industrial effluent and the amount of CH4 for energy recovery in industrial wastewater), but no explanations are provided in CRF table 9. ERT: Finding is an issue and/or a problem: Yes	Resolved	2015, 2016	ARR	W.5, Table 5	CRF-Tables 5.D and 9

CRF	Review Findings	Improvement	Report [year]	Source	Reference	Resolved in …
5.A.1.	Germany uses measured values for the fraction of methane in landfill gas (F), estimated at 49%. According to the 2006 IPCC Guidelines (volume 5, page 3.15) it is good practice to adjust for the CO2 absorption in seepage water, if the fraction of CH4 in landfill gas is based on measurements of CH4 concentrations measured in landfill gas emitted from the SWDS (see IPCC 2006 Vol 5 p 3.15). It was confirmed during the review week, that this adjustment has not been performed by Germany in the 2015 and 2016 annual submissions. Furthermore, German experts, as part of a broad internal review of the solid waste estimation method for CH4, have recommended that Germany apply the 2006 IPCC default value for F of 50%. The ERT considers that Germany is not following the method included in the 2006 IPCC Guidelines (as required by paragraph 9 of the annex to decision 24/CP.19), nor has it provided sufficient documentation to support the use of a country-specific assumption as required by paragraph 50(a) of the same annex. From this information, the ERT can conclude that Germany's CH4 emissions estimates from managed waste disposal sites may be underestimated for the 2015 and 2016 annual submissions.	Resolved	2015, 2016	ARR	SP- 5	NIR 2019, chapter 7.2.1.2.6
5.B.2.	During the review, in response to questions raised by the ERT regarding ID# W.10 above and the agricultural application of compost/digestate to agricultural land (as referred to on page 665 of the NIR), the Party explained that the AD for composting/digestion may include quantities of manure/crop digestate. During subsequent discussions, Germany confirmed that digestate and compost from the treatment of kitchen and garden waste are used in agricultural applications (category 3.D (agricultural soils)) but that no N2O emissions are included from this material under category 3.D on the basis that the Party is of the view that these materials contain negligible N ERT: Finding is an issue and/or a problem: Yes	Resolved.	2015, 2016	ARR	W.11, Table 5	NIR, chapter 7.3.2.2
5.D.	ERT (2015+2016) assessment and rationale: Not resolved. There are still issues related to the reporting of the AD (and, in addition, of the methods and assumptions) used for this source in the NIR (see ID# W.13 in table 5). Recommendation made in previous review: Correctly report the AD values in the NIR. Reference to previous review issue(s): § 54, 2014	Resolved.	2015, 2016	ARR	W.4, Table 3	NIR, chapter 7.5.1.1
5.D.	The method, assumptions and AD underpinning Germany's estimates of CH4 and N2O emissions from wastewater treatment and discharge are not transparently documented in the NIR. For example, it was confirmed during the review that an adjustment (1.25) to account for co-discharged industrial wastewater was made to the BOD calculation for domestic wastewater but this is not documented in the NIR. Additionally, the number of people connected to cesspools and septic systems is also not documented and should be included in the NIR. There are other examples of AD and assumptions that were published in the 2015 NIR but not included in the 2016 NIR that were discussed with the Party during the review and documented. ERT: Finding is an issue and/or a problem: Yes	Resolved. The requested informations have been added.	2015, 2016	ARR	W.13, Table 5	NIR, chapter 7.5.1.1 and 7.5.1.3.2

CRF	Review Findings	Improvement	Report [year]	Source	Reference	Resolved in …
5.D.1.	Germany applies an MCF of 0 (zero) for domestic wastewater treatment on the assumptions that all domestic wastewater treatment is considered aerobic, and that all CH4 from anaerobic sludge digestion is recovered for energy production. However, research referred to in the NIR (page 670) and summarized in two documents provided during the review week (Gärtner, 2014;n Becker et al., 2012o) indicates that CH4 emissions from wastewater treatment plants occur from both wastewater and anaerobic sludge digestion elements of the wastewater treatment system. Therefore, the ERT concludes that Germany is not justified in the use of the MCF value of 0 for this category as the available research contradicts these assumptions. As a result of this finding, the ERT further concludes that Germany may be underestimating CH4 emissions from domestic wastewater for all years of the time series as a result of the application of an MCF value of 0 and the assumption that all CH4 generated from anaerobic sludge digestion is recovered for energy. Accordingly, this issue was included in the list of potential problems and further questions raised by the ERT. In response to this list, Germany submitted revised estimates that used a per-capita value for CH4 emissions from domestic and commercial wastewater treatment taken from Becker et al. (2012).o The use of a per-capita emissions value implicitly applies an appropriate non-zero MCF to organic matter treated in Germany's wastewater treatment plants, which is appropriately underpinned by country-specific empirical research. The ERT agrees with the approach taken to varying the per-capita value throughout the times series, which is also supported by appropriate documentation. ERT: Finding is an issue and/or a problem: Yes	Resolved.	2015, 2016	ARR	W.12, Table 5	NIR, chapter 7.5.1.1.2
KP	The ERT concluded that, taking into account the confirmed changes in the national registry, including additional information provided to the ERT during the review, Germany's national registry continues to perform the functions set out in the annex to decision 13/CMP.1 and the annex to decision 5/CMP.1 and continues to adhere to the technical standards for data exchange between registry systems in accordance with relevant decisions of the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol. With respect to the provision of information related to database structure specifically, the ERT encourages the Party to provide additional information in the NIR. The ERT recommends that Germany include all other additional information in response to the SIAR findings in its NIR in accordance with decision 15/CMP.1, annex, chapter I.G.	Resolved	2013	ARR	§ 86	-
KP	The ERT encourages Germany to increase the transparency of the NIR by including quantitative information on any recalculations that have occurred on the basis of updated AD	Closed, due to beeing an encouragement achieved (see NIR 2019).	2015, 2016	ARR	KL.4, Table 5	NIR 2019, chapter 11.3.1.4
KP	Germany reported in CRF table 4(KP-I)A.2 gains included in the CSCs for the above-ground (80.22 kt C for 2014) and below-ground biomass pools (31.05 kt C for 2014). During the review, the Party clarified that the areas subject to deforestation activities have not been replanted and the reported gains result from the estimation process. The Party further clarified that regrowth of deforested areas to areas with forest cover does not happen on a significant basis and thus is considered as not occurring ERT: Finding is an issue and/or a problem: Yes	Resolved	2015, 2016	ARR	KL.5, Table 5	NIR, chapter, chapter 11.3.1.1.2
KP	Germany did not apply a technical correction to the FMRL in the 2016 submission. During the review, Germany provided information on the main methodological inconsistencies between the FMRL and forest management reporting, and the consequent need for a technical correction ERT: Finding is an issue and/or a problem: Yes	Resolved, a technical correction is implemented.	2015, 2016	ARR	KL.9, Table 5	NIR 2019, chapter 11.5.3.4
KP	Germany reports the CSCs under cropland management as "NO" (see ID# L.6 above) ERT: Finding is an issue and/or a problem: Yes	Resolved, Transparency is improved	2015, 2016	ARR	KL.13, Table 5	NIR 2019, chapter 11.3.1.1.1

All measures are aimed at achieving complete consistency with the UNFCCC report guidelines and the IPCC Guidelines and at preventing any adjustments under the Kyoto Protocol.

The following table summarises the information, as provided in the various category chapters of the inventory reports (since 2011), relative to planned improvements. That information is supplemented with details on the resulting required action, the planned deadlines for completing the measures and the current processing status in each case.

Table 480: Compilation of a) the planned improvements completed as of the present report and of b) the planned improvements that are mentioned in NIR category chapters and are still pending

CRF	Planned improvement	Data quality objective	Deadline	STATUS	Comment	Resolved in ...	Year of reporting	Reference NIR-chapter
1.A.3.a.	After the specific LTO consumptions were last updated during an ad hoc revision, a further revision of the TREMOD AV model is now planned.	As soon as the upcoming revision of TREMOD AV has taken place, it must be included in the inventory and documented.	[2021]	to do	Germany is continuing to work on that issue.		2019	3.2.2.1.6
2.B.4.a.	Plans call for the production quantities of ε-caprolactam as of 2009 to be determined via other sources, and for the N_2O reductions of other producers to be determined.	Results of the survey related to verification of produced caprolactam and of N2O-mitigation efforts have to be implemented in the national inventory and reporting and be completely documented.	[2016]	done	Resolved. The only other possible source were press reports referring to capacities. The EM calculation is based on these press reports.	see NIR, chap. 4.3.4.4	2015	4.3.4.6
1.A.3.d	With regard to inland waterway transport, in cooperation with the responsible modellers (ifeu) and national experts (ZKR: Zentralkommission für die Rheinschifffahrt / CCNR: Central Commission for the Navigation of the Rhine), ways are sought for the exact separate collection of national and international vessels.	National and international ships are to be recorded exactly and separately. The procedure should be developed with ifeu and the ZKR and documented in the NIR and the IB. If needed, the inventory has to be updated.	[2020]	to do	Germany is continuing to work on that issue.		2017	3.2.10.4.6
2.C.6.	Specific data for determination of emission factors will be collected in the next rounds of reporting.	Revision of EF as well as complete documentation of results..	[2016]	closed	Closed. Germany uses a process-dependent standard EF for CO2. The adaptation effort to national conditions would be high and the benefit low (savings potential < 180 kt). Therefore, the EF will not be adapted.	-	2015	4.4.6.6
2.D.3	Currently a consisteny check is performed to systematically check the plausibility of emissiontrends.	The results of the consisteny check to systematically check the plausibility of emissiontrends has to be implemented into the NIR and inventory description. If necessary the inventory has to be updated.	[2018]	done	Resolved. The current NIR 2019 contains a brief description of the results of the consistency/plausibility checks for the years 2005-2015.	NIR 2018, chap. 4.5.3.3	2017	4.5.3.6
1.B.2.	A research project is currently underway to evaluate the emission declarations of the refineries from 2004 to 2016. The new emission factors are to be included in future reporting.	The result of the research project (evaluation of the emission declarations of the refineries from 2004 to 2016) must be adopted for the inventory and documented. The new emission factors must be included in the reporting.	[2020]	to do	Germany is continuing to work on that issue.		2019	3.3.2.6

CRF	Planned improvement	Data quality objective	Deadline	STATUS	Comment	Resolved in ...	Year of reporting	Reference NIR-chapter
2.A.4.a.	On the basis of information provided by the Federal Association of the German Brick and Tile Industry (Bundesverband der Deutschen Ziegelindustrie e. V.) on a research project still in progress, in which the product quantities are of particular relevance, the raw densities used as a basis for the product groups facing bricks, backing bricks and roof tiles will have to be checked in future and adjusted if necessary. Since the said raw densities are to be used for the conversion from a volume or piece-unit to a mass flow within these product groups, the total CO2 emissions and other emission parameters are likely to change. However, it is not necessary to review the entire methodology for the ceramics industry to calculate emissions.	The raw densities for the product groups facing wall, back wall and roof tiles must be checked and adjusted if necessary. The inventory must then be revised and the result documented.	[2020]	to do	Germany is continuing to work on that issue.		2019	4.2.4.1.6
2.B.8.	Plans call for improving the database	The database needs to be improved	[2017]	overdue	Germany is continuing to work on that issue.		2016	4.3.8.1.6
2.D.2	It is planned not to take any more into account the biogenic wax component.	The biogenic wax content must be deducted from the results and the inventory updated accordingly. The process is to be documented.	[2020]	to do	Germany is continuing to work on that issue.		2019	4.5.2.6
2.D.3.(b)	Relevant findings currently available from a research project are to be used for specific evaluation of emission factors.	The emission factors need to be evaluated on the basis of the existing project report.	[2012]	overdue	Germany is continuing to work on that issue.		2012	4.2.6.6
3.A.	In data management and emissions calculations for this area, a transition is being made from spreadsheet files to a relational database and procedural programmes. That step, for which work began in summer 2010, is oriented primarily to QC/QA purposes. Its benefits, for example, will include facilitation of automatic plausibility checks.	The relational database needs to be completed.	[2020]	to do	Germany is continuing to work on that issue.		2011	6.2.6
3.A.	In data management and emissions calculations for this area, a transition is being made from spreadsheet files to a relational database and procedural programmes. That step, for which work began in 2010, is oriented primarily to QC/QA purposes. Its benefits, for example, will include facilitation of automatic plausibility checks.	The relational database needs to be completed.	[2020]	to do	Germany is continuing to work on that issue.		2012	6.2.6

CRF	Planned improvement	Data quality objective	Deadline	STATUS	Comment	Resolved in ...	Year of reporting	Reference NIR-chapter
3.B.	In data management and emissions calculations for this area, a transition is being made from spreadsheet files to a relational database and procedural programmes. That step, for which work began in summer 2010, is oriented primarily to QC/QA purposes. Its benefits, for example, will include facilitation of automatic plausibility checks.	The relational database needs to be completed.	[2020]	to do	Germany is continuing to work on that issue.		2011	6.3.2.6
3.B.	In data management and emissions calculations for this area, a transition is being made from spreadsheet files to a relational database and procedural programmes. That step, for which work began in 2010, is oriented primarily to QC/QA purposes. Its benefits, for example, will include facilitation of automatic plausibility checks.	The relational database needs to be completed.	[2020]	to do	Germany is continuing to work on that issue.		2012	6.3.2.6
3.D.	In data management and emissions calculations for this area, a transition is being made from spreadsheet files to a relational database and procedural programmes. That step, for which work began in summer 2010, is oriented primarily to QC/QA purposes. Its benefits, for example, will include facilitation of automatic plausibility checks.	The relational database needs to be completed.	[2020]	to do	Germany is continuing to work on that issue.		2011	6.5.6
4. LULUCF (Total area)	To improve the inventory, the following measures are planned:	Derivation of country-specific emission factors or development of models for recording the annually changing logging and the growth and incorporation into the inventory.	[2018]	closed	Closed. The evaluation has shown that these methods do not improve the inventories..	NIR 2019, chap. 6.10.2	2016	6.1.4
3.D.	In data management and emissions calculations for this area, a transition is being made from spreadsheet files to a relational database and procedural programmes. That step, for which work began in summer 2010, is oriented primarily to QC/QA purposes. Its benefits, for example, will include facilitation of automatic plausibility checks.	The relational database needs to be completed.	[2020]	to do	Germany is continuing to work on that issue.		2012	6.5.6
4.	The results of the Agricultural Soil Inventory are being used for step-by-step validation of the current emission factors.	The currently used EF are to be verified with the results of the Agricultural Soil Inventory	[2019]	overdue	Germany is continuing to work on that issue.		2014	19.5.2.3
4.	Development of new, country-specific emission factors for mineral soils, via a major inventory (Agricultural Soil Inventory).	Integration of new EF for mineral soils into the inventory and complete documentation of background data, results and assumptions.	[2021]	to do	Germany is continuing to work on that issue.		2015	6.1.5

CRF	Planned improvement	Data quality objective	Deadline	STATUS	Comment	Resolved in …	Year of reporting	Reference NIR-chapter
4.	Derivation of country-specific emission factors, and development of models for determination of the impacts of cultivation on cropland and grassland areas, using data from the Agricultural Soil Inventory, data from long-term soil monitoring and mathematical models.	Integration of new EF for mineral soils into the inventory and complete documentation of background data, results and assumptions.	[2025]	to do	Germany is continuing to work on that issue.		2015	6.1.5
4.	Mineral soils: Agricultural soil inventory: generation of national measurements of C stocks, for cropland and grassland.	On the basis of the Agricultural Soil Inventory, data on C stocks in mineral soils need to be derived for cropland and grassland, and the inventory has to be improved accordingly.	[2020]	to do	Germany is continuing to work on that issue.		2012	7.3.8
5.A.1.	In an international comparison, collection rates of landfill gas, at about 20 %, seem very low. They also seem low in that nearly all German landfills have gas-collection facilities and that the technical characteristics of German landfills would seem to provide a comparatively good basis for high collection rates. This apparent contradiction will need to be cleared up for future reports.	The causes for the high differences between statistical data and estimated amount of landfill gas shall be determined.	[2018]	overdue	Germany is continuing to work on that issue.		2013	8.2.1.6
5.A.1.	For some years now, there has been increasing evidence in Germany that the formation of landfill gas calculated according to the FOD model of the IPPC and the resulting methane emissions are considerably overestimated compared to the real behaviour of landfills. The Federal Environment Agency has therefore commissioned two research projects to investigate this issue and to determine national values for half-lives, k-values and DOCf-values. Translated with www.DeepL.com/Translator	After completion of the current SV project (for the textual and mathematical incorporation of the results from two previously finished Research projects into the NIR), the results are to be transferred to the NIR and the inventory revised.	[2020]	to do	Germany is continuing to work on that issue.		2019	7.2.1.6
5.D.1.	In the area of wastewater treatment, only CH_4 emissions from open cesspools and N_2O emissions from aeration tanks and from effluent are currently being reported. Other possible treatment steps that could be emissions-relevant – such as sludge treatment – are not reported, since the 2006 IPCC Guidelines do not cover them and since no pertinent data are available to date.	The inventory needs to be adjusted in keeping with the results of the R&D project on "fugitive emissions."	[2020]	to do	Germany is continuing to work on that issue.		2016	7.5.1.1.1

10.4.2 KP & LULUCF

The LULUCF-sector improvements described for the Convention inventory, in Chapter 10.4.1, are also to be applied to the KP-LULUCF inventory.

10.4.3 Implementing Regulation Article 9: Reporting on implementation of recommendations and adjustments

Table 481: Implementing Regulation Article 9: Reporting on implementation of recommendations and adjustments

Member State:	Germany			
Reporting year:	UNFCCC Annual Review Report 2018			
CRF category / issue	**Review recommendation**	**Review report / paragraph**	**MS response / status of implementation**	**Chapter/section in the NIR**
	The Annual Review Report 2018 was not officially published in due time			

11 Supplementary information as required pursuant to Article 7 (1) of the Kyoto Protocol

11.1 General information

11.1.1 The definition of forest, and any other criteria

The National Forest Inventory is the main data source used, in the forest sector, for determination of activity data and emission factors. Its forest definition, which serves as a basis for the report, is presented in Chapter 6.2.1.

In keeping with Germany's initial report under the Kyoto Protocol (UNFCCC, 2007), Germany has defined the following specific parameters for its national forest definition:

Table 482: Definition of "forest" in Germany

Parameter	Range	Selected value
Minimum area of land (minimum area of land)	0.05 – 1.00 ha	0.1 ha
Tree crown cover or equivalent stocking level (tree crown cover or equivalent stocking level)	10 – 30 %	10 %
Potential tree height at maturity (potential tree height at maturity)	2 – 5 m	5 m

Within the range defined by the Marrakesh Accords (c.f. the above range), these parameters are the ones that come closest to the definition used in the National Forest Inventory. As comparative studies have shown, the differences between different activity-data calculations carried out in accordance with the aforementioned parameters are negligible Tomter (2010).

Pursuant to the Kyoto Protocol (UNFCCC, 1998a), areas are to be assigned to the activities "afforestation" and "deforestation" if they have been afforested / deforested since 1990. Such areas remain in those assigned categories until the end of the commitment period. As a result, the areas of said categories increase constantly. In the context of greenhouse-gas reporting, short-rotation plantations are not included as Forest Land, and are reported under Cropland.

Germany does not have any forest plantations that have been transferred into another land-use category (non- Forest Land) and credited under Forest Managament (KP 3.4). All afforestation and deforestation are reported under KP 3.3. As a result, the management form described in Decision 2/CMP.7, Annex, Paragraphs 37–39 does not apply to Germany.

In general, reforestation requirements apply in Germany (cf. Art. 11 (1) p. 2 Federal Forest Act (BWaldG)), meaning that clear-cut forest areas and thinned forest stands have to be reforested or replenished. Areas that have been afforested since 1990, but temporarily have no forest cover as a result of natural disasters, continue to fall within the definition of forest and must be reforested. No deforestation as a result of natural disasters takes place in Germany.

11.1.2 Elected activities under Article 3 Paragraph 4 of the Kyoto Protocol

In the second commitment period, Germany has to credit the activity *Forest Management* (FM activity pursuant to Article 3 (4) of the Kyoto Protocol. In addition, Germany is reporting emissions from harvested wood products. Germany has not selected the option *natural disturbances*.

Germany has selected the following voluntary activities under Article 3.4 of the Kyoto Protocol:

- Cropland management (CM)
- Grazing land management (GM).

Germany has opted for accounting at the end of the second commitment period.

11.1.3 Description of how the definitions of each activity under Article 3.3, and each elected activity under Article 3.4, have been implemented and applied consistently over time

11.1.3.1 Afforestation, reforestation and deforestation (ARD)

The definitions used by Germany for afforestation, reforestation and deforestation are in accordance with the Marrakesh Accords (MA). Pursuant to the MA, afforestation is defined as "the direct human-induced conversion of land that has not been forested for a period of at 50 years to forested land through planting, seeding and / or the human-induced promotion of natural seed sources[177]." Reforestation differs from afforestation solely with regard to the time since the area was last forested and, pursuant to the IPCC, occurs on land that has not been forest since 31 December 1989[178]. Since the reporting period for Germany begins with base year 1990, and since adequate data for differentiation of land-use forms are available only for the period as of 1970, afforestation and reforestation are considered together in the present context (and hereafter are both referred to as afforestation). Afforestation means the establishment of trees on abandoned land, if the relevant rejuvenation suffices for producing forest in accordance with the national forest definition. In general, the time of afforestation is the time at which the first activity in the relevant regeneration process was carried out. In the case of spontaneous regeneration of trees, the time of afforestation is considered to be the time at which the national criteria for the forest definition have been met, i.e. when the natural forest cover has reached an average age of five years, and a crown cover of at least 50 % (cf. Chapter 6.2.1).

The afforestation category corresponds to the following categories in reporting under the UN Framework Convention on Climate Change:

177 "Afforestation is the direct human-induced conversion of land that has not been forested for a period of at least 50 years to forested land through planting, seeding and/or the human-induced promotion of natural seed sources." (IPCC KP Supplements (IPCC et al., 2014a))

178 Original: "Reforestation" is the direct human-induced conversion of non-forested land to forested land through planting, seeding and/or the human-induced promotion of natural seed sources, on land that was forested but that has been converted to non-forested land. For the first commitment period, Reforestation activities will be limited to Reforestation occurring on those lands that did not contain forest on 31 December 1989. (IPCC KP Supplements (IPCC et al., 2014a))

Table 483: Afforestation in KP and UNFCCC categories

Category in KP reporting	Category pursuant to UNFCCC	
Afforestation under Art. 3.3 KP	4.A.2.1 Cropland converted to Forest Land	
	4.A.2.2. Grassland converted to Forest Land	4.A.2.2.1 Grassland (in the strict sense – i.t.s.s.) converted to Forest Land
		4.A.2.2.2 Woody Grassland converted to Forest Land
	4.A.2.3. Wetlands converted to Forest Land	4.A.2.3.1 Wetlands (terrestrial) converted to Forest Land
		4.A.2.3.2 Waters converted to Forest Land
	4.A.2.4. Settlements converted to Forest Land	
	4.A.2.5. Other land converted to Forest Land	

The IPCC defines deforestation as "the direct human-induced conversion of forested land to non-forested land"[179]. In accordance with the provisions of the IPCC, harvest that is followed by regeneration is not considered deforestation, since harvest is a forest-management activity pursuant to Art. 3.4. This definition also does not include "forest cover loss resulting from natural disturbances, such as wildfires, insect epidemics or wind storms", since "in most cases these areas will regenerate naturally or with human assistance." Such areas also fall within the category of managed land pursuant to Art. 3.4 or, if the areas are afforested land, within the category of afforested land pursuant to Art. 3.3.

Where, since 1990, human activities have however taken place on such areas temporarily without forest cover – activities such as road construction, settlement construction or other forms of land use (management of grassland or wetlands) – with the result that forest regeneration is prevented, then, so the IPCC, the areas must be considered deforested.

The deforestation category corresponds to the following categories in reporting under the UN Framework Convention on Climate Change:

[179] Original: "Deforestation is the direct human-induced conversion of forested land to non-forested land" (IPCC KP Supplements (IPCC et al., 2014a))

Table 484: Deforestation in KP and UNFCCC categories

Category in KP reporting	Category pursuant to UNFCCC	
Deforestation under Art. 3.3 KP	4.B.2.1. Forest Land converted to Cropland	
	4.C.2.1. Forest Land converted to Grassland	4.C.2.1.1 Forest Land converted to Grassland (i.t.s.s.)
		4.C.2.1.2 Forest Land converted to Woody Grassland
	4.D.2.1. Forest Land converted to Wetlands	4.D.2.1.1 Forest Land converted to Wetlands (terrestrial)
		4.D.2.1.2 Forest Land converted to Waters
	4.E.2.1. Forest Land converted to Settlements	
	4.F.2.1. Forest Land converted to Other Land	(NO)

NO: not occurring

11.1.3.2 Forest management (FM)

In Germany, all forest areas that have been forest since 1990 are considered managed within the meaning of the Marrakesh Accords[180] and are reported under *forest management*[181] pursuant to Art. 3.4 KP. A detailed pertinent description is presented in Chapter 11.5.1.

Table 485: Forest management in KP and UNFCCC categories

Category in KP reporting	Category pursuant to UNFCCC
Forest management pursuant to Art. 3.4 KP	4.A.1 Forest Land remaining Forest Land

Since every land-use change to forest is considered afforestation, every land-use change from Forest Land to a different land-use category is considered deforestation, and all forest areas not afforested are subject to forest management, there is no possibility that the manner in which the relevant definitions are applied could change over time.

The emissions contribution from harvested wood products in Germany, in terms of greenhouse emissions from sources and removals in sinks, in the land-use sector, was estimated with the help of the WoodCarbonMonitor model, via a calculation approach based on wood-product production data. The estimation covers all harvested wood products that are produced in Germany, that consist of wood which originates from trees harvested in Germany and that are used for their material (not energy) value.

11.1.3.3 Cropland management (CM)

Cropland management (CM) is agricultural use of land for cultivation of field crops (such as grain, pulses, root crops) and berries (such as strawberries); of garden land for cultivation of vegetables, fruit and flowers and for culturing of crops; and of special crop areas, for cultivation of certain plants (such as hops, wine grapes, fruit in orchards). Cropland management includes annual crops and permanent crops such as wine grapes, fruit trees, Christmas trees and short-rotation plantations. Permanent crops do not fall within the German definition of forest.

[180] Paragraph 1 lit. f of Annex A of Decision 16/CMP.1

[181] Original: "'Forest management' is a system of practices for stewardship and use of forest land aimed at fulfilling relevant ecological (including biological diversity), economic and social functions of the forest in a sustainable manner." (IPCC KP Supplements (IPCC et al., 2014a))

The definition of cropland management is in keeping with the definition of areas under cropland as used for reporting under the UN Framework Convention on Climate Change (cf. Chapter 6.2 and Table 379).

The afforestation category corresponds to the following categories in reporting under the UN Framework Convention on Climate Change:

Table 486: Afforestation in KP and UNFCCC categories

Category in KP reporting	Category pursuant to UNFCCC	
Cropland management pursuant to Art. 3.4 KP	4.B.1 Cropland remaining Cropland	
	4.B.2.2 Grassland converted to Cropland	4.B.2.2.1 Grassland (in the strict sense) converted to Cropland
		4.B.2.2.2 Woody Grassland converted to Cropland
	4.B.2.3 Wetlands converted to Cropland	4.B.2.3.1 Wetlands (terrestrial) converted to Cropland
		4.B.2.3.2 Waters converted to Cropland
	4.B.2.4 Settlements converted to Cropland	
	4.B.2.5 Other areas converted to Cropland	
	4.C.2.2.2 Cropland converted to Woody Grassland[1)]	
	4.D.2.2 Cropland converted to Wetlands[2)]	4.D.2.2.3 Cropland converted to Terrestrial Wetlands[3)]
		4.D.2.2.2 Cropland converted to Wetlands[4)]
	4.E.2.2 Cropland converted to Settlements[5)]	
	4.F.2.2 Cropland converted to Other Land (NO)[6)]	

Numbers: 1), 2), 3), 4), 5) emissions and removals are listed as zero (IPCC KP Supplement (2014) Chapter 2.9.2). Footnote 6) NO: Not occurring

All areas under cropland management are subject to periodic cultivation measures, and thus the pertinent emissions and removals are anthropogenic.

11.1.3.4 Grazing land management (GM)

Grazing land management (GM) is the use of Grassland (in the strict sense) as meadows, pastures, mountain pastures, rough pastures, heath land, natural grassland, recreational areas or swamps/marshes.

The definition of grazing land management is in keeping with the definition of areas under Grassland (in the strict sense) as used for reporting under the UN Framework Convention on Climate Change (cf. Chapter 6.2 and Table 379).

The grazing land management category corresponds to the following categories in reporting under the UN Framework Convention on Climate Change:

Table 487: Grazing land management in KP and UNFCCC categories

<table>
<tr><th>Category in KP reporting</th><th colspan="2">Category pursuant to UNFCCC</th></tr>
<tr><td rowspan="14">Grazing land management pursuant to Art. 3.4 KP</td><td colspan="2">4.C.1.1 Grassland (in the strict sense) remaining as Grassland (i.t.s.s.)</td></tr>
<tr><td colspan="2">4.C.2.2.1 Cropland converted to Grassland (i.t.s.s.)</td></tr>
<tr><td colspan="2">4.C.1.3 Woody Grassland converted to Grassland (i.t.s.s.)</td></tr>
<tr><td rowspan="2">4.C.2.3.1 Wetlands converted to Grassland (i.t.s.s.)</td><td>4.C.2.3.3.1 Terrestrial Wetlands converted to Grassland (i.t.s.s.)</td></tr>
<tr><td>4.C.2.3.2.1 Waters converted to Grassland (i.t.s.s.)</td></tr>
<tr><td colspan="2">4.C.2.4.1 Settlements converted to Grassland (i.t.s.s.)</td></tr>
<tr><td colspan="2">4.C.2.5.1 Other land converted to Grassland (i.t.s.s.)</td></tr>
<tr><td colspan="2">4.C.1.4 Grassland (i.t.s.s.) converted to Woody Grassland[1)]</td></tr>
<tr><td rowspan="2">4.D.2.3 Grassland (i.t.s.s.) converted to Wetlands[2)]</td><td>4.D.2.3.1.3 Grassland (i.t.s.s.) converted to Terrestrial Wetlands[3)]</td></tr>
<tr><td>4.D.2.3.1.2 Grassland (i.t.s.s.) converted to Waters[4)]</td></tr>
<tr><td colspan="2">4.E.2.3.1 Grassland (i.t.s.s.) converted to Settlements[5)]</td></tr>
<tr><td colspan="2">4.F.2.3.1 Grassland (i.t.s.s.) converted to Other Land[6)]</td></tr>
</table>

Numbers 1), 2), 3), 4), 5) emissions and removals are listed as zero (IPCC KP Supplement (IPCC et al., 2014a): Chapter 2.9.2).

Footnote 6) NO: Not occurring

All areas under grazing land management are subject to periodic cultivation measures, and thus the pertinent emissions and removals are anthropogenic.

11.1.4 Description of precedence conditions and/or hierarchy among Article 3.4 activities, how they have been consistently applied in determining how land was classified

Germany has defined the hierarchy of activities relative to Art. 3.4 of the Kyoto Protocol pursuant to the provisions of the 2013 IPCC KP Supplement (IPCC et al., 2014a). The activity *forest management* is binding, and thus has priority over the voluntary activities *cropland management* and *grazing land management*. In the first commitment period, Germany selected *forest management* voluntarily. The hierarchy makes it possible to carry out consistent reporting for the first and second commitment periods.

Pursuant to the provisions of the 2013 IPCC KP Supplement (IPCC et al., 2014a), forest management (FM) can take place only on lands that meet the definition of forest. The forest areas reported under FM are the forest areas reported, pursuant to the Convention, under *Forest Land remaining Forest Land*, except for areas assigned either to the categories of conversion leading to Forest Land (Convention) or to the category of afforestation (Kyoto Protocol). The total forest area under the Convention and the total forest area under the Kyoto Protocol are the same. All German forest lands are considered managed within the meaning of the provisions of the Marrakesh Accords. The definition of forest management is broadly interpreted (cf. for a detailed discussion Chapter 11.5.1).

Within the group of voluntary activities, allocations to *cropland management* have priority over allocations to *grazing land management*. Agricultural grass within the context of crop rotations is allocated to cropland management. By contrast, permanent land-use changes from cropland to Grassland (in the strict sense), and vice-versa, are reported as activity changes from cropland management to grazing land management, and vice-versa. As a result, the land classifications for cropland management and grazing land management are in keeping with the inventory's classifications of Cropland and Grassland (in the strict sense) under the UNFCCC.

11.2 Land-oriented information

11.2.1 Spatial assessment unit used for determining the area of the units of land under Article 3.3

The method used to derive activity data (areas) is described in Chapter 6.3. It corresponds to Approach 3 pursuant to the IPCC 2006 Guidelines (IPCC, 2006). The reference area is Germany; it comprises 35,779.63 kha. The areas in the "forest" categories, and their additions and removals, are derived primarily from the point data of the National Forest Inventories (Schmitz et al., 2005). For the new German Länder in 1990, the BWI data are supplemented with CIR data. A detailed description of land-use-classification procedures is provided in Chapter 6.2, while a description of the procedures for derivation of the land-use matrix (LUM) is provided in Chapter 6.3.

Thanks to the use of a consistent method for derivation of the LUM, the same spatial assessment unit is used for deforestation areas as is used for afforestation areas.

11.2.2 Method used to develop the land-transition matrix

The method used to define forest areas, and to derive areas for the "change" categories, is described in detail in Chapter 6.3. Table 488 provides an overview of land-use changes (LUC) leading to Forest Land (afforestation/reforestation), of land-use changes leading away from Forest Land (deforestation), and of managed areas (forest management). Conversion areas remain in the relevant conversion categories until the end of the 2nd commitment period of the Kyoto Protocol, 2020; for this reason, the annual areas accumulate. In Table 488, the column for the accumulated areas lists those areas as they are reported. An adjacent column shows the corresponding annual areas.

Table 488: Accumulated and annual areas in the categories afforestation, deforestation and forest management

Year	Afforestation/ Reforestation (KP 3.3) [kha]		Deforestation (KP 3.3) [kha]		Forest Management (KP 3.4) [kha]	
	Accumulated areas	Annual areas	Accumulated areas	Annual areas	Accumulated areas	Annual areas
1990	27,619	27,619	12,539	12,539	10,901,001	10,901,001
1995	165,712	27,619	75,235	12,539	10,838,306	10,976,399
2000	303,806	27,619	137,931	12,539	10,775,610	11,051,797
2005	380,558	15,350	185,033	9,420	10,728,508	11,093,715
2010	458,815	16,557	240,988	11,005	10,672,552	11,114,810
2011	475,372	16,557	251,994	11,005	10,661,547	11,120,362
2012	491,930	16,557	262,999	11,005	10,650,541	11,125,914
2013	506,001	14,071	270,808	7,809	10,642,732	11,134,662
2014	520,072	14,071	278,617	7,809	10,634,924	11,140,924
2015	534,142	14,071	286,425	7,809	10,627,115	11,147,187
2016	548,213	14,071	294,234	7,809	10,619,306	11,153,449
2017	562,284	14,071	302,043	7,809	10,611,498	11,159,711

The method used to define cropland and grassland areas, and to derive areas for the "change" classes, is described in detail in Chapter 6.3. Table 489 provides an overview of Cropland Management areas and Grazing Land Management areas. In the base years, the land-use changes (LUC) in the period 1970 through 1990 are included, except those consisting of land-use changes leading to Forest Land. For purposes of methodological consistency with KP Art. 3.3, those changes have been recorded cumulatively, since 1990, as afforestation. The areas are divided into the categories

- Cropland remaining Cropland and Grassland remaining Grassland (in the strict sense)
- Land-use changes leading to Cropland or to Grassland (in the strict sense) (except for Forest Land)
- Land-use changes from Cropland, and from Grassland (in the strict sense), to land-use categories that are not included in other activities under KP Art. 3.3. or 3.4.

In the case of land-use changes from Cropland, and from Grassland (in the strict sense), to land-use categories that are not included in other activities under KP Art. 3.3. or 3.4, the following procedure is used: in keeping with the IPCC 2013 KP Supplements (IPCC et al., 2014a), Chapter 2.9.2, that area is reported that has been converted from Cropland or Grassland (in the strict sense) to other use categories. The emissions from those areas are accounted, in keeping with the IPCC 2013 KP Supplement (IPCC et al., 2014a), Chapter 2.9.2, as zero. In tables 4(KP-I)B.2 and 4(KP-I)B.3 of the CRF, they are thus listed as "NO" for the individual pools.

Included Elsewhere is used in connection with land-use changes from Cropland management or Grazing Land management to the category Afforestation/Reforestation. In addition, IE is used for the litter and dead wood pools, since the total phytomass of the plants involved enters into the emission calculation.

Table 489: Overview of Cropland Management areas and Grazing Land Management areas, 1990-2016 (in boldface type: areas of relevance to Kyoto II)

Cropland Management (CM)				
Year	Cropland remaining Cropland [ha]	∑LUC to Cropland [ha]	∑LUC from Cropland [ha]	∑Cropland Management [ha]
1990	12,587,710	1,041,719	462,690	14,092,119
1995	12,529,098	1,024,875	578,363	14,132,335
2000	12,470,486	1,008,030	694,035	14,172,552
2005	12,381,063	848,922	900,491	14,130,477
2010	12,384,461	997,208	1,049,852	14,431,521
2013	12,384,320	1,056,200	1,145,473	14,585,993
2014	12,384,003	1,055,614	1,176,501	14,616,117
2015	12,383,686	1,055,027	1,207,529	14,646,242
2016	12,383,369	1,054,440	1,238,558	14,676,366
2017	12,383,052	1,053,853	1,269,586	14,706,491
Grazing Land Management (GM)				
Year	**Grazing Land remaining Grazing Land [ha]**	**∑LUC to Grazing Land [ha]**	**∑LUC from Grazing Land [ha]**	**∑Grazing Land Management [ha]**
1990	5,808,654	903,073	224,550	6,936,277
1995	5,708,702	888,757	280,688	6,878,147
2000	5,608,749	874,442	336,826	6,820,017
2005	5,615,615	815,442	439,153	6,870,210
2010	5,306,502	706,150	546,130	6,558,783
2013	5,149,747	636,746	600,043	6,386,536
2014	5,115,939	614,702	619,565	6,350,206
2015	5,082,131	592,659	639,087	6,313,877
2016	5,048,323	570,615	658,608	6,277,547
2017	5,014,515	548,572	678,130	6,241,217

11.2.3 Maps and/or databases to identify the geographical locations, and the pertinent system of identification codes for the geographical locations

The following data sources were used in determination of activity data:

- National Forest Inventory 1987 (Bundeswaldinventur; BWI 1987)
- National Forest Inventory 2002 (Bundeswaldinventur; BWI 2002)
- National Forest Inventory 2012 (Bundeswaldinventur; BWI 2012)
  Inventory Study 2008 (Inventurstudie; IS08)
- Maps, derived from CIR data, from the mapping of biotopes and use types carried out for 1990,
- Official topographic-cartographic information system (Amtliches Topographisch-Kartographisches Informationssystem; ATKIS®)
- CORINE Land Cover (CLC)
- Soil map for the Federal Republic of Germany 1:1,000,000 (Bodenübersichtskarte der Bundesrepublik Deutschland – BÜK 1000; BGRBGR - Bundesanstalt für Geowissenschaften und Rohstoffe (1997))
  Map of Germany's organic soils (Roßkopf et al., 2015)
- Forest-fire statistics of the Federal Republic of Germany
- Agricultural statistics for determination of areas under cultivation with perennial crops {Federal Statistical Office (various years)}

Detailed descriptions of the data sources are presented in Chapters 6.4.2.1 and 6.3.2.1.

All afforestation and deforestation are accounted for under Article 3.3 and are not listed under forest management, cropland management and grazing land management pursuant to Article 3.4. The changes in areas between the measures pursuant to Article 3.3 and to Article 3.4 are listed in KP table NIR 2. The method for deriving areas uses a sample-based system that records the area for each land-use category and the land-use changes to and from the various land-use categories (cf. Chapter 6.3). The sampling network used is based on the grid for the BWI 2012. Each sample point is proportionally assigned to the land-use categories forest management, afforestation and deforestation, cropland management and grazing land management. In the categories afforestation and deforestation, no changes of pertinent sample-point proportions into other land-use categories can take place. Each proportion of a sample point corresponds to an area. Such an area's geographic position is determined in terms of the pertinent sample-point coordinates. This identification system ensures that differentiation between a) afforested and deforested areas under KP Article 3.3 and b) forest management, cropland management and grazing land management areas under KP Article 3.4 is unambiguous.

11.3 Activity-specific information

11.3.1 Methods for determination of carbon-stock changes, greenhouse-gas emissions and reduction estimates

11.3.1.1 Description of methodologies and the underlying assumptions used

11.3.1.1.1 Summary

Forest management, afforestation and deforestation

As described in Chapter 11.1.3 , the activities forest management and afforestation in the Kyoto Protocol are equivalent to the UNFCCC categories 4.A.1 Forest Land remaining Forest Land and 4.A.2 Land converted to Forest Land, respectively. The relevant calculation methods are as follows:

- Changes in carbon stocks in above-ground and below-ground biomass: Chapter 6.4.2.2,

- Carbon-stocks change in dead wood: Chapter 6.4.2.3,
- Carbon-stocks change in litter: Chapter 6.4.2.4,
- Carbon-stocks change in mineral soils: Chapter 6.4.2.5,
- CO_2, CH_4 and N_2O emissions from drained organic soils: Chapter 6.4.2.6,
- Direct and indirect N_2O emissions from humus losses connected to land-use changes: Chapter 6.1.2.7 and Chapter 6.1.2.8
- CO_2, CH_4 and N_2O emissions from forest fires: Chapter 6.4.2.7.5,
- Carbon-stocks change in harvested wood products: Chapter 6.10,

In deforestation, carbon losses occur in biomass, dead wood and litter and in mineral and organic soils. In the case of biomass, dead wood and litter, it is assumed that the pertinent losses take the form of emissions in the year of conversion. Emissions from organic soils take place each year on the entire deforested area. For mineral soils, a transition time of 20 years is assumed.

Table 490 provides an overview for 2017 of changes in carbon stocks, greenhouse-gas emissions and areas in connection with forest management, afforestation and deforestation.

Table 490: Carbon-stock changes and greenhouse-gas emissions as a result of forest management, afforestation and deforestation, for the year 2017

	Forest management	Afforestation	Deforestation
C-stock changes in biomass [kt C] *	10,980.131	1,913.407	-315.954
C-stock changes in dead wood [kt C] *	-551.105	19.330	-15.505
C-stock changes in litter [kt C] *	-132.644	262.341	-145.729
C-stock changes in mineral soils [kt C] *	4,309.939	-98.826	26.521
CO_2 from organic soils [kt C] *	-223.129	-109.877	-126.10
N_2O from organic soils [kt N_2O] **	0.218	0.107	0.055
CH_4 from organic soils [kt CH_4] **	0.462	0.227	0.385
Direct and indirect N_2O from decomposition of organic material in mineral soils [kt N_2O] **	0.000	0.289	0.028
CO_2 from forest fires [kt C] *	IE	IE	NO
N_2O from forest fires[10]) [kt N_2O] **	0.005	IE	NO
CH_4 from forest fires[11]) [kt CH_4] **	0.090	IE	NO
C-stock changes in harvested wood products [kt C] *	828.182	IE	NO
Total[kt CO_2-eq.]**	**-55,694.912**	**-7,159.525**	**2,149.074**
Annual areas [ha]	**11,159,711**	**14,071**	**7,809**
Accumulated areas [ha]	**10,611,498**	**562,284**	**302,043**

* Stock change, positive: Carbon sink; stock change, negative: carbon source

** GHG emissions, positive: GHG source; GHG emissions, negative: GHG sink

Cropland management

- Methodologically, the activity cropland management corresponds to the UNFCCC categories 4.B.1 and 4.B.2, with the exception of 4.B.2.1 Forest Land converted to Cropland. In keeping with the IPCC 2013 KP Supplements (IPCC et al., 2014a), Chapter 2.9.2, emissions and removals on areas converted from cropland to non-credited land-use categories are credited as zero. The relevant calculation methods are as follows:
- Changes in carbon stocks in above-ground and below-ground biomass: Chapter 6.5.2.2,
- Carbon-stocks change in mineral soils: Chapter 6.5.2.3,
- CO_2, CH_4 and N_2O emissions from drained organic soils: Chapter 6.5.2.4,
- Direct and indirect N_2O emissions from humus losses connected to land-use changes: Chapter 6.1.2.7 and Chapter 6.1.2.8 and
- proof to the effect that cropland under "remaining as" management is not a net source for greenhouse gases: Chapter 6.5.2.3.2

The carbon pools dead wood and litter occur only on Forest Land; they do not occur in cropland management (NO), since land-use changes from Forest Land to Cropland are accounted under deforestation. N_2O emissions from organic soils under cropland are reported not under the cropland management activity pursuant to Art. 3.4, but as part of the agricultural sector.

Table 491 provides an overview for 2017 of carbon-stock changes, and of greenhouse-gas emissions, in connection with cropland management.

Table 491: Carbon-stock and greenhouse-gas emissions as a result of cropland management, for the year 2017

Sub-categories	C-stock changes in biomass [182] [kt C]	C-stock changes in mineral soils [79] [kt C]	CO_2 from organic soils [79] [kt C]	CH_4 from organic soils [183] [kt CH_4]	Direct and indirect N_2O from decomposition of organic material in mineral soils [80] [kt N_2O]	Total [80/184] [kt CO_2-eq.]
Cropland remaining Cropland	-26.31	NO	-2,122.86	6.81	NO	7,958.258
Total for LUC to Cropland	-1.13	-770.57	-951.88	3.06	1.18	6,829.73
Total for LUC from Cropland	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Total	**-27.44**	**-770.57**	**-3,074.73**	**9.87**	**1.18**	**14,797.01**

The emissions from cropland management in 2017 are dominated by CO_2 from organic soils. Carbon losses from mineral soils, as a result of conversions of Grassland (in the strict sense) to Cropland, are also significant.

In 2016, the net emissions from cropland management were lower than they were in the base year 1990 (cf. Table 507), with the result that a net emissions reduction of 2,128.37 kt CO_2-eq. can be credited in 2017. The majority of this results from an increase of Cropland areas on organic soils. It also originates in mineral soils, however – especially in connection with grassland tillage. These effects offset, far and away, the decrease in the (still-positive) emissions from the sub-categories settlements and wetlands to cropland since 1990.

Greenhouse-gas emissions and removals from land-use changes from cropland to activities that are not accounted (terrestrial wetlands, waters, settlements) are reported, pursuant to the IPCC 2013 KP Supplements (IPCC et al., 2014a), Chapter 2.9.2, as zero. Consequently, no pertinent emissions have been reported.

Grazing land management:

Methodologically, the activity grazing land management corresponds to the sub-category Grassland (in the strict sense) (4.C.1.1 and land-use changes to Grassland (in the strict sense), except for changes from Forest Land to Grassland (in the strict sense)). In keeping with the IPCC 2013 KP Supplements (IPCC et al., 2014a), Chap. 2.10.2, emissions and removals on areas converted from Grassland (in the strict sense) to non-accounted land-use categories are accounted as zero. The relevant calculation methods are as follows:

- Changes in carbon stocks in above-ground and below-ground biomass: Chapter 6.6.2.2,
- Carbon-stocks change in mineral soils: Chapter 6.6.2.3,
- CO_2, CH_4 and N_2O emissions from drained organic soils: Chapter 6.6.2.4,
- Direct and indirect N_2O emissions from humus losses connected to land-use changes: Chapter 6.1.2.7 and 6.1.2.8.

[182] Stock change, positive: Carbon sink; negative: carbon source

[183] GHG emissions, positive: GHG source; negative: GHG sink

[184] Not including N_2O emissions from organic soils; they are reported as part of the agricultural sector

The carbon pools dead wood and litter occur only on Forest Land; they do not occur in grazing land management (NO), since land-use changes from Forest Land to Grassland (in the strict sense) are accounted under deforestation.

Table 492 provides an overview for 2017 of carbon-stock changes, and of greenhouse-gas emissions, in connection with grazing land management. N_2O emissions from organic soils under cropland are reported not under the grazing land management activity pursuant to Art. 3.4, but as part of the agricultural sector.

Table 492: Carbon-stock and greenhouse-gas emissions as a result of grazing land management, for the year 2016

Sub-categories	C-stock changes in biomass [185] [kt C]	C-stock changes in mineral soils [82] [kt C]	CO_2 from organic soils [82] [kt C]	CH_4 from organic soils [186] [kt CH_4]	Direct and indirect N_2O from decomposition of organic material in mineral soils [83] [kt N_2O]	Total [83/187] [kt CO_2-eq.]
Grassland (in the strict sense) remaining as Grassland (i.t.s.s.)	NO	NO	-6,012.72	18.69	NO	22,513.86
Total for LUC to Grassland (in the strict sense)	-28.60	425.46	-238.97	0.74	NO	-560.33
Total for LUC from Grassland (in the strict sense)	NO	NO	NO	NO	NO	NO
Total	**-28.60**	**425.46**	**-6,251.70**	**19.43**	**NO**	**21,953.52**

Almost all of the emissions from grazing land management in 2016 come from drained organic soils. Those emissions are slightly offset by the carbon sink resulting in mineral soils following land-use changes.

In 2016, the net emissions from grazing land management were lower than they were in the base year 1990 (cf. Table 508), with the result that a net emissions reduction of -3,818.29 kt CO_2-eq. can be credited in 2017. Most of that reduction is due to decreases of the grassland areas on organic soils. The relevant emissions reduction since 1990 (- 15 %) offsets, far and away, the reduction of the sink function for mineral soils (-32 %), during the period covered by the report, due to the absolute size difference involved.

Greenhouse-gas emissions and removals from areas with land-use changes to activities that are not accounted (terrestrial wetlands, waters, settlements) are reported, pursuant to the IPCC 2013 KP Supplements (IPCC et al., 2014a), Chap. 2.10.2, as zero. Consequently, no pertinent emissions have been reported.

11.3.1.1.2 Biomass

Forest management and afforestation:

Information on methods used for calculating carbon stocks, and carbon-stock changes, in above-ground and below-ground biomass is presented in the following chapters:

- Forest Land remaining Forest Land, cf. Chapter 6.4.2.2.1.
- Land converted to Forest Land cf. Chapter 6.4.2.2.2.

[185] Stock change, positive: Carbon sink; negative: carbon source
[186] Emissions, positive: GHG source; negative: GHG sink
[187] Not including N_2O emissions from organic soils; they are reported as part of the agricultural sector

Deforestation:

With regard to deforested areas, an individual-tree calculation was carried out on the basis of the BWI (NFI) 1987, BWI 2002 and BWI 2012 inventories. The data of the 2008 Inventory Study were not taken into account, due to the small size of that survey's sample of trees on deforestation areas. For the period between the BWI 1987 and BWI 2002 inventories, only trees in the old German Länder were considered, since the BWI 1987 inventory was carried out only there. The wood-stocks data for the old German Länder were applied to the new German Länder. The emission factor for the decreasing above-ground and below-ground biomass for the period 1990 through 2001 is -28.93 t C ha^{-1} a^{-1}. For the period as of 2002, an individual-tree calculation, spanning the BWI 2002 and BWI 2012 inventories, was carried out for Germany as a whole. The emission factor for the decreasing above-ground and below-ground biomass for the period 2002 through 2015 is -54.66 t C ha^{-1} a^{-1}. The carbon stocks released upon deforestation are counted, completely, as emissions in the same year. The stocks in the following use classes are listed for the relevant conversion year, on a one-time basis, under "gains" in the CRF table. They are thus taken into account.

Table 493: Emission factors (EF) for biomass in connection with deforestation; positive: carbon sink; negative: carbon emissions

		1990	2000	2010	2015	2016	2017
Above-ground biomass [tC/ha]	gains[1)]	8.04	8.22	8.97	10.23	10.22	10.23
	losses[2)]	-24.53	-24.53	-46.48	-46.48	-46.48	-46.48
	net change[3)]	-16.49	-16.32	-37.52	-36.25	-36.26	-36.25
Below-ground biomass [tC/ha]	gains[1)]	3.25	3.26	3.56	3.96	3.96	3.96
	losses[2)]	-4.39	-4.39	-8.18	-8.18	-8.18	-8.18
	net change[3)]	-1.14	-1.13	-4.62	-4.22	-4.22	-4.22

1) Biomass in connection with the subsequent land use; 2) Biomass of forest; 3) Biomass change from deforestation

Cropland management:

Information on methods used for calculating carbon stocks, and carbon-stock changes, in above-ground and below-ground biomass is presented in Chapter 6.1.2.3 and Chapter 6.5.2.2, divided into the following categories:

- Permanent crops (perennial crops), including stratification and weighting; cf. Chapter 6.1.2.3.4.
- For annual crops that are taken into account in connection with land-use changes, cf. Chapter 6.1.2.3.3. The biomass stocks are calculated from annual cultivation and yield statistics, in a manner consistent with the method used in Chapter 5 (agriculture) to calculate N inputs from crop residues.
- For aggregation of the biomass figures, cf. Chapter 6.5.2.2.1.

In its "Member State recommendations on reporting systems for cropland & grazing land management emissions & removals" {ECOFYS 2017}, the EU Commission recommended that activity-data sources be developed for Germany, and that a system be implemented for georeferenced identification of perennial Woody Grassland areas within the Cropland category, as well as of their area changes. This recommendation is being implemented; intensive efforts are currently underway to develop a solution for this methodological issue.

Grazing land management:

Information on methods used for calculating carbon stocks, and carbon-stock changes, in above-ground and below-ground biomass is presented in Chapter 6.6.2.2.

11.3.1.1.3 Dead wood

Forest management and afforestation:

Information on methods used for calculating carbon stocks and carbon-stock changes in dead wood is presented in the following chapters:

- Forest Land remaining Forest Land, cf. Chapter 6.4.2.3.1.
- Land converted to Forest Land cf. Chapter 6.4.2.3.2.

Deforestation:

The C stocks in dead wood were calculated with data of the BWI 2002, the 2008 Inventory Study (IS08) and the BWI 2012. In the BWI 2002, terrestrial sampling was limited to dead wood with a diameter > 20 cm at its thicker end, for fallen dead wood, or with a DBH > 20 cm, for standing dead wood (Polley, 2001). For other sampling, the boundary used conformed to the provisions for climate reporting, i.e. was > 10 cm.

For the dead-wood diameter class > 20 cm, the change in dead-wood C stocks was calculated with the data of the BWI 2002 and 2012, for the period 2002 through 2012. For the diameter class 10 cm through 20 cm, the change was calculated for the period 2008 through 2012, with the data of the IS08 and the BWI 2012. For the same diameter class in the period 2002 through 2008, the ratio of the two diameter classes' changes in dead-wood C stocks for the period 2008 through 2012 was used as a basis. The mean value for the change in dead-wood C stocks in the period 2002 through 2012 was used as the change in such stocks for the period 1990 through 2002. Table 494 presents the changes in dead-wood C stocks for the different relevant periods and diameter classes. For the period as of the year 2013, the emission factor for the period 2008 through 2012 has been extrapolated. In each case of deforestation, the carbon stocks in dead wood, for the relevant year, were taken into account immediately as carbon emissions.

Table 494: Emission factors (EF) for dead wood for the periods 1990-2001, 2002-2007 and 2008-2012

t C ha^{-1} a^{-1}	1990 – 2001	2002 – 2007	2008 – 2012
EF dead wood, total	-1.884	-1.817	-1.986
EF dead wood, diameter class > 20cm	-1.298	-1.298	-1.298
EF dead wood, diameter class 10 through 20cm	-0.586	-0.519	-0.687

Cropland management and grazing land management:

Dead wood does not occur in connection with cropland management and grazing land management. Dead wood and tree cuttings are removed from areas with permanent crops. Such measures have already been taken into account in the biomass calculation.

11.3.1.1.4 Litter

Forest management and afforestation:

Information on methods used for calculating carbon stocks and carbon-stock changes in litter is presented in the following chapters:

- Forest Land remaining Forest Land, cf. Chapter 6.4.2.4.1.
- Land converted to Forest Land cf. Chapter 6.4.2.4.2.

Deforestation:

Calculations relative to the litter ground cover were carried out with the status data of the BZE I and BZE II forest soil inventories. According to the relevant calculations, the average carbon stocks in litter amounted to 19.05 t C ha^{-1} in 1990 (BZE I) and to 18.83 t C ha^{-1} in 2006 (BZE II). For the years 1991 through 2005, the stocks were derived by interpolating the status data for the years 1990 and 2006. For the period as of 2007, the stocks were obtained via extrapolation. In each case of deforestation, the carbon stocks in litter, for the relevant year, were taken into account immediately as carbon emissions.

Cropland management and grazing land management:

Litter does not occur in connection with cropland management and grazing land management, and it is included in the relevant biomass pool.

11.3.1.1.5 Mineral soils

Forest management:

- Information on methods used for calculating carbon stocks and carbon-stock changes in mineral soils of the "Forest Land remaining Forest Land" area is provided in Chapter 6.4.2.5.1.

Afforestation and deforestation:

For each land-use-change category, the carbon-stock changes in mineral soils are calculated as the difference between the carbon stocks of the final land-use category and the carbon stocks of the original land-use category. Pursuant to the IPCC Guidelines (IPCC, 2003, 2006; IPCC et al., 1997), the total changes are linearly distributed over a period of 20 years. For afforested and deforested areas, the carbon-stock changes in mineral soils were calculated in keeping with the procedures in Table 495 and Chapter 6.1.2.1. For each relevant year, the forest-soil carbon stocks were calculated via linear interpolation of the results of the forest-soil surveys.

Table 495: Implied emission factors (IEF) [t C ha^{-1} a^{-1}] for mineral soils in the categories afforestation and deforestation (negative = emission, positive = removal)

[t C ha^{-1} a^{-1}]	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
KP 3.3 Afforestation/ Reforestation	-0.608	-0.558	-0.509	-0.478	-0.399	-0.361	-0.326	-0.297	-0.270	-0.245	-0.221	-0.193
KP 3.3 Deforestation	0.454	0.405	0.356	0.343	0.266	0.232	0.202	0.176	0.153	0.131	0.111	0.095

Cropland management:

The mineral soils category is subdivided by land use, soil type / soil-parent-rock groups and climate region (cf. Chapter 6.1.2.1). Information on methods used for calculating carbon stocks and carbon-stock changes in mineral soils is provided in Chapter 6.5.2.3.

For areas remaining as cropland, national measurements show no change in carbon stocks in mineral soils. Proof to the effect that this pool is not a net sink is provided in Chapter 6.5.2.3.2.

The EU Commission's recommendation {ECOFYS 2017} calling for development of a system that would make it possible to determine carbon-stock changes, in soils, that, as a result of special cropland management measures, led to emissions reductions or carbon sequestration, is currently being reviewed. In addition, work on potential implementations is underway (cf. also Chapter 6.5.2.3).

Grazing land management:

The mineral soils category is subdivided by land use, soil type / soil-parent-rock groups and climate region (cf. Chapter 6.1.2.1). Information on methods used for calculating carbon stocks and carbon-stock changes in mineral soils is provided in Chapter 6.6.2.3. A similar EU Commission recommendation {ECOFYS 2017} (similar to that for cropland management), for the category of grazing land management is currently being reviewed (see above).

For areas remaining as Grassland (in the strict sense), national measurements show no change in carbon stocks in mineral soils (cf. Chapter 6.6.2.3.).

11.3.1.1.6 Organic soils

Forest management and afforestation:

Information on methods used for calculating carbon stocks and carbon-stock changes in organic soils is presented in the following chapters:

- Forest Land remaining Forest Land, cf. Chapter 6.4.2.6.1.
- Land converted to Forest Land cf. Chapter 6.4.2.6.2.

Deforestation:

For deforestation areas, the emission factors of sub-categories, and the area-weighted emission factors for deforestation on organic soils, were calculated pursuant to Table 496 and Chapter 6.1.2.2. It is important to remember that these calculations do not yield the carbon-stock difference between Forest Land and the subsequent use; they yield the emissions for the new use, in keeping with drainage intensity. Organic soils under forest emit -2.244 t C ha^{-1} a^{-1}.

Table 496: Emission factors for organic soils, relative to deforestation and the pertinent sub-categories, for the year 2017 (negative = loss; positive = sink)

Land-use category	CO_2 [t C ha^{-1}]	N_2O [kg N_2O ha^{-1}]	CH_4 [kg CH_4 ha^{-1}]
Forest Land converted to Cropland	-8.100	[188]	26.000
Forest Land converted to Grassland (in the strict sense)	-6.828	[188]	21.221
Forest Land to Woody Grassland	-2.244	2.188	4.642
Forest Land converted to Wetlands	-4.977	0.481	15.314
Forest Land to Waters	0.000	0.000	0.000
Forest Land converted to Settlements	-7.400	4.243	23.000
Forest Land converted to Other Land	0.000	0.000	0.000
Deforestation	**-5.857**	**2.536**	**17.890**

Cropland management and grazing land management:

Emission factors for organic soils were derived from spatially explicit data. This was done by differentiating the frequency distribution for depths to water table by uses, and by applying regressions betweens depths to water table and CO_2 emissions. For land-use changes, the emission factor for the new land-use category applies right away. Additional information is presented in the following chapters:

- Derivation of emission factors, cf. Chapter 6.1.2.2.
- Methods for Cropland, cf. Chapter 6.5.2.4
- Methods for Grassland (in the strict sense), cf. Chapter 6.6.2.4

11.3.1.1.7 Harvested wood products

In the first commitment period of the Kyoto Protocol, and in accordance with the IPCC 2003 GPG (IPCC, 2003), the contribution from carbon storage in wood products was taken into account as

[188] Is reported in the agricultural sector

an immediate emission and thus was neither reported nor credited (cf. Chapter 2.8.2, IPCC et al. (2014a)).

As described in detail in Chapter 6.10, for the present reporting year, the emissions contribution made by harvested wood products in Germany, in terms of sources and removals into sinks for greenhouse gases, was determined (as in past years) with the *WoodCarbonMonitor* model, in keeping with the specifications of the IPCC KP Supplement (IPCC et al., 2014a).

First, the availability of activity data, i.e. data on the production of and foreign trade in harvested wood products, was reviewed (cf. Chapter 2.8.1.1, IPCC et al. (2014a)), and the product fractions originating from domestic harvest were calculated. Then, in a second step (cf. Chapter 2.8.1.2, IPCC et al. (2014a)), the carbon contained in those products was allocated, using the procedure described in Chapter 6.10.2.1, to the forest activities listed in the Kyoto Protocol under Article 3, paragraphs 3 and 4. For Germany, the wood harvest can be fully assigned to the two activities *forest management* and *deforestation*. In keeping with the provisions of the IPCC 2013 KP Supplement (IPCC et al., 2014a), harvested wood products from deforestation are taken into account on the basis of instantaneous oxidation. As a result, the annual wood-harvest fractions from the activity forest management $f_{FM}(i)$ can be calculated from the inventory information available for Germany and from Equation 2.8.3 (IPCC et al., 2014a).

Germany has no wood that comes from deforestation areas but not from the actual deforestation events involved (cf. the CRF table). For this reason, "NO" was entered at this point in the CRF table. Wood from the activities afforestation and reforestation, on the other hand, is included in the forest management data, and thus is marked "IE" in the table. The biomass of short-rotation plantations in Germany is used exclusively for energy purposes (cf. category 1.A, Chapter 3.2), and thus that biomass is not reported under "harvested wood products" (HWP).

Further information, and details on the emission factors used and on the calculation carried out for Germany, in keeping with the provisions of the IPCC 2013 KP Supplement (IPCC et al., 2014a), are provided in Chapters 6.10.2.2 and 6.10.2.3. In keeping with these provisions, wood used for energy purposes, and wood in landfills, are taken into account on an immediate-emission basis (cf. Chapter 2.8.2, IPCC et al. (2014a)).

11.3.1.1.8 Other greenhouse-gas emissions

Information relative to calculations of other greenhouse-gas emissions is presented in the following chapters:

Forests:

- Nitrous oxide emissions from nitrogen fertilisers (CRF Table 4(KP-II)1); cf. Chapter 6.4.2.7.1
- Drainage and rewetting of organic and mineral soils (CRF Table 4(KP-II)2); cf. Chapter 6.4.2.7.2
- Direct nitrous oxide emissions from nitrogen mineralization and immobilization (CRF Table 4(KP-II)3); cf. Chapter 6.4.2.7.3
- Indirect nitrous oxide emissions from cultivated soils (CRF Table 4(KP-II)3); cf. Chapter 6.4.2.7.4
- Forest fires (CRF Table 4(KP-II)4); cf. Chapter 6.4.2.7.5

Cropland management and grazing land management:

- Drainage and rewetting of organic and mineral soils (CRF Table 4(KP-II)2); cf. Chapters 6.1.2.6, 6.5.2.4, 6.6.2.4
- Direct nitrous oxide emissions from nitrogen mineralization and immobilization (CRF Table 4(KP-II)3); cf. Chapter 6.1.2.7

- Indirect nitrous oxide emissions from cultivated soils (CRF Table 4(KP-II)3); cf. Chapter 6.1.2.8

For purposes of Kyoto reporting, the direct and indirect nitrous oxide emissions are combined, and the pertinent joint emission factor is reported in CRF Table 4(KP-II)3. N_2O emissions from organic soils under cropland management and grazing land management are reported in the agricultural sector, in the sub-category cultivation of histosols.

11.3.1.2 Justification when omitting any carbon pool or of greenhouse-gas emissions / removals from activities under Article 3.3 and elected activities under Article 3.4

No fertilization of forest areas, with mineral fertilizers, takes place in Germany. For this reason, the CRF Table 4(KP-II)1 spaces labelled as "Direct N_2O emissions from N fertilization" have been marked "NO" (not occurring).

Dead wood and litter do not occur in connection with cropland management and grassland management (NO; not occurring).

Emissions from mineral soils in the "remaining as" categories are not taken into account, because such soils are not a net source for greenhouse gases. Proof of this is provided in Chapter 6.5.2.3.2.

11.3.1.3 Information on whether or not indirect and natural greenhouse gases and removals have been factored out

No indirect or natural greenhouse-gas emissions or sinks were taken into account.

11.3.1.4 Changes in data and methods since the previous submission (recalculations)

This year's submission includes recalculations for forest management in reported years 2015 and 2016, to take account of available updated export data, in the FAO database (cf. Table 497), for harvested wood products. No pool-specific or sub-category-specific recalculations have been carried out for the other categories, afforestation, deforestation, cropland management and grassland management.

Table 497: Comparison of the changes in forest-management emissions, with regard to the relevant figures reported in the 2018 and 2019 submissions

Emissions [kt CO_2-eq]		2015	2016
KP 3.4 Forest management	2018 Submission	<-54,648.830	-55,023.952
	2019 Submission	-54,648.743	-54,454.256

11.3.1.5 Estimation of uncertainties

The uncertainties for activities pursuant to Article 3.3 Afforestation/Deforestation and 3.4 Forest Management, Cropland Management and Grazing Land Management of the Kyoto Protocol (KP) were determined in keeping with the provisions of the 2006 IPCC Guidelines (IPCC, 2006). The uncertainty statistics given for a normal distribution include the 95 % confidence interval, ± half of the 95 % confidence interval and 1.96 x the standard error, in % of the mean. For asymmetric distributions – in the present context, usually consisting of data sets with a logarithmic normal distribution – the relevant deviations are described as upper and lower bounds, expressed as % values of the pertinent position scale. The propagation of uncertainties was calculated via a conservative approach in which the distance between the extreme value of the sloping axis section and the position scale is defined as half of the 95 % confidence interval.

Table 498 shows the results of uncertainties calculation for all categories and sub-categories of the KP 3.3/3.4 inventory (except for harvested wood products, cf. Chapter 11.3.1.5.3). The total uncertainty is ± 24.58 %.

Further information relative to uncertainties is provided as follows: for estimation of land-use-change areas, in Chapter 11.3.1.5.3; for above-ground and below-ground biomass and dead wood, in Chapter 11.3.1.5.1; for litter and mineral soils, in Chapter 11.3.1.5.2; and summarised for the LULUCF sector overall, in Chapter 6.1.2.10.

Table 498: Uncertainties for greenhouse-gas reporting for Kyoto Protocol activities in Articles 3.3 and 3.4

Category	Sub-category / Pool	Gas	Base year emissions [CO_2-eq.] kt a^{-1}	Year 2017 emissions [CO_2-eq.] kt a^{-1}	Combined uncertainty, maximum value %	Contribution to Variance by Category in Year 2017 %
KP 3.3 Afforestation/Reforestation	Mineral soils	CO_2	57.14	362.36	34.93	0.01
KP 3.3 Afforestation/Reforestation	Organic soils	CO_2	15.36	402.88	86.57	0.10
KP 3.3 Afforestation/Reforestation	Organic soils	CH_4	0.22	5.68	879.53	0.00
KP 3.3 Afforestation/Reforestation	Organic soils	N_2O	1.22	31.94	176.46	0.00
KP 3.3 Afforestation/Reforestation	Above-ground biomass	CO_2	323.67	-5,925.15	43.05	5.26
KP 3.3 Afforestation/Reforestation	Below-ground biomass	CO_2	226.81	-1,090.67	43.51	0.18
KP 3.3 Afforestation/Reforestation	Litter	CO_2	-48.10	-961.92	6.18	0.00
KP 3.3 Afforestation/Reforestation	Deadwood	CO_2	-3.48	-70.88	48.98	0.00
KP 3.3 Afforestation/Reforestation	SOM	N_2O	9.32	86.23	168.25	0.02
KP 3.3 Deforestation	Mineral soils	CO_2	-19.77	-97.24	39.86	0.00
KP 3.3 Deforestation	Organic soils	CO_2	15.82	462.35	41.95	0.03
KP 3.3 Deforestation	Organic soils	CH_4	0.34	9.63	385.37	0.00
KP 3.3 Deforestation	Organic soils	N_2O	0.37	16.27	168.57	0.00
KP 3.3 Deforestation	Above-ground biomass	CO_2	758.38	1,037.87	32.01	0.09
KP 3.3 Deforestation	Below-ground biomass	CO_2	52.73	120.63	90.99	0.01
KP 3.3 Deforestation	Litter	CO_2	873.56	534.34	8.79	0.00
KP 3.3 Deforestation	Dead wood	CO_2	86.64	56.85	57.35	0.00
KP 3.3 Deforestation	SOM	N_2O	0.00	8.38	177.39	0.00
KP 3.4 Forest Management	Mineral soils	CO_2	-16,206.97	-15,803.11	52.60	55.89
KP 3.4 Forest Management	Organic soils	CO_2	927.89	818.14	24.66	0.03
KP 3.4 Forest Management	Organic soils	CH_4	13.09	11.57	1,011.57	0.01
KP 3.4 Forest Management	Organic soils	N_2O	73.55	64.85	200.69	0.01
KP 3.4 Forest Management	Above-ground biomass	CO_2	-52,340.82	-35,075.62	63.03	395.36
KP 3.4 Forest Management	Below-ground biomass	CO_2	-4,981.66	-5,184.86	49.74	5.38
KP 3.4 Forest Management	Litter	CO_2	499.63	486.36	294.00	1.65
KP 3.4 Forest Management	Dead wood	CO_2	-1,471.56	2,020.72	106.88	3.77
KP 3.4 Forest Management	Forest fires	CH_4	13.09	11.54	38.08	0.00
KP 3.4 Forest Management	Forest fires	N_2O	73.55	64.85	38.08	0.00
KP 3.4 Forest Management	SOM	N_2O	0.00	0.00	0.00	0.00
KP 3.4 to Cropland Management	Mineral soils	CO_2	2,676.32	2,825.44	49.25	1.57
KP 3.4 to Cropland Management	Organic soils	CO_2	3,035.28	3,490.22	45.66	2.05
KP 3.4 to Cropland Management	Organic soils	CH_4	66.43	76.39	233.40	0.03
KP 3.4 to Cropland Management	Above-ground biomass	CO_2	231.38	-166.31	38.67	0.00
KP 3.4 to Cropland Management	Below-ground biomass	CO_2	316.66	262.79	33.72	0.01

Category	Sub-category / Pool	Gas	Base year emissions [CO_2-eq.] kt a[-1]	Year 2017 emissions [CO_2-eq.] kt a[-1]	Combined uncertainty, maximum value %	Contribution to Variance by Category in Year 2017 %
KP 3.4 Cropland Management	Mineral soils	CO_2	0.00	0.00	50.52	0.00
KP 3.4 Cropland Management	Organic soils	CO_2	5,909.20	7,783.80	45.66	10.22
KP 3.4 Cropland Management	Organic soils	CH_4	129.33	170.35	233.93	0.13
KP 3.4 Cropland Management	Above-ground biomass	CO_2	-15.53	2.24	11.43	0.00
KP 3.4 Cropland Management	Below-ground biomass	CO_2	-13.33	1.89	23.61	0.00
KP 3.4 total Cropland Management	SOM	N_2O	332.91	350.22	181.63	0.33
KP 3.4 to Grazing Land Management	Mineral soils	CO_2	-2,375.99	-1,560.01	42.28	0.35
KP 3.4 to Grazing Land Management	Organic soils	CO_2	2,237.67	876.23	46.91	0.14
KP 3.4 to Grazing Land Management	Organic soils	CH_4	47.42	18.57	219.04	0.00
KP 3.4 to Grazing Land Management	Above-ground biomass	CO_2	389.86	185.73	34.87	0.00
KP 3.4 to Grazing Land Management	Below-ground biomass	CO_2	-116.51	-80.85	27.65	0.00
KP 3.4 Grazing Land Management	Mineral soils	CO_2	0.00	0.00	77.89	0.00
KP 3.4 Grazing Land Management	Organic soils	CO_2	25,058.33	22,046.65	55.36	120.49
KP 3.4 Grazing Land Management	Organic soils	CH_4	531.03	467.20	258.59	1.18
KP 3.4 Grazing Land Management	Above-ground biomass	CO_2	0.00	0.00	36.24	0.00
KP 3.4 Grazing Land Management	Below-ground biomass	CO_2	0.00	0.00	50.86	0.00
KP 3.4 total Grazing Land Management	SOM	N_2O	0.00	0.00	0.00	0.00
Uncertainty total ARD / FM / CM / GM [%]:					**24.58**	

11.3.1.5.1 Estimation of uncertainties in emission factors for biomass and dead wood

Table 499 shows the uncertainties that result for the calculation of carbon-stock changes in living biomass, as carried out in keeping with the information provided in Chapter 6.4.3.2. The following should be noted in this regard:

- It was not possible to derive emission factors for KP Afforestation/Reforestation and KP Deforestation for the new German Länder for the period 1993 – 2002, since the Datenspeicher Wald forest database does not contain the data necessary for such derivation. Consequently, the emission factors for the old German Länder have been used for that period.
- In the 2008 Inventory Study, no afforestation areas were surveyed, and those survey data for deforested points lack reliability. For this reason, the emission factors and uncertainties errors for the period 2002 through 2012 have been derived from the data of the BWI 2002 and BWI 2012.

Table 499: Total error for estimation of C-stock changes in biomass for the inventory periods of the National Forest Inventory, 1987–2002, 2002–2008 and 2008–2012 (RMSE% – root mean square error percent)

RMSE%	1987-2002 Old German Länder	1993-2002 New German Länder	2002-2008 Germany as a whole	2008-2012 Germany as a whole
Afforestation (KP 3.3)	13.08	-	11.53	11.53
Deforestation (KP 3.3)	12.73	-	10.95	10.95
Forest Management (KP 3.4)	6.95	10.05	28.75	12.60

Table 500 shows the uncertainties that result, on the basis of the information provided in Chapter 6.4.3.2, for the calculation of C-stock changes in dead wood. The following should be noted in this regard:

- For deforestation, the uncertainty for the period 1987–2002 is derived from the mean uncertainties for the period 2002–2012.
- For areas under forest management, the applicable uncertainty for dead wood for the period 1987–2002 is calculated from the mean uncertainties for the period 2002–2012.

Table 500: Total error for estimation of C-stock changes in dead wood for the inventory periods of the National Forest Inventory, 1987–2002, 2002–2008 and 2008–2012 (RMSE% - root mean square error percent)

RMSE%	1987-2002	2002-2008	2008-2012
Afforestation (KP 3.3)	24.84	24.84	24.84
Deforestation (KP 3.3)	28.96	24.88	24.02
Forest Management (KP 3.4)	46.67	27.11	54.52

The total-error calculation for purposes of reporting under the Kyoto Protocol is presented in Table 498 in Chapter 11.3.1.5.

11.3.1.5.2 Estimation of uncertainties in emission factors for mineral soils and litter

Table 501 shows the uncertainties that result for the emission factors for mineral soils and litter, as determined in keeping with the information provided in Chapter 6.4.3.3.

Table 501: Error budget for the emission factors for mineral soils and litter; se = standard deviation of the mean value; C 90, C 06 = laboratory error in carbon-stocks determination, BZE I and BZE II; FE = error in determination of the fine-earth fraction

LULUCF category	Sub-category / Pool	Emission factor					
		se [%]	C 90 [%]	C 06 [%]	FE [%]	error total [%]	Uncertainty [%]
KP Forest Management	Litter	105.9	111.2	73.4		168.9	337.8
KP Forest Management	Mineral soil	9.0	14.1	13.6	12.2	26.7	53.4

11.3.1.5.3 Estimation of uncertainties for harvested wood products

Pursuant to information in the IPCC 2013 KP Supplement (IPCC et al., 2014a) Guidelines, the uncertainties for the activity data for harvested wood products amount to -25/+5%. For the emission factors, the standard values listed in Table 2.8.2 of the IPCC 2013 KP Supplement (IPCC et al., 2014a) Guidelines are used. Those values include no uncertainties. Due to the lack of uncertainties, no error calculation can be carried out for harvested wood products.

11.3.1.6 Information on other methodological issues

In this chapter, the individual-pools results in the present submission are compared with those of other countries. As described in Chapter 6.4.4.3, any comparison of Germany with other countries can only serve the purpose of general categorization. A range of different methods and approaches have been used, especially in connection with the definition of Forest Land and with selection of activities under Article 3.4. All countries that can be usefully compared to Germany report forest management as a mandatory category pursuant to Article 3.4. To date, only Germany, Denmark and the UK have committed to reporting in the reporting-optional categories Cropland Management and Grazing Land Management. As a result, no comparison with other countries has been carried out for these two activities.

The comparison data for the carbon-stock changes of other countries are obtained from the national inventory reports of countries neighbouring Germany and the UK. The emission factor data have been obtained from the 2016 Submission to the UN Climate Secretariat, and they are in keeping with the 2014 inventory year. The comparisons, which are broken down by pools, are found in the following tables: for biomass, in Table 502; for dead wood and litter, in Table 503; for mineral and organic soils, in Table 504.

Table 502: Carbon-stock changes in living biomass (for 2016)

Country	Afforestation		Deforestation		Forest management	
[t C ha^{-1}]	Above-ground	Below-ground	Above-ground	Below-ground	Above-ground	Below-ground
Belgium	1.51	0.28	-5.13	-1.16	0.50	0.09
Denmark	-0.31	0.03	-2.17	-0.35	-0.06	0.17
France	1.15	0.47	-1.41	-0.38	0.45	0.17
UK	1.73	IE	-2.75	IE, NO	1.07	IE
Netherlands	2.98	0.37	-3.10	-0.45	0.87	0.16
Austria	0.97	0.26	-0.66	-0.16	0.26	0.03
Poland	0.80	0.21	-23.67	-4.73	0.77	0.21
Switzerland	1.04	0.41	-2.13	-0.65	0.43	0.05
Czech Republic	1.91	0.38	-2.42	-0.48	0.35	0.07
Germany	2.87	0.53	-0.96	-0.11	0.90	0.13

Source: (UNFCCC, 2018a)

Table 503: Carbon-stock changes in dead wood and litter (for 2016)

Country	Afforestation		Deforestation		Forest management	
[t C ha^{-1}]	Dead wood	Litter	Dead wood	Litter	Dead wood	Litter
Belgium	NO	NO	-0.12	-0.47	NO	NO
Denmark	-0.01	0.25	-0.15	-1.71	-0.09	-0.38
France	0.03	0.14	-0.05	-0.15	-0.03	0.00
UK	IE	0.20	IE, NO	-0.10	IE	0.46
Netherlands	0.14	NE	-0.10	-1.54	0.22	NO
Austria	0.02	0.082	0.00	-0.51	0.06	IE, NE
Poland	NO	NO	-0.03	0.00	NO	NO
Switzerland	0.02	-0.02	-1.56	-6.90	0.04	-0.03
Czech Republic	0.02	0.48	-0.07	-0.33	NO	IE
Germany	0.03	0.47	-0.05	-0.5	-0.05	-0.01

Source: (UNFCCC, 2018a)

Table 504: Carbon-stock changes in mineral and organic soils (for 2016)

Country	Afforestation		Deforestation		Forest management	
[t C ha^{-1}]	Mineral soil	Organic soil	Mineral soil	Organic soil	Mineral soil	Organic soil
Belgium	1.13	NO	-1.81	NO	0.53	NO
Denmark	0.08	-1.30	-0.09	-5.00	NO	-1.30
France	0.10	IE	-0.61	IE	NA	IE
UK	-0.71	-1.03	-2.14	IE, NO	0.42	1.02
Netherlands	-0.04	-0.16	0.02	-2.22	NO	NO
Austria	0.47	NO	-0.46	NO	-0.18	NO
Poland	0.05	-0.68	-19.19	NO	0.11	-0.68
Switzerland	1.66	0.00	-0.69	-4.83	0.00	-0.08
Czech Republic	0.10	NO	-0.04	NO	NE	NO
Germany	-0.22	-2.24	0.11	-5.86	**0.41**	-2.24

Source: (UNFCCC, 2018a)

11.3.1.7 The year of the onset of an activity, if after 2013

Table 505 shows the area sizes for KP 3.3 activities that began after 2013. The activity Forest Management (KP.3.4) is included only for those areas that have been forest since 1990. As the table indicates, there are no areas on which forest management began after 2013.

Table 505: Relevant area sizes for activities that began after 2013.

KP 3.3 Activity	Year of onset			
	2014	2015	2016	2017
Afforestation/Reforestation [ha]	14,071	14,071	14,071	14,071
Deforestation [ha]	7,809	7,809	7,809	7,809

11.4 Article 3.3

11.4.1 Information that demonstrates that activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2020 and are directly human-induced

As described in Chapter 6.3, the procedure for determining land-use changes from and to Forest Land identifies area changes as of 1970, while the methods used for purposes of reporting under the Kyoto Protocol take account only of changes since 1990. As of the 2014 Submission, submissions take account of the results of the third National Forest Inventory, for which the reference year is 2012. Those results provide the database for the initial year of the second commitment period. All included activities in this context fall within the period 1 January 1990 to 31 December 2020.

While each land-use change from and to Forest Land is recorded primarily via the National Forest Inventory (Bundeswaldinventur; BWI), such changes are also recorded in additional data sets. The relevant sampling points form a grid that covers all of Germany. Via repeated surveying of the sample points, all changes can be mapped on a large scale. If a point is mapped as forest that was mapped as non-forest in the previous inventory, it represents a specific area of afforestation. The BWI differentiates between afforestation via planting / sowing and afforestation via natural rejuvenation. However, an area afforested via natural rejuvenation is classified as *afforested* only when the relevant stand has an average age of five years and crown cover of at least 50 % (cf. Chapter 6.2.1).

Agricultural land can change from (managed) cropland to unmanaged land and, via spontaneous establishment of trees (natural rejuvenation), into Forest Land. Pursuant to the IPCC 2013 KP Supplements (IPCC et al., 2014a), this type of afforestation may be accounted only if it is "directly human-induced". "It is good practice to provide documentation that all afforestation and reforestation activities included (…) are directly human-induced. Relevant documentation includes forest management records or other documentation that demonstrates that a decision had been taken to replant or to allow forest regeneration by other means."[189] German law requires a "permit from the competent authority under the law of the Länder" (Art. 10 (1) Federal Forest Act (BWaldG)) for each afforestation. Pursuant to Para. 2, no permit is required only in those cases in which, for the area to be afforested, "afforestation has been mandated in a legally binding way, on the basis of other public legal provisions, or the requirements of regional planning and Land (state) planning are not affected". Germany is a densely populated, intensively managed country in which all areas nation-wide are subject to land-use plans. In addition, Germany has different planning levels, ranging from large-scale planning (e.g. regional planning) to specific small-scale planning (e.g. landscape plans, operational plans for forest management). Preparation of, and compliance with, plans is monitored by the relevant competent authorities in each case, including authorities of the Federal Government, of the Länder and of individual municipalities. Thus it may be assumed that all afforested areas fulfill the "directly human-induced" requirement, since the act of permission, as well as the act of mandating in a legally binding manner and the preparation and establishment of regional and landscape plans all presuppose active decisions by humans.

11.4.2 Information about a Scheme for differentiation between a) harvest or forest disturbance that is followed by reforestation, and b) deforestation

Pursuant to Art. 11 (1) Federal Forests Act (BWaldG), "forests (…) (should) be properly and sustainably managed, in the framework of their defined purposes. Länder laws are to be enacted that set forth obligations for all forest owners whereby clear-cut or degraded forest areas

5. are to be reforested, or
6. replenished, in cases in which natural regrowth remains incomplete,

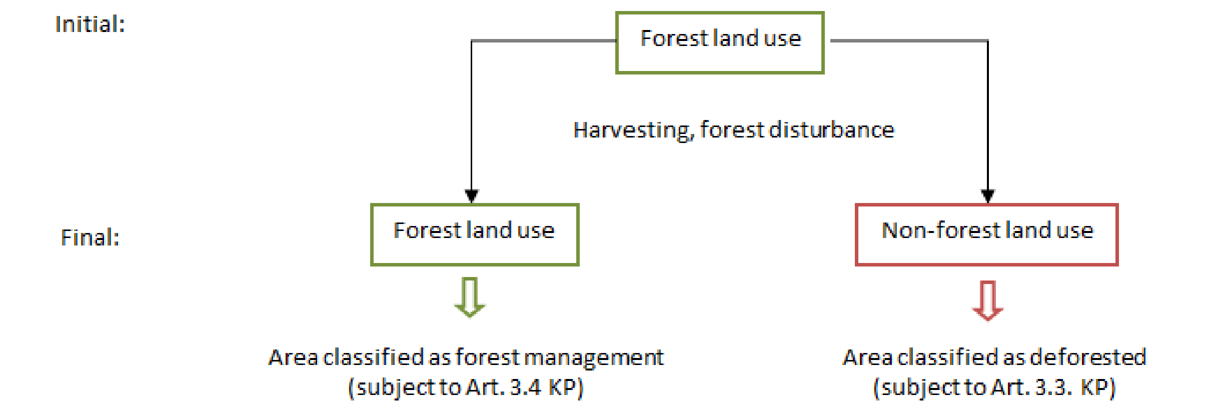
within a reasonable period of time, unless conversion to another type of use has been approved or is otherwise permitted."

In general, reforestation is called for on all forest areas that are to remain in use as Forest Land. That is a legal requirement, and it is the customary practice in the German forestry sector. Forest land that is temporarily unstocked thus continues to fall within the scope of required reporting on forest management pursuant to Art. 3.4 KP. The situation is different in cases in which Forest Land becomes unstocked and planning calls for subsequent use of the land to fall within the category "non-Forest Land". Such land is to be considered deforested land, with the relevant deforestation

[189] Vgl. IPCC 2014, Section 2.5.2

directly human-induced, regardless of whether the deforestation was caused by harvesting or by natural disturbances.

Figure 84: Scheme for differentiation between a) harvest or forest disturbance that is followed by reforestation, and b) deforestation



11.4.3 Information about the size and geographic location of forest areas that have lost forest cover but which are not yet classified as deforested

Forest management routinely generates small unstocked areas (bare areas) in forests. Pursuant to the data of the BWI 2012, such areas total about 41,742 ha and account for 0.36 % of the total forest area. As explained above in Chapter 11.4.2, such areas continue to fall within the national forest definition and continue to figure in calculations relative to carbon stocks and their changes.

11.4.4 Information about natural disturbances under Article 3.3

As explained in Chapter 11.1.2, Germany has not selected the natural disturbances option. Natural disturbances that occur are not considered separately; instead, they enter into the change calculations for the relevant pools.

11.4.5 Information about harvested wood products under Article 3.3

As described in detail in Chapter 6.10, the emissions contribution made by harvested wood products in Germany, in terms of sources and removals into sinks for greenhouse gases, was determined with the WoodCarbonMonitor model, in keeping with the specifications of the IPCC KP Supplement (IPCC et al., 2014a).

For Germany, the wood harvest can be fully assigned to the two activities forest management and deforestation. Wood products from deforestation (Article 3.3) are accounted for, pursuant to the provisions of the IPCC KP Supplements (IPCC et al., 2014a), on the basis of instantaneous oxidation.

11.5 Article 3.4

11.5.1 Information that demonstrates that activities under Article 3.4 have occurred since 1 January 1990 and are human-induced

11.5.1.1 Forest management

Since an integrated procedure is used for surveying Forest Lands, land-use changes and the carbon-stock changes caused by relevant activities, the statements made in Chapter 11.4.1 apply mutatis mutandis for the activity "forest management".

Pursuant to Art. 1 No. 1 Federal Forest Act (BWaldG), "forests are to be preserved, to be enlarged as necessary and to be properly and sustainably managed, in light of their economic value (utility function) and of their importance with regard to the environment, especially the long-term vitality of natural systems and cycles, and with regard to climate, water cycles, air quality, soil fertility, landscape beauty, agrarian structures and infrastructure and the population's needs for rest and recreation (protection and recreation functions)".

Forests are thus assigned three key basic functions, namely utility, conservation and recreation functions, in light of which they are to be preserved and properly and sustainably managed. In addition, Art. 11 (1) p. 1 BWaldG sets forth that "forests (…) (should) be properly and sustainably managed, in the framework of their defined purposes." While that formulation does not mean that forests "must" be managed, and thus it does not establish a general obligation, it is important to note that it does not use "may" phrasing, which would rule out any obligation. The wording chosen thus clearly reveals a basic orientation – namely, that forests should be managed. An obligation to manage forest lands thus applies to all of Germany.[190]

In the interest of protecting forests' three basic functions, forests, pursuant to Art. 1 No. 1 in conjunction with Art. 11 (1) p.1 BWaldG, should be protected and properly and sustainably managed. The aim of proper forest management as set forth by the Marrakesh Accords (MA) thus agrees with the requirements set forth by the Federal Forest Act (BWaldG). In both cases, management is oriented to the aim of ensuring that the forest can continue to fulfill its functions in perpetuity.

The Marrakesh Accords define forest management as "a system of practices". That indicates that management involves actions / measures. A forest area that is left untouched, and for which no measures are taken, is thus not a managed forest area. For a forest area to qualify as "unmanaged", however, no human activities may take place in it, i.e. no active human interventions may be permitted in it (equivalent to MCPFE conservation category 1.1). Forest areas meeting those criteria are "practically non-existent" in Germany (BMELV, 2009). In 2007, forest conservation areas in which permitted human interventions are restricted to a minimum, i.e. fully protected areas (MCPFE conservation category 1.2), accounted for 1.1% of Germany's total forest area, and were tending to be enlarged (BMELV, 2009). The primary focus with regard to such forest areas is on biotope and species conservation (for example, protected forests, natural forest reserves, core zones of national parks and biosphere reserves). Certain types of interventions are expressly permitted, however (for example, measures to control wildfires, hoofed game, diseases or insect calamities[191]). For protected forests, as for all protected areas, concepts are to be prepared that set forth / define / describe the object/focus of protection, the protection purpose, the necessary requirements and prohibitions for achieving the protection purpose and the necessary relevant care, management, development and restoration measures[192] (for example, in ordinances or guidelines on protected areas; cf. for example, Art. 23 (2) State Forest Act (LWaldG) of Mecklenburg – West Pomerania). In addition, some 23% of Germany's forest area consists of protected areas whose conservation purpose is actively assured via management measures (MCPFE conservation category 1.3); 56 % consist of forests whose primary purpose is to conserve landscapes and specific natural elements (MCPFE conservation category 2); and 34 % have the primary purpose of providing protective functions (MCPFE conservation category 3). In MCPFE

[190] Häusler and Scherer-Lorenzen (2002) speak of an obligation, for all forest owners, "to carry out sustainable, proper management"; the citation appears in: Nachhaltige Forstwirtschaft in Deutschland im Spiegel des ganzheitlichen Ansatzes der Biodiversitätskonvention. BfN – Skripten 62, p. 5 and 15.

[191] In addition, environmentally compatible measures to develop forests for recreational purposes and for nature-compatible research are permitted.

[192] Cf. for example, Art. 22 (1) Federal Nature Conservation Act (BnatSchG).

conservation categories 1.3 through 3, management is to be aligned with the relevant conservation purpose. Such categories thus fulfill the criteria for forest management. Human activities for protecting conservation areas are also certainly allowed in MCPFE category 1.2. Pursuant to the 2006 IPCC Guidelines (IPCC, 2006), such areas thus fulfill forest-management criteria in accordance with Art. 3.4 KP: "For example forested national parks (…) where these parks are managed to fulfil relevant ecological (including biodiversity) and social functions, and are subject to forest management activities such as fire suppression, a country may choose to include these forested national parks as lands subject to forest management."[193] It should be noted that the aforementioned area shares in the different forest-conservation categories cannot simply be summed, since they overlap to some extent; in some cases, the same forest area will have been repeatedly included (BMELV, 2009).

Much of Germany's forest land is subject to planning. According to estimates of the BMEL, forest-management plans (economic plans, operational plans or reports) are in place for about ¾ of the country's forested area (BMELV, 2009). In addition to such operational plans, in many cases forest landscape plans (forest framework plans) are also prepared for forests, in the framework of landscape planning[194]. The aim of forest framework planning is to "safeguard the forest functions necessary for the development of ecological and economic conditions pursuant to Art. 1 No. 1 (BWaldG)". That accords precisely with the aim prescribed by the IPCC Good Practice Guidance (IPCC, 2003) with respect to forest management. To that end, measures may be, or must be, prescribed (cf. for example, Art. 6 (3) No. 4 p. 2 BWaldG old version; Art. 6 (1) No. 2 Bavarian Forest Act (BayWaldG); Art. 9 (4) State Forest Act (LWaldG) of Mecklenburg – West Pomerania; Art. 6 p. 2 Forest and Landscape Act of the State of Lower Saxony (NWaldLG); Art. 7 (1) State Forest Act for the State of North Rhine – Westphalia (LFoG NRW); Art. 6 (2) Forest Act of the State of Saxony-Anhalt (WaldG Sachsen-Anhalt)[195]). In some cases, requirements explicitly call for such planning to serve as a guideline for management, inter alia (cf. Art. 8 (3) LFoG NRW).

All in all, it must thus be considered confirmed that all forests in Germany are managed in accordance with forest-management criteria as set forth by the Marrakesh Accords and by the IPCC 3013 KP Supplements (IPCC et al., 2014a).

A compilation of excerpts from state forest acts, relative to requirements for forest management and for forest framework planning, is provided by Steuk (2010). A pertinent summary is presented in Table 506.

[193] IPCC KP Supplements (2014) Chapter 2.7.2 and IPCC 2006 Guidelines, Chapter 2, Volume 4

[194] Until 2005, the Federal Forest Act (BWaldG) required the preparation of forest framework plans. Because the Länder differ widely in their planning structures, those provisions were eliminated, however. Cf. BMELV (2009) Waldbericht der Bundesregierung (Forest Report of the Federal Government), p. 28.

[195] For definition of measures in operational plans, cf. Art. 5 (6) p. 3 State Forest Act (LWaldG) of Schleswig-Holstein.

Table 506: Overview of obligations relative to forest management, preparation of plans and use of forest framework plans, as set forth by the forest acts of the Länder

State (Land)	Forest-management obligations			Obligations to prepare plans (economic plans, operational plans, operational reports or other specialised forest-management plans)			Obligations to prepare forest framework plans
	State forest	Municipal forest	Private forest	State forest	Municipal forest	Private forest	
Baden-Württemberg	X	X	X	X	X	(X)	(X)
Bavaria	X	X	X	X	[X]		(X)
Berlin	X	X	X				X
Brandenburg							X
Bremen	X	X	X				
Hamburg	X	X	X				X
Hesse	X	X	X	X	X	[X]	
Mecklenburg – West Pomerania	X	X	X				X
Lower Saxony	X	X	X	[X]	[X]		X
North Rhine – Westphalia	X	X	X		X		X
Rhineland-Palatinate	X	X	X	[X]	[X]	[X]	X
Saarland	X	X	X	X	X	(X)	X
Saxony	X	X	X	X	X		(X)
Saxony-Anhalt	X	X	X	X	X		X
Schleswig-Holstein				[X]	[X]		
Thuringia	X	X	X	X	X	[X]	X

Legend:

X Binding requirement (includes "should" requirements)

[X] Requirement is binding only under certain conditions (for example, conditions pertaining to minimum size)

(X) Optional guideline / not binding (a "can" requirement)

11.5.2 Information relative to cropland management and grazing land management for the base year

All areas under cropland management and grazing land management are subject to periodic cultivation measures (carried out once or several times per year), and thus the pertinent emissions and removals are anthropogenic.

11.5.2.1 Cropland management

The emissions from cropland management in 1990 are dominated by CO_2 from organic soils. Carbon losses from mineral soils, as a result of conversions to Cropland, are also significant (Table 507). The emission pattern is very similar to that seen in 2017 (Table 491).

Table 507: Carbon-stock and greenhouse-gas emissions as a result of cropland management, in the base year 1990

Sub-categories	C-stock changes in biomass, 1990[196] [kt C]	C-stock changes in mineral soils, 1990[93] [kt C]	CO_2 from organic soils, 1990[93] [kt C]	CH_4 from organic soils, 1990[197] [kt CH_4]	Direct and indirect N_2O from decomposition of organic material in mineral soils, 1990[94] [kt N_2O]	Total, 1990[94/198] [kt CO_2-eq.]
Cropland remaining Cropland	7.87	NO	-1,611.60	5.17	NO	6,009.66
Total for LUC to Cropland	**-149.47**	**-729.91**	**-827.80**	**2.66**	**1.12**	**6,658.98**
Total for LUC from Cropland	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Total	**-141.60**	**-729.91**	**-2,439.40**	**7.83**	**1.12**	**12,668.64**

Emissions and removals from land-use changes from cropland to other land-use categories are taken into account under Art. 3.3 (afforestation), Art. 3.4 (grazing land management) or, in keeping with the IPCC 2013 KP Supplements (IPCC et al., 2014a), Chapter 2.9.2, are accounted as zero. N_2O emissions from organic soils under cropland are reported in the agricultural sector, in the sub-category cultivation of histosols.

11.5.2.2 Grazing land management

The emissions from cropland management in 1990 are dominated by CO_2 from organic soils. The carbon sink in mineral soils, resulting from land-use changes to grassland, only slightly offsets the pertinent emissions (Table 508). The emission pattern is very similar to that seen in 2017 (Table 492).

Table 508: Carbon-stock and greenhouse-gas emissions as a result of grazing land management, in the base year 1990

Sub-categories	C-stock changes in biomass, 1990[199] [kt C]	C-stock changes in mineral soils, 1990[96] [kt C]	CO_2 from organic soils, 1990[96] [kt C]	CH_4 from organic soils, 1990[200] [kt CH_4]	Direct and indirect N_2O from decomposition of organic material in mineral soils, 1990[97] [kt N_2O]	Total, 1990[97/201] [kt CO_2-eq.]
Grassland (in the strict sense) remaining as Grassland (i.t.s.s.)	NO	NO	-6,834.09	21.24	NO	25,589.36
Total for LUC to Grassland (in the strict sense)	**-74.55**	**648.00**	**-610.27**	**1.90**	**NO**	**182.46**
Total for LUC from Grassland (in the strict sense)	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Total	**-74.55**	**648.00**	**-7,444.36**	**23.14**	**NO**	**25,771.82**

Emissions and removals from land-use changes from Grassland (in the strict sense) to other land-use categories are taken into account under Art. 3.3 (afforestation), Art. 3.4 (grazing land management) or, in keeping with the IPCC 2013 KP Supplements (IPCC et al., 2014a), Chapter 2.10.2, are accounted as zero. N_2O emissions from organic soils under Grassland (in the strict sense) are reported in the agricultural sector, in the sub-category cultivation of histosols.

[196] Stock change, positive: C sink; negative: C source
[197] GHG emissions, positive: GHG source; negative: GHG source
[198] Not including N_2O emissions from organic soils; they are reported as part of the agricultural sector
[199] Stock change, positive: C sink; negative: C source
[200] GHG emissions, positive: GHG source; negative: GHG source
[201] Not including N_2O emissions from organic soils; they are reported as part of the agricultural sector

11.5.3 Information relating to Forest Management

11.5.3.1 Definition of forest management

As explained above in Chapter 11.5.1, the law requires German forests to be managed properly and sustainably. National provisions on forest management are set forth in the Federal Forest Act (BWaldG). In addition, the Länder have their own Land (state) forest acts in place that further detail the provisions of the Federal Forest Act. A comparison of Germany's national provisions with the relevant international definition shows broad agreement.

International definition pursuant to the Marrakesh Accords[202]*:*

"'Forest management' is a system of practices for stewardship and use of forest land aimed at fulfilling relevant ecological (including biological diversity), economic and social functions of the forest in a sustainable manner."

Translation: "'Forest management' is a system of practices for stewardship and use of forest land aimed at fulfilling relevant ecological (including biological diversity), economic and social functions of the forest in a sustainable manner."

National definitions pursuant to state forest acts (Landeswaldgesetze - LWaldG):

Pursuant to Art. 1 No. 1 Federal Forest Act (BWaldG), the purpose of the Act is, in particular, "to conserve forest for the sake of its economic value (utility function) and for the sake of its (...) (conservation and recreation function), to increase it, if necessary, and to assure its proper management for the long term". Pursuant to Art. 11 (1) p. 1 BWaldG, forests are to be "managed properly and sustainably, in the framework of their defined purposes." In keeping with the Federal Government's restricted legislative competence in this regard, the Federal Government simply provides a framework that the Länder implement and detail with regard to specific applications (cf. Art. 5 and Art. 11 (1) p. 2 BWaldG). As a result, the Länder define what is to be understood by "proper and sustainable forest management". A compilation of relevant sections of Länder forest acts is provided by Steuk (2010).

The forest-management requirements pursuant to Länder forest acts are comparable to those set forth by international forest legislation. The requirement that forests are to be managed sustainably, with a view to fulfilling ecological (including biological diversity), economic and social functions[203], is found in all Länder forest acts. In Germany, ecological, economic and social functions are often referred to as "conservation, utility and recreation" functions[204] (cf. Table 509). Where the ecological, economic and social functions that are to be served by management are not referred to explicitly as such in Länder laws, the laws add the phrase "within the framework of its [their] defined purposes"[205]. Forests are thus to be managed sustainably, within the framework of their defined purposes. This orientation is found in Art. 1 BWaldG (purpose of the act), which appears verbatim in every Land forest act. In addition, Art. 1 No. 1 BWaldG sets forth that forests are to be protected especially "in light of their economic value (utility function) and their (...) (conservation and recreation functions)". The aim of protecting economic, ecological and social functions is thus found in all such laws. Furthermore, both the Federal Forest Act and the forest acts of the Länder warrant the sustainability of forest management.

[202] Paragraph 1 lit. f of Annex A of Decision 16/CMP.1

[203] Cf. Art. 4 No. 1 BayWaldG; Art. 1a LFoG NRW; a similar meaning also is seen in Art. 6 (1) LWaldG RLP; and a similar meaning is seen in Art. 18 (1) in conjunction with Art. 19 (1) p. 2 ThürWaldG.

[204] Cf. Art. 1 No. 1 BWaldG; Art.13 LWaldG BW; Art. 11 (2) No. 1 LWaldG B; Art. 4 (2) LWaldG Bbg; Art.5 (1) BremWaldG, Art. 6 (1) HeFoG; Art. 6 (1) No. 1 LWaldG MV; Art. 11 (1) NWaldLG; Art. 5 (1) LWaldG SH.

[205] Cf. Art. 6 (1) LWaldG Ha; Art. 11 (1) LWaldG SL; Art. 17 SächsWaldG; Art. 4 (1) WaldG LSA; Art. 18 (1) ThürWaldG.

Table 509: Comparison of forest functions pursuant to the Federal Forest Act and the IPCC

Forest functions pursuant to BWaldG	Forest functions pursuant to MA
Utility function	Economic functions
Conservation function	Ecological functions
Recreation function	Social functions

11.5.3.2 Conversion of Natural Forest to Planted Forest

Within the meaning of the Kyoto Protocol, the majority of German forests are defined as part of the Planted Forest (cf. Annex 4A.1, Chapter 4, Volume 4, IPCC (2006)). Within this meaning, this definition includes all managed forests, plantations and planted stocks. With its broadest sense of the definition, a management plan can be in place even when a protection concept is in place. Consequently, Germany has no forest areas for which no management concept is in place. Germany has no primary forest – or no such areas of relevance – within this sense (Krismann & Hennenberg, 2012).

For the aforementioned reasons, Germany has no conversion of Natural Forest to Planted Forest.

11.5.3.3 Forest Management Reference Levels (FMRL)

Pursuant to resolution 2/CMP.6 (Cancun Agreements), for the second commitment period of the Kyoto Protocol, anthropogenic greenhouse-gas emissions from sources and sinks that result from forest management under Article 3.4 are to be accounted against the Forest Management Reference Levels (FMRL). In each case, the FMRL contains a value that projects the average annual net emissions from forest management, in the second commitment period, from historic data and political decisions.

For Germany, an FMRL of -22,418 Mt CO_2-eq per year has been reported. The documents submitted in 2011 relative to the FMRL, and the pertinent review report, are provided on the UNFCCC website [206]. Those documents include a description of the methods used to obtain the FMRL.

11.5.3.4 Technical correction of the FMRL

The IPCC KP Supplements (IPCC et al., 2014a) require a technical correction of the FMRL if methodological changes result in calculation of the time series, if new or corrected historical data become available or if pools are included in current reporting that could not be taken into account in the original FMRL calculation.

With regard to carbon stocks in living biomass, the previous FMRL, which was reported to the UNFCCC Secretariat and the EU in 2011, is based on data of the 2008 Inventory Study and, for the projection, on the forest management scenario of the WEHAM forest development and wood-production model. For the pools dead biomass (litter, dead wood) and soils, and for emissions from fertilisation, drainage and combustion of biomass (forest fires), country-specific emission factors either were not available or were not recorded. Carbon in harvested wood products (HWP) was not accounted for in a manner consistent with decision 2/CMP.7 and the KP Supplement adopted following the submission of the FMRL. The reference level used to date does not contain all categories and other emissions that are reported relative to KP 3.4, pursuant to the current rules for GHG reporting, and thus are part of the pertinent accounting (cf. Table 510). Additional recommendations relative to corrections are provided in the "Report of the technical assessment of the FMRL submission of Germany submitted in 2011" (FCCC/TAR/2011/DEU). For this reason, Germany has carried out a technical correction of the FMRL.

[206] UNFCCC AWG-KP: Forest management reference levels http://unfccc.int/bodies/awg-kp/items/5896.php

Table 510: Improvements and changes in the greenhouse-gas inventory, since 2011, that necessitate a technical correction of the Forest Management Reference Level

Storage/GHG source	Relevant change	Need for a technical correction
Living biomass in forest	BWI 2012	New run of the WEHAM model, and adaptation to GHG-inventory methods and factors, as a result of new calculation of HWP
	New parameters for growth function	
	New biomass functions	
Soil / litter	Forest soil survey (Bodenzustandserhebung (BZE) Wald) (country-specific emission factors)	Adjustment to GHG-inventory methods and factors
	In future: Use of a soil-carbon model, in combination with BZE data	
Dead wood	BWI 2012 (complete survey; adjusted survey threshold)	
HWP	BWI 2012 (projection of wood harvest)	New run of the WEHAM model
	No wood from deforestation	Methodological specifications from the IPCC KP Supplement not available until 2014
	New available and conversion factors	
Other	minor changes	Minor adjustments possible

For the technical correction, the FMRL for the reported pools and sources was calculated with the methods given in Table 511. In the process, a distinction was made between activity data (AD) and emission factors (EF). The resulting emissions projections for the period 2013 through 2020 are summarised in Table 512. Additional details relative to the data and methods used, with regard to pools and sources, are provided in the following sub-chapters.

Table 511: Methods for the technical correction of the FMRL by pools and sources

Pool / source	Area (AD) / Emission factor (EF)	GHG	Method, FMRL – technical correction (2013-2020)
Mineral soil	AD	C	Change from 2012 carried forward
Organic soil	AD	C / CH_4 / N_2O	Change from 2012 carried forward
Mineral soil	EF	C	Modelling with Yasso
Organic soil	EF	C	Trend 1990-2012
Organic soil	EF	CH_4	Trend 1990-2012
Organic soil	EF	N_2O	Trend 1990-2012
Above-ground biomass	EF	C	Modelling with WEHAM 2012; run 23
Below-ground biomass	EF	C	Modelling with WEHAM 2012; run 23
Litter	EF	C	in Yasso results, including
Dead wood	EF	C	Average value, 1990-2012
Forest fires / wildfires	AD	CO_2 / CH_4 / N_2O	Average value, 1990-2012
Forest fires / wildfires	**EF**	CO2	Average value, 1990-2012
Forest fires / wildfires	EF	CH_4	Average value, 1990-2012
Forest fires / wildfires	EF	N_2O	Average value, 1990-2012
HWP	**AD /EF**	C	Modelling with WoodCarbonMonitor (including WEHAM 2012; run 23)

Table 512: Emissions projections by pools/sources, for the period from 2013 through 2020

Sub-category / Pool	GHG	Units	2013	2014	2015	2016	2017	2018	2019	2020
Mineral soil	AD	Gg CO_2-Eq.	-13,275	-6,572	-12,736	-21,382	-28,289	-29,645	-1,540	-8,110
Organic soil	AD	Gg CO_2-Eq.	834	832	830	828	825	823	821	818
Organic soil	EF	Gg CO_2-Eq.	12	12	12	12	12	12	12	12
Organic soil	EF	Gg CO_2-Eq.	66	66	66	66	65	65	65	65
Above-ground biomass	EF	Gg CO_2-Eq.	6,615	6,610	6,605	6,601	6,596	9,741	9,734	9,727
Below-ground biomass	EF	Gg CO_2-Eq.	781	780	780	779	779	498	497	497
Litter	EF	Gg CO_2-Eq.	IE	IE	IE	IE	IE	IE	IE	IE
Dead wood	EF	Gg CO_2-Eq.	-1,294	-1,293	-1,292	-1,291	-1,290	-1,289	-1,288	-1,287
Forest fires / wildfires	EF	Gg CO_2-Eq.	4	4	4	4	4	4	4	4

Forest fires / wildfires	EF	Gg CO_2-Eq.	3	3	3	3	3	3	3	3
Forest fires / wildfires	AD	Gg CO_2-Eq.	54	54	54	54	54	54	54	54
SOM_mineral soil	EF	Gg CO_2-Eq.	0	0	0	0	0	0	0	0
Mineral soil	EF	Gg CO_2-Eq.	NO	NO	NO	NO	NO	NO	NO	NO
Mineral fertiliser	EF	Gg CO_2-Eq.	NO	NO	NO	NO	NO	NO	NO	NO
Harvested wood products (HWP)	AD /EF	Gg CO_2-Eq.	-11,891	-11,321	-10,851	-10,452	-10,105	-8,856	-8,685	-8,508
Total	All	Gg CO_2-Eq.	**-18,091**	**-10,825**	**-16,525**	**-24,778**	**-31,346**	**-28,590**	**-323**	**-6,725**

For the technical correction of the FMRL, the new FMRL has to be calculated. It is obtained as the sum of all emissions for the period 2013-2020, as listed in Table 512, divided by the relevant number of years. The difference between the old and the new FMRL serves as the value for the technical correction. The results are shown in Table 513.

Table 513: Results of the technical correction of the Forest Management Reference Level

	Total 2013-2020 [Gg CO_2-Eq.]	Average value 2013-2020 [Gg CO_2-Eq.]
FMRL new	-137,203	-17,150
FMRL old	-179,344	-22,418
Technical correction		5,268

AD for mineral and organic soils

The derivation of the applicable areas is described in detail in Chapter 6.3. A distinction is made between the areas with mineral soils and those with organic soils. For the projection of the land areas for the period from 2013 through 2020, it is assumed that the areas will continue to develop in keeping with the changes that have occurred in the last few years. In the report, the area changes for the period 2013-2016 are shown in Table 363 in Chapter 6.3.5. The same annual changes are assumed to apply for the projection period 2013 through 2020.

EF for mineral soils

The Yasso model was used for the projection of soil organic carbon stocks. Yasso is a dynamic soil-C model that was developed especially for forestry applications. It was developed at the European Forest Institute (EFI) in Finland by {LISKI et al. (2005)}. A new version, Yasso15, is now available (en.ilmatieteenlaitos.fi/yasso). Yasso makes it possible to project soil-C stocks, their changes and the related CO_2 releases via decomposition processes. The input values in YASSO include the quantities of litter that drop to the ground, the chemical composition of the litter and climate data. Yasso does not differentiate between the pools dead wood, litter and mineral soils. Since Yasso models these three pools as a whole, while GHG reporting reports the pools separately, the EF for dead wood was calculated out of the whole. In addition, the model results were adjusted in keeping with the results of the soil surveys, in order to obtain a consistent time series leading from the measured data for the period as of 1990 to the modelled data for the period as of 2013. Further information about the method is provided in {Ziche et. al.} (in preparation).

EF for organic soils

CO_2, N_2O and CH_4 emissions from organic forest soils are reported. Reporting also covers methane emissions from drainage ditches, as well as carbon losses in connection with dissolved organic carbon (DOC)(cf. also Chapter 6.1.2.2). For the projection for the period 2013 through 2020, in the FMRL framework, the trends for all three greenhouse gases for the period 1990 through 2012 are carried forward.

EF for biomass

The living biomass data are determined for the FMRL with the WEHAM model. On the basis of the National Forest Inventory, the WEHAM forest development and wood production model estimates how forests will develop, in light of a given outset situation, and how much raw wood they can be expected to produce. On that basis, the carbon content in above-ground and below-ground biomass is then estimated (cf. also Chapter 6.4.2.2). The outset data consist of the data from the 2012 National Forest Inventory and, for the management scenarios, the data from 2003 (archive: WEHAM 2012; run 23). This is in keeping with the requirement, set forth by the IPCC 2013 KP Supplement (IPCC et al., 2014a), to the effect that no post-2009 policies be used in the projection. Further information about the WEHAM model is provided in {BÖSCH et al. (2016)} and {BMEL (2016)}.

EF for litter

In the Yasso model, litter data are estimated together with mineral soils data, as described in the sub-chapter on mineral soils. Results for litter are not given separately; they are given together with results for mineral soils. For this reason, notation key IE (included elsewhere) has been entered in table 4xxc.

EF for dead wood

Carbon stocks in dead wood are calculated on the basis of the data of the National Forest Inventories (cf. Chapter 6.4.2.3). On this basis, for the projection as of 2013 it is assumed that the dead-wood C stocks do not change significantly, and an average emission factor for the period 1990 through 2012 is calculated.

AD and EF for forest fires

The derivation of forest-fire emissions is described in Chapter 6.4.2.7.5. As a result of Germany's prevailing climate conditions, and of the country's measures to prevent forest fires, forest fires tend to occur rather rarely. It is assumed that no basic changes in the characteristics of forest fire events will take place. For this reason, the average forest-fire burn area in the period 1990 through 2012, and the emission factors for the greenhouse gases CO_2, N_2O and CH_4 from that period, are assumed to apply as well for the period as of 2013.

AD and EF for harvested wood products

The carbon stocks in harvested wood products are calculated with the WoodCarbonMonitor computer model. Taking account of various outset data items and various methods, the model calculates the carbon stocks in harvested wood products for the period 2013 through 2020. Logging statistics are a key set of input data. They are also derived with WEHAM (cf. the sub-chapter on biomass). A comprehensive description of the model used in provided in {RÜTER (2017)}.

11.5.3.5 Information about natural disturbances under Article 3.4

As explained in Chapter 11.1.2, Germany has not selected the natural disturbances option. Natural disturbances that occur are not considered separately; instead, they enter into the change calculations for the relevant pools.

11.5.3.6 Information about harvested wood products under Article 3.4

As described in detail in Chapter 6.10, the emissions contribution made by harvested wood products in Germany, in terms of sources and removals into sinks for greenhouse gases, was determined with the WoodCarbonMonitor model, in keeping with the specifications of the IPCC KP Supplement (IPCC et al., 2014a).

First, the availability of activity data, i.e. data on the production of and foreign trade in harvested wood products, was reviewed (cf. Chapter 2.8.1.1, IPCC et al. (2014a)), and the product fractions originating from domestic harvest were calculated. Then, in a second step (cf. Chapter 2.8.1.2, IPCC

2014), the carbon contained in those products was allocated, using the procedure described in Chapter 6.10.2.1, to the forest activities listed in the Kyoto Protocol under Article 3, paragraphs 3 and 4. For Germany, the wood harvest can be fully assigned to the two activities forest management and deforestation. In keeping with the provisions of the IPCC 2013 KP Supplement (IPCC et al., 2014a), harvested wood products from deforestation are taken into account on the basis of instantaneous oxidation. As a result, the annual wood-harvest fractions from the activity forest management fFM(i) can be calculated from the inventory information available for Germany and from Equation 2.8.3 (IPCC et al., 2014a).

Further information, and details on the emission factors used and on the calculation carried out for Germany, in keeping with the provisions of the IPCC 2013 KP Supplement (IPCC et al., 2014a), are provided in Chapters 6.10.2.2 and 6.10.2.3.

11.6 Other information

11.6.1 Key-category analysis for Article 3.3 activities and any elected activities under Article 3.4

In connection with analysis for the UNFCCC inventory, key-category analysis was also carried out for activities pursuant to Article 3.3 and for selected activities pursuant to 3.4. The results are presented in tabular form in Chapter 1.5.2 of this report. The procedures, bases and methods used are described in detail in Chapter 17.1.4.

11.7 Information relative to Article 6 (JI & CDM projects / management of ERU)

Pursuant to Section 5 (1) Sentence 1 of the Project Mechanisms Act[207] (Projekt-Mechanismen-Gesetz; ProMechG), no projects in the area of LULUCF may be approved that are to take place in Germany.

The impermissability results from Section 5 in conjunction with the concept of emissions reduction pursuant to Art. 2 No. 5 ProMechG, which states that "emission reduction" "means the reduction of emissions from sources; this shall not include the increased removal of greenhouse gases by sinks in the areas of land use, changes in land use and forestry." Furthermore, JI projects are hindered in that use of JI in Germany ended at the end of 2012; cf. Section 5 (3) ProMechG.

12 Information relative to accounting for Kyoto units

12.1 Background information

Chapter 12 and 14 include information on the German emission trading registry. The accounting on Kyoto units and the public availability of information is described in chapter 12. Any significant changes in the national registry are reported in chapter 14.

12.2 Summary of information reported in the SEF tables

According to decision 15/CMP.1, annex, part 1, section E each Party must include information on its aggregate holdings and transactions of Kyoto units in its annual report. The information has to be reported in the Standard Electronic Format (SEF), which is an agreed format, embodied in a special report, for reporting on Kyoto units.

The SEF for 2018 was generated on 14 January 2019 with the Union registry software in version 8.2.2 r.13212, provided by the EU commission on 4.10.2018 and the SEF application version 3.8.3,

[207]ProMechG http://www.gesetze-im-internet.de/promechg/__5.html

provided by the secretariat on 26.1.2018. The German SEF for 2017 contains the information required in paragraph 11 of the annex to decision 15/CMP.1 and adhere to the guidelines of the SEF. The SEF has been submitted to the UNFCCC Secretariat electronically.

12.3 Discrepancies and Notifications

15/CMP.1 annex I.E paragraph 12 List of discrepant transactions	**No discrepant transactions occurred in 2018.**
15/CMP.1 annex I.E paragraph 13 and 14 List of CDM notifications	No CDM notifications occurred in 2018.
15/CMP.1 annex I.E paragraph 15 List of non-replacements	No non-replacements occurred in 2018.
15/CMP.1 annex I.E paragraph 16 List of invalid units	No invalid units exist as at 31 December 2018.
15/CMP.1 annex I.E paragraph 17 Actions and changes to address discrepancies	No actions were taken or changes made to address discrepancies for the period under review.

12.4 Publicly accessible information

13/CMP.1 annex II paragraph 45 Account information	**The requested information is publicly available for all accounts. The data of all accounts can be viewed online at:** **https://ets-registry.webgate.ec.europa.eu/euregistry/DE/public/reports/publicReports.xhtml** **Representative name and contact information is classified as confidential due to Article 107 Registry Regulation No. 389/2013.**
13/CMP.1 annex II paragraph 46 Joint implemention project information	The complete documentation of the JI projects is presented in the German JI project database which is accessible at the following URL. The database also contains already registered but not yet approved JI projects. https://jicdm.dehst.de/promechg/pages/project1.aspx A complete list of ERU issuance years is available at: https://www.dehst.de/SharedDocs/downloads/EN/project-mechanisms/ERU_table.pdf In 2018, no ERU were converted from AAU and no ERU converted from RMU were issued.
13/CMP.1 annex II paragraph 47 Unit holding and transaction information	The information requested in (a), (d), (f) and (l) is classifed as confidential due to Article 107 Registry Regulation No. 389/2013 as well as national data protection law and therefore not publicly available. Transactions of units within the most recent five year period are also classified as confidential, therefore the transactions provided are only those completed more than five years in the past. The information requested in (b), (c), (e), (g), (h), (i), (j) and (k) is publicly available at https://ets-registry.webgate.ec.europa.eu/euregistry/DE/public/reports/publicReports.xhtml
13/CMP.1 annex II paragraph 48 Authorized legal entities information	The following legal entities are authorized by the Member State to hold Kyoto units:

	Legal entities authorised by Germany to hold units
AAU	Federal Government only
ERU	Each account holder
CER	Each account holder
RMU	Federal Government only
tCER	Federal Government only
lCER	Federal Government only

12.5 Calculation of the Commitment Period Reserve

Germany's Commitment Period Reserve (CPR) is calculated as 90 percent of Germany's assigned amount (3,592,699,888 tonnes CO_2 equivalent) calculated pursuant to Article 3 paragraphs 7 and 8 of the Kyoto Protocol. The initial CPR of the current commitment period did not change and is still 3,233,429,899 tonnes CO_2 equivalent (or AAU), as 100 % times the most recent inventory times eight would amount to a higher value.

In accordance to Article 4 paragraph 4 Registry Regulation No. 389/2013 the Union registry has to prepare for keeping the CPR. If a transfer proposal would result in an infringement of the CPR, the registry should reject it internally.

The German registry did not violate the CPR during the reported year.

13 Information on changes in the National System

Following the 2016 In-Country Review, the institutional consolidation of the National System, pursuant to the requirements for the 2nd commitment period of the Kyoto Protocol, as set forth in the Revised UNFCC Reporting Guidelines, and in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, may be considered completed. The emphasis in the present reporting period was thus on safeguarding existing data streams and on closing any occurring data gaps.

A data stream was interrupted in July 2018, when the Wirtschaftsvereinigung Stahl German steel industry association informed the Single National Entity that it would not be able to provide data for 2017 in keeping with the applicable cooperation agreement it was part of. The cooperation agreement was not terminated, and is still in force. Nonetheless, the association's failure to supply data created a significant gap in the available calculation bases for categories 1.A.2 and 2.C.1, and it significantly downgraded the reliability of the overall data streams.

The Single National Entity is currently working with the competent federal ministries, the Federal Ministry for Economic Affairs and Energy (BMWi) and the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), on closing the data gap. No other changes were made in 2018 in the institutionalisation of the National System.

14 Information on changes in the national registries

The following changes to the national registry of Germany have occurred in 2017.

15/CMP.1 annex II.E paragraph 32.(a) Change of name or contact	No change in the name or contact information of the registry administrator occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(b) Change regarding cooperation arrangement	No change of cooperation arrangement occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(c) Change to database structure or the capacity of national registry	The versions of the EUCR released after 8.0.8 (the production version at the time of the last Chapter 14 submission) introduced minor changes in the structure of the database. These changes were limited and only affected EU ETS functionality. No change was required to the database and application backup plan or to the disaster recovery plan. The database model is provided in Annex A. No change to the capacity of the national registry occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(d) Change regarding conformance to technical standards	Changes introduced since version 8.0.8 of the national registry are listed in Annex B. Each release of the registry is subject to both regression testing and tests related to new functionality. These tests also include thorough testing against the DES and were successfully carried out prior to the relevant major release of the version to Production (see Annex B). No other change in the registry's conformance to the technical standards occurred for the reported period.
15/CMP.1 annex II.E paragraph 32.(e) Change to discrepancies procedures	No change of discrepancies procedures occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(f) Change regarding security	No changes regarding security occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(g) Change to list of publicly available information	No change to the list of publicly available information occurred during the reporting period.
15/CMP.1 annex II.E paragraph 32.(h) Change of Internet address	The registry internet address changed during the reported period. The new URL is https://unionregistry.ec.europa.eu/euregistry/DE/index.xhtml
15/CMP.1 annex II.E paragraph 32.(i) Change regarding data integrity measures	No change of data integrity measures occurred during the reporting period.

15/CMP.1 annex II.E paragraph 32.(j) Change regarding test results	Changes introduced since version 8.0.8 of the national registry are listed in Annex B. Both regression testing and tests on the new functionality were successfully carried out prior to release of the version to Production. The site acceptance test was carried out by quality assurance consultants on behalf of and assisted by the European Commission.
1/CMP.8 paragraph 23 PPSR account	The opening of the PPSR account is linked to the entry into force of the Doha amendment (Article 73f introduced by the Delegated Regulation 2015/1844). Since only 122 countries have ratified out of the 144 needed in total, it currently prevents the carry-over of AAUs and thus the creation of PPSR accounts in the Union Registry.
Annual Review report Previous Expert Review Team recommendations	The last available report (FCCC/ARR/2016/DEU published 12.04.2017) does not contain recommendations related to the national registry.

15 Information regarding minimisation of negative impacts pursuant to Article 3 (14)

Most of the measures that would be carried out in Germany would not be expected to have direct effects on developing countries. In the case of other measures, the expected effects are largely considered to be positive. Such effects, for example, would include establishment of technical and administrative structures for climate protection.

Almost all of the possible indirect effects are also considered to be positive. Such effects would include beneficial impacts on energy supplies and prices in co-operating countries. Detailed descriptions of the individual measures were provided in the 2016 NIR. The areas covered by the measures include promotion of use of biofuels, reduction of subsidies for hard coal, policies and measures at the EU level – especially EU emissions trading – and support for developing countries in energy-supply diversification. No current changes have been made with respect to these reported measures.

16 Other information

This chapter is currently not required.

17 Annex 1: Key categories within the German greenhouse-gas inventory

Pursuant to the *2006 IPCC Guidelines*, the parties to the UN Framework Convention on Climate Change and to the Kyoto Protocol are required to calculate and publish emissions data annually.

These emissions inventories must be readily comprehensible (transparency); must be calculated in a consistent manner in the time series since 1990 (consistency); must be evaluated uniformly at the international level via application of the prescribed calculation methods (comparability); must contain all the relevant emission sources and sinks in the reporting country (completeness); must be evaluated with regard to error; and must undergo ongoing internal and external quality management (accuracy).

To facilitate concentrating the many and detailed activities and resources required for this purpose on the inventory's principal categories, the IPCC has introduced the term "key category." Key categories are categories which are highlighted in the national inventory system because their emissions have a significant influence on total emissions of direct greenhouse gases, either in terms of absolute emissions, or as a contribution to the emissions trend over time, or in both ways.

Chapter 4 of the 2006 IPCC Guidelines describes the methods to be applied for identifying key categories. These methods include inventory analysis for one year (Approach 1, Level Assessment), time-series analysis of inventory data (Approach 1, Trend Assessment), detailed analysis of inventory data with error evaluation (Approach 2, Trend Assessment with consideration of uncertainties) and assessment of qualitative criteria (pursuant to Chapter 4.3.3 of 2006 IPCC GL, Vol. 4, Ch. 1)

Approach 1 analyses must always be carried out using two procedures. In a first procedure, only emissions from sources are evaluated, and storage in sinks is not considered. In a second procedure, emissions storage in sinks is then included (without any consideration of whether it is positive or negative). As would be expected, the two results differ. Pursuant to the 2006 IPCC GL, both results must be taken into account in identification of key categories.

For identified key categories, the Parties are then required to use highly detailed calculation methods (Tier 2 or higher; the relevant methods are also specified in the 2006 IPCC GL). Should direct use of such methods prove impossible, for whatever reason (e.g. data are not available for the required input variables, etc.), Parties are required to prove that the methods applied nationally achieve at least a comparable degree of accuracy in the calculation result. Such proof, as well as the key-category analysis performed overall, must be outlined in the national inventory report to be prepared annually.

17.1 Description of the method for identifying key categories

The results of key-category analysis via the two Approach -1 - procedures (Level and Trend), the Approach 2 procedure and assessment in terms of qualitative criteria, are presented in Table 6 in Chapter 1.5. In this context, we call attention to the description of the underlying methods in the *2006 IPCC GL* (IPCC (2006): Vol. 1).

17.1.1 Approach 1 procedures

Level analysis has the purpose of identifying those source categories responsible for 95 % of total national emissions (as CO_2-equivalent emissions), in the Kyoto Protocol's base year and in the current year; those sources are then defined as key categories (•). Calculations were performed using formula 4.1 from the 2006 IPCC Guidelines (IPCC (2006): Vol. 1).

Trend analysis identifies as key categories (•) those categories which have made an especially significant contribution to changes in total GHG emissions in the most recent year, in terms of the development of their contribution since the base year. In this respect, it is irrelevant whether such changes have led to a reduction or an increase in total emissions. Calculations were performed using formula 4.2 from the 2006 IPCC Guidelines (IPCC (2006): Vol. 1).

17.1.2 Approach 2 procedure

Key-category analysis using the Approach 2 procedure is based on the results of current uncertainties determination in accordance with Approach 1. In the present case, the results have provided extensive confirmation of the results of the Approach 1 key-category analyses. Five additional categories also have to be considered, however (cf. Table 8, Chapter 1.5.1).

17.1.3 Assessment with qualitative criteria

Germany assesses key categories with help of qualitative criteria. The criteria to be applied are listed in Criteria 4.3.3 of the 2006 IPCC Guidelines (IPCC (2006): Vol. 1). The criteria allow assessment on the basis of use of emissions-reduction equipment, of expected disproportionate emissions increases, of a high level of uncertainty or of unexpectedly lower or higher emissions in a given category. The criteria may be used as a basis for defining additional categories as key categories.

In the category adipic acid production (2.B.3), a redundant waste-gas-treatment system was installed. In light of that installation, the category has been classified as a key category, on the basis of qualitative criteria. 2.B.3 is already a key category, however, in terms of Approach 1 Level and Trend assessment. SF_6 emissions from soundproof windows are reported in 2.G.2. Even though such a trend cannot yet be recognized, it is clear that SF_6 emissions must be expected to increase sharply in coming years as disposal of old windows increases. For that reason – i.e. on the basis of qualitative criteria – the category has already been identified as a key category. That classification leads to no change, however, since 2.G is already a key category, according to Approach 1 Level and Trend, for SF_6. Qualitative assessment on the basis of large uncertainties is not required, since Germany carries out Approach 2 key-category analysis for the entire inventory every year. No unexpectedly low or high emissions have been seen in the inventory.

Use of qualitative criteria has not identified any additional key categories in Germany.

Germany uses all recommended procedures for identifying and evaluating categories. The IPCC Guidelines mandate that 95% of emissions from sources / removals in sinks be classified in key categories. The key categories that Germany has identified comprise emission-causing activities that account for about 98 % of the total inventory. This high percentage results from Germany's practice of identifying key categories by combining the results of all analysis procedures and evaluations.

17.1.4 Key-category analysis for Kyoto reporting

The following CRF Table NIR.3 summarises information relative to key-category analysis for Kyoto reporting.

Table 514: KP CRF Table NIR.3: Summary Overview for Key Categories for Land Use, Land-Use Change and Forestry Activities under the Kyoto Protocol

KEY CATEGORIES OF EMISSIONS AND REMOVALS	Gas	CRITERIA USED FOR KEY CATEGORY IDENTIFICATION			Comments [4]
		Associated category in UNFCCC inventory[1] is key (indicate which category)	Category contribution is greater than the smallest category considered key in the UNFCCC inventory[2] (including LULUCF)	Other[3]	
Specify key categories according to the national level of disaggregation used[1]					
Afforestation and Reforestation					
CO_2	CO_2	Land converted to Forest Land	Yes	High expected growth.	The value is very close to the value in the smallest category considered key in the UNFCCC inventory. The value has increased about tenfold since 1990.
Deforestation					
CO_2	CO_2	Land converted to Cropland	Yes	None	No comment
Forest Management					
CO_2	CO_2	Forest Land remaining Forest Land	Yes	None	No comment
Cropland management					
CO_2	CO_2	Cropland remaining Cropland, Land converted to Cropland	Yes	None	No comment
Grazing Land Management					
CO_2	CO_2	Grassland remaining Grassland	Yes	None	No comment

(1) See section 2.3.6 of the 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol.

(2) If the emissions or removals of the category exceed the emissions of the smallest category identified as key in the UNFCCC inventory (including LULUCF), Parties should indicate YES. If not, Parties should indicate NO.

(3) This should include qualitative assessment as per section 4.3.3 of the 2006 IPCC Guidelines or any other criteria.

(4) Indicate the criteria (level, trend of both) identifying the category as key.

18 Annex 2: Detailed discussion of the methodology and data for calculating CO_2 Emissions from combustion of fuels

18.1 The Energy Balance for the Federal Republic of Germany

The *Federal Statistical Office (Statistisches Bundesamt) is the most important data source for determination of energy data and the key data source for preparation of Energy Balances. Data on renewable energy sources are determined by the Working Group on Renewable Energy Statistics (Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat).* The Energy Balances of the Federal Republic of Germany, which are prepared under commission to the German Federal Ministry for Economic Affairs and Energy (BMWi), are the central data foundation for determining energy-related emissions. On an annual basis, the associations in the German energy sector, working in co-operation with economic research institutes, and in the framework of the Working Group on Energy Balances (AGEB), combine the relevant data to form a complete picture. They then make the data available to the public in the form of Energy Balances. In the Federal Republic of Germany, energy statistics are published by numerous other agencies, and their statistics can differ in terms of their presentation, scope and aggregation.

The complete Energy Balances for the years since 1990 are available on the Internet at:

http://www.ag-energiebilanzen.de/index.php?article_id=7&clang=0

The AGEB's website presents a foreword for the Energy Balances, in German and English, that describes the structure of the Energy Balance.

The members of the Working Group on Energy Balances (AGEB) include (as of: November 2018):

- Bundesverband der deutschen Energie- and Wasserwirtschaft e.V. (BDEW) (Association of the German Energy and Water Industry), Berlin
- Deutscher Braunkohlen-Industrie-Verein e.V. (DEBRIV) (Federal German association of lignite-producing companies and their affiliated organisations), Cologne,
- Deutsches Institut für Wirtschaftsforschung (DIW) (German Institute for Economic Research), Berlin,
- EEFA GmbH, Münster
- Institute of Energy Economics at the University of Cologne (EWI), Cologne,
- Gesamtverband Steinkohle (GVSt) association of the German hard-coal-mining industry, Herne,
- Mineralölwirtschaftsverband (MWV) (Association of the German Petroleum Industry), Berlin,
- Rheinisch-Westfälisches Institut für Wirtschaftsforschung (RWI) (Rhine-Westphalian Institute for Economic Research), Essen.
- Verein der Kohlenimporteure e.V. (German Coal Importer Association), Hamburg
- Centre for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW), Stuttgart

The work of the Working Group on Energy Balances (AGEB) is also supported by the Energieeffizienzverband für Wärme, Kälte und KWK e.V. (AGFW; Association for energy efficiency in heating, cooling and CHP systems) and the Association of Industrial Energy and Power Producers (VIK). Since the 1994 balance year, overall responsibility for preparation of Energy Balances has lain with the German Institute of Economic Research (DIW; Berlin); since 2002, the DIW has carried out relevant work in co-operation with EEFA (Energy Environment Forecast Analysis GmbH).

Official statistics are the most important source. The surveys of the Federal Statistical Office that were used are listed in Table 517. The final Energy Balance continues to include data of the following associations: German Association of Energy and Water Industries (BDEW), German Atomic Forum

(DAtF), Gesamtverband Steinkohle association of the German hard-coal-mining industry (GVSt), DEBRIV Federal German association of lignite-producing companies and their affiliated organisations and Association of the German Petroleum Industry (MWV). In addition, for the period until 2011 figures on wood consumption in the residential sector were obtained from GfK-Rheinbraun data that are reported via DEBRIV, in February/March of the relevant subsequent year + 1. For wood consumption by private households as of the year 2012, data from an RWI survey (Erhebungsstudie) was used as a basis, while for wood consumption in the Commercial and Institutional sector figures of the Johann Heinrich von Thünen Institute (Federal Research Institute for Rural Areas, Forestry and Fisheries) are being used for the period as of 2013.

In addition, figures of the Working Group on Renewable Energy Statistics (Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat) are used for the final Energy Balance. Provisional data on renewable energy sources are provided by the Centre for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW) and checked in collaboration with the German Association of Energy and Water Industries (BDEW). Those data enter into the estimated Energy Balance and the evaluation tables. Because they appear earlier (August) than the data of AGEE-Stat (September), they tend to show discrepances with the AGEE-Stat data.

In a number of categories, furthermore, experts personally provide relevant data – in categories, for example, such as non-energy-related consumption by the chemical industry.

18.2 Structure of the Energy Balances

The Energy Balances, which are structured in matrix form, provide an overview of the interconnections within the energy sector. As a result, they not only provide information about consumption of energy resources in the various source categories, they also show the relevant flows of such resources, from production to use in the various production, transformation and consumption areas. The ***production balance*** shows:

- domestic production
- imports
- removals from stocks
- exports
- maritime bunkering
- additions to stocks

of energy resources, and it summarises them under ***primary energy consumption***. The primary Energy Balance provides the basis for calculations under the IPCC reference procedure (Plinke & Schonert, 2000). The ***usage balance*** provides a key basis for preparation of emissions inventories. The usage balance can also be used for determination of primary energy consumption. It comprises:

- the transformation balance
- flaring and line losses
- non-energy-related consumption, and
- final energy consumption.

Differences between the production and usage balances are compensated for in the position "Statistical differences".

The ***transformation balance***, part of the usage balance, shows what energy resources are transformed, as well as what other resources they are transformed into. The transformation production shows the results of such transformation. Energy transformation can involve either substance modification – such as transformation of crude oil (transformation input) into petroleum products (transformation production) – or physical transformation – such as combustion of hard coal (transformation input) – in power stations, for production of electrical energy (transformation production). The energy consumption in the transformation sector shows how much energy was needed for operation of transformation systems (the transformation sector's own consumption). The transformation balance is broken down by facility type; a total of 12 different types of facilities are considered.

Non-energy-related consumption, as a component of the consumption balance, is shown as a total, without allocation to facility types or branches of industry. It describes which energy resources are used as raw materials (e.g. in the chemicals industry, transformation of energy resources into plastics).

Finally, the consumption balance indicates the final consumption sectors in which energy is transformed into the useful energy ultimately needed (such as power, light, room and process heating) (***final energy consumption***). This includes industry, sub-divided into 14 sectors, transport, households and commercial use, trade, services and other consumers (including agriculture).

The energy flow in the Energy Balances is depicted for 30 energy resources. These energy resources can be allocated to the following main groups:

- hard coal,
- lignite,
- petroleum (including LPG and refinery gas),
- gases (coke-oven and blast furnace gas, natural gas and firedamp, and excluding landfill gas and the gases in the previous category),
- Renewable energies (including renewable waste and, as of 2013, sewage sludge),
- Other energy sources (non-renewable waste, waste heat),
- Electrical power and other energy resources.

Energy Balances are available for the years as of 1990. In a satellite balance, renewable energies are further broken down as of 1996 (AGEB, 2003).

As of the year 2000, the energy-resource structure in the area of renewable energies / waste was changed: hydroelectric and windpower systems, and photovoltaic systems, were combined, and waste/biomass was divided into renewable and non-renewable fractions. Since 2003, non-renewable waste and waste heat are also listed under final-energy consumption within the Energy Balance.

In the Energy Balance, fuels / energy resources are listed in *natural units*, including tonnes (t) for solid and liquid fuels, cubic metres (m^3) for gases (except for natural gas), kilowatt hours (kWh) for electrical power and natural gas, and joules (J) for waste, renewable energy sources, nuclear power and district heating. In order to render the data comparable and suitable for addition, all values are converted into joules (J) using calorific value tables and conversion factors. Unlike gas statistics, the Energy Balance lists even gases in terms of calorific value.

To date, Energy Balances through 2016 have been published. To meet the need for currentness in emissions reporting, the Working Group on Energy Balances (AGEB) provides the Federal Environment Agency with a complete provisional Energy Balance – on an annual basis, and in early August of each year – for purposes of inventory preparation.

18.3 Methodological issues: Energy-related activity rates

Essentially, the inventories for air pollutants and greenhouse gases prepared by the Federal Environment Agency are based on the Energy Balances for Germany prepared by the Working Group on Energy Balances (AGEB). The data required for emissions calculation can be read directly from Energy Balance lines 11, 12, 15, 16, 40, 60, 65 and 68. For biomass fuels, and for natural gas and light heating oil, EB line 14, depending on the fuel in question, is also used in calculation.

In a few cases, the special requirements pertaining to emissions calculation, and the need to assure the completeness of data, necessitate a departure from the above-described system, and additional data have to be added:

- The emissions-relevant fuel inputs for lignite drying have to be calculated out of EB line 10. A precise description of category 1.A.1.c is provided in Chapter 3.2.8.2.
- Natural gas inputs in compressors, for the years 1995-2002, can be read directly from the Energy Balance (EB line 33). For the years 1990-1994, and for the period as of 2003, the values have to be calculated outside of the Energy Balance. The method is described in the Chapter for category 1.A.3.e.
- For systematic reasons, and for reasons having to do with a focus on energy production, the Energy Balance does not list incinerated waste quantities completely for all relevant years. In this area as well, therefore, the lacking data have to be added from waste statistics. Relevant explanations are provided in Chapter for category 1.A.1.a and in the Chapter for category 1.A.2.g Other (stationary).
- Firewood use in the categories commercial and institutional is not listed in the Energy Balance through 2012 and has to be added. The method is described in Chapter for category 1.A.4.

In the Energy Balance, inputs of reducing agents, in pig-iron production, are listed in part as energy-related consumption, in EB line 54, and in part as transformation inputs, in EB line 17 (top-gas equivalent). Use of the related blast-furnace gas for energy production is listed in the relevant Energy Balance lines, 11, 12, 15, 33 and 54. To prevent double counting, the reducing-agent inputs from blast furnaces, as listed in EB line 54, and the relevant top-gas equivalent, are not reported.

18.4 Uncertainties, time-series consistency and quality assurance in the Energy Balance

As a result of increasing energy-market liberalisation, and in conjunction with the formation of a European single market, the condition of the statistical energy database has worsened in recent years of change (ZIESING et al, 2003). While the Act on Energy Statistics (which entered into force in 2003) improved the relevant basic data foundations, relatively speaking, the dynamic development of the energy sector again created a need for amendment of that Act. The amendment of the Act on Energy Statistics of 6 March 2017 (Federal Law Gazette (BGBl) I p. 392) introduces improvements in statistical coverage, updates of the survey groups involved and a number of new aspects to be surveyed. In addition, survey periodicity has changed – in part, in favour of monthly surveys. The first survey will be carried out in the 2018 survey year.

The data structures of the Energy Balance are adjusted on an ongoing basis, in order to enhance data availability to the best possible extent.

These changes are made at relatively large intervals and are documented by the Working Group on Energy Balances (AGEB) in each case:

- Explanations relative to revision of the Energy Balances 2003 – 2006[208]
- Remarks regarding changes in the Energy Balances 2003 through 2007[209]
- Revision of the Energy Balances 2003 through 2009[210]
- Methodological changes in the 2012 Energy Balance[211]

[208] http://www.ag-energiebilanzen.de/#revision_der_eb_2003_bis_2006
[209] http://www.ag-energiebilanzen.de/#aktualisierungen_der_energiebilanzen_2003_bis
[210] http://www.ag-energiebilanzen.de/#revision_der_energiebilanzen_2003_bis_2009_05
[211] http://www.ag-energiebilanzen.de/#methodische_aenderungen_der_eb_2012

- Explanation relative to the Energy Balances (updated as of November 2015)[212]

18.4.1 Quality report of the Working Group on Energy Balances (AGEB) regarding preparation of Energy Balances for the Federal Republic of Germany

In 2012, the Working Group on Energy Balances (AGEB) began submitting annual joint quality reports, to the Federal Environment Agency (UBA), that document its quality-assurance measures in preparation of Energy Balances. The new contract, covering the Energy Balances for the period 2018-2020 (a tendering procedure for the contract award is currently underway), will have new aspects that will enter into preparation of Energy Balances as of 2019. One such new aspect, an additional quality-assurance measure, will call for Energy Balances to be prepared in time series. This will facilitate detection of year-to-year discontinuities during data compilation.

The following section presents the content of the current reports, in their original wording (marked with a different typeface).

18.4.1.1.1 Background

In the framework of greenhouse-gas reporting, the National Co-ordinating Committee for the National System of Emissions Inventories has established minimum requirements pertaining to quality control and quality assurance (QC/QA). Those requirements are to be fulfilled on all levels of inventory preparation. One of the most important data sets for determination of greenhouse-gas emissions consists of the Energy Balances for the Federal Republic of Germany, which the Working Group on Energy Balances (AGEB) has been commissioned to prepare. The German Institute for Economic Research (DIW, Berling) and the EEFA research institute also work on such Energy Balances, as sub-contractors to the AGEB. All persons working on Energy Balances are required to comply with minimum requirements pertaining to QC/QA, in areas such as transparency, consistency, comparability, completeness and accuracy.

To document its data sources and quality-assurance measures in preparation of Energy Balances, the Working Group on Energy Balances (AGEB) herewith submits its current quality report to the Federal Environment Agency (UBA). It focuses especially on the 2016 Energy Balance.

18.4.1.1.2 Work-sharing in preparation of Energy Balances

The DIW Berlin is responsible for preparing Energy Balances for the following energy areas:

- Natural gas, petroleum gas
- Non-renewable waste, waste heat,
- Nuclear power,
- Crude oil, and
- Petroleum products (gasoline; naphtha; jet fuels; diesel fuel; light heating oil; heavy heating oil; petroleum coke; LP gas; refinery gas; other petroleum products)

Also in the framework of its Energy Balance work, the DIW Berlin coordinates the quarterly estimates of primary energy consumption for the Federal Republic of Germany, and it prepares estimates for the energy area "Other".

In addition, the DIW Berlin awards a sub-contract to the Centre for Solar Energy and Hydrogen Research Baden-Württemberg, which prepares the renewable energies data for the Energy Balances. The data concerned include data on:

- Hydroelectric power, wind power on land and at sea, and photovoltaics,
- Biomass (solid, liquid, biofuels, biogas, sewage gas, landfill gas) and renewable waste (settlement waste)

[212] http://www.ag-energiebilanzen.de/index.php?article_id=29&fileName=vorwort.pdf

- Other renewable energy sources (solar-thermal, deep geothermal, near-surface geothermal).

The tasks of the EEFA research institute include preparing complete Energy Balances for the following fuels:

- Hard coal, hard-coal coke, hard-coal briquettes and other hard-coal products,
- Lignite (raw), lignite briquettes, other lignite products and hard lignite, and
- Coking-plant gas and city gas, blast furnace gas and basic oxygen furnace gas, and mine gas.
- Electricity,
- District heat (Fernwärme).

In the framework of its work on the Energy Balances, the EEFA institute also coordinates deliveries and reporting of energy-statistics data in the context of European and international obligations (IEA/EUROSTAT Joint Annual Questionnaires).

Since Energy Balance year 2009, estimate balances have been prepared in the framework of work for the evaluation tables. They incorporate data from Statistik-Nr. 066 (Erhebung über die Elektrizitäts- und Wärmeerzeugung der Stromerzeugungsanlagen der allgemeinen Versorgung; Survey of electricity and heat generation of public-sector electricity generation systems) of the Federal Statistical Office (StBA), and association data – for example, of the German Association of Energy and Water Industries (BDEW). The estimates are coordinated especially with the BDEW and the -Stat. Data from Official Mineral Oil Statistics (AMS of the Federal Office of Economics and Export Control (BAFA)) are also used.

At that early stage in Energy-Balance preparation, important official data sources, such as surveys relative to energy consumption of industrial sectors, are normally not yet available. The pertinent data gaps are closed with the help of estimates. It is thus clear that an estimated Energy Balance cannot fulfill the strict requirements pertaining to data quality that the final Energy Balance meets, a work published with a time lag of somewhat less than one year.

18.4.1.1.3 Quality of the data sources used

The following *data of the Federal Statistical Office (StBA)* are used in the preparation of the Energy Balances for the Federal Republic of Germany:

- Survey (No. 060) of energy use of mining, quarrying and manufacturing companies,
- Survey (No. 061E) in coal imports,
- Survey (No. 062) of geothermal energy,
- Survey (No. 064) of heat generation, demand, use and supply,
- Survey (No. 066) of electricity and heat generation of public-supply electricity generation systems,
- Survey (No. 067) of electricity generation systems in the mining and manufacturing sectors,
- Survey (No. 070) of network operators relative to electricity feed-in,
- Survey (No. 073) of production, use and supply of sewage gas,
- Survey (No. 075) of production, demand, use and supply of LP gas,
- Survey (No. 082 P) of supply, import and export of natural gas and petroleum gas, and of revenue of producers,
- Survey (No. 082) of production, supply, import and export of gas, and of revenue of gas utilities and gas sellers.
- Energiesteuerstatistik (energy taxation statistics), Fachserie 14, Reihe 9.3).

The data of the Federal Statistical Office (StBA) are subject to official quality requirements. The quality reports of the Federal Statistical Office are available on the Internet:

https://www.destatis.de/DE/Publikationen/Qualitaetsberichte/Energie/EnergieWasserversorgung.html.

In addition, data from the *Official Mineral Oil Statistics (AMS)* of the Federal Office of Economics and Export Control (BAFA) are used. The Official Mineral Oil Statistics for Germany (AMS), which are published monthly and annually, comprise a closed, contradiction-free system covering all petroleum production and consumption in Germany. The statistical basis for the AMS consists of the Integrated Mineral Oil Report (Integrierte Mineralölbericht – IM), which is prepared monthly, on the basis of the Act on mineral oil data (Mineralöldatengesetz), with input from companies operating in Germany's petroleum market. The Federal Office of Economics and Export Control (BAFA) reports the pertinent production and consumption data, together with the relevant data of the Federal Statistical Office, to IEA and Eurostat, which publish internationally comparable energy balances. The calorific values for crude oil inputs, and the petroleum products, that are covered by these reports are cross-checked against the national Energy Balance. For its section on petroleum, that balance also uses data from the AMS and data of the Federal Statistical Office. In addition to the available official data, *association data* are also used. The *Statistik der Kohlenwirtschaft* coal statistics play a special role among the association statistics. The data used for the Energy Balance include the following:

For hard coal:

- Statistics on domestic sales, broken down by types of hard coal and consumer groups, and
- Statistics on production, use in transformation sectors and changes in stocks (form 4a).

For lignite:

- Data on extraction, production of lignite products, producers' own consumption and sales (form 5), and information from production reports,
- Data on domestic sales / use, broken down by Länder and consumer groups,

The coal-statistics data available in Germany have a semi-official status, and they are very precise and reliable. For more than 60 years, the Statistik der Kohlenwirtschaft coal-sector-statistics association has served as a liaison between coal-sector companies and official producers of statistics. Official coal statistics in this area are based on surveys carried out by the Statistik der Kohlenwirtschaft association. A large portion of the coal data is made publicly accessible on the website http://www.kohlenstatistik.de. The transparency this provides also attests to the reliability and accuracy of these data sources. The Act on Energy Statistics (Energiestatistikgesetz) has no separate paragraph relative to surveys on the domestic coal sector; its refers instead explicitly to the functioning system of coal statistics.

The following *additional sources* are also used:

- With regard to wood consumption in the Residential sector for the year 2016, results from the survey by RWI/forsa are carried forward.
- Since 2013, wood consumption in the Commercial and Institutional sector has been determined as a remainder. The basis for this work consists of data on total energy-wood production in Germany, data obtained through surveys and calculations of the Johann Heinrich von Thünen Institute (Federal Research Institute for Rural Areas, Forestry and Fisheries).
- Data on wind energy yields on land and at sea, and on electricity production via photovoltaics, are derived from the quantities certified by auditors of transmission system operators (TSO), relative to electricity feed-in and relevant compensation, pursuant to the Renewable Energy Sources Act (EEG).
- In the framework of monitoring under the CHP act (Kraft-Wärme-Kopplungsgesetz), the Öko-Institut e.V. Institute for Applied Ecology estimates natural gas inputs, for electricity and heat generation, in compact gas-/oil- fired CHP systems that are not covered by official statistics.
- Model calculations are used in the areas of feed-in of biomass-based electricity into the grid, of solar-thermal energy and of use of environmental heat.

In addition to quality, the important aspects of the available data, relative to preparation of Energy Balances, include their multi-year availability and their standardised, consistent presentations of time series. Such aspects play a critically important role in ensuring that the procedures and methods used for preparation of Energy Balances generate data that can be consistently integrated, without structural discontinuities, in the basic scheme for the Balances. Both the relevant official sources and the coal statistics data have a long tradition. Where breaks in time series cannot be avoided, as a result of reviews or changes in statistical foundations (for example in the Act on Energy Statistics), such breaks are well-documented in the sources used for preparation of Energy Balances. This ensures that methods are always properly adjusted.

18.4.1.1.4 Transparency of methods and procedures

The Act on Energy Statistics (Energiestatistikgesetz – (EnStatG) entered into force on 1 January 2003. That act consolidates official energy statistics, from different legal frameworks, and adapts them to users' current information requirements. Since the act's entry into force, the Federal Statistical Office has also collected and provided data for the areas heat market, combined heat / power generation (CHP) and renewable energy sources. As a result of the restructuring, the Federal Statistical Office, in addition to providing data on electricity and heat generation from combined heat / power generation (CHP), also provides data on all fuel inputs for CHP, for both the general public supply and industry (broken down by energy sources).

Such changes in the available statistics have made it necessary to adjust the methods used for the Energy Balances – especially for their descriptions of industrial final energy consumption. As a consequence of the described expansion in the data supply, separate data on fuel inputs as of 2003 for industrial electricity generation – i.e. for electricity-only generation – are now available.

The Federal Statistical Office does not collect data on breakdowns of fuel inputs by "electricity" and "heat" in industrial and public-supply combined heat / power generation (CHP) systems; such statistics are collected by the Working Group on Energy Balances (AGEB) and estimated by institutes it commissions. The "Finnish" method used for such purposes is based on Directive 2004/8/EC of the European Parliament and of the Council of 11 February 2004. That method is precisely defined, mathematically, and it is explained in the forewords to the Energy Balances.

With regard to quality assurance, the Finnish method makes calculations relative to power/heat production for the public supply and for industry logical and transparent. The necessary pertinent framework assumptions, such as the reference efficiencies of non-CHP generation as provided in the documentation for the Energy Balances, are clearly stated in the process. In sum, although Energy Balance preparation is a process that makes use of frequently complex transformational methods, its results can still be highly transparent and unambiguous. As a result, all Energy Balance entry fields can always be traced back to their primary statistical foundations.

Primary data provided by official or association sources – regardless of its quality – can seldom simply be "plugged into" the Energy Balance without undergoing the statistical processing normally used to prepare the Energy Balances. Description of relevant complex energy flows, using matrices that conform to the formal parameters and methodological specifications for the Energy Balances, and on the basis of statistical raw data, requires numerous transformation steps, recalculations and reallocations. What is more, in some (few) areas of the Energy Balance primary statistics are no longer available, and thus data gaps have to be closed through use of formal estimation methods, applied in accordance with the requirements of each relevant individual case.

18.4.1.1.5 Checking and verification of results

Measures for quality assurance and control cover the following areas:

- Assurance of data quality / transparency of methods and procedures,

- Mechanisms for checking and critically reviewing the Energy Balances, measures that assure the Balances' correctness, completeness and consistency,
- Measures for documentation and archiving, designed to ensure the Balances' clarity and reproducibility,
- Expert responsibility for preparation of Energy Balances.

Critical discussion, verification and checking of results take place on various levels:

- The annual Energy Balance is prepared independently by several experts, in a process that includes cross-checking of work.
- The involved experts mutually check their work and review it, on the basis of control figures (such as changes emerging year-to-year comparisons, implied calorific values, utilisation levels), for plausibility.
- The time-series consistency is regularly verified. Where a time series shows implausible jumps that cannot be attributed to transfer or calculation errors, and that must be tied to developments in the underlying primary statistics, the problem is discussed constructively with the relevant data-supplying institution (such as the Federal Statistical Office).
- The Energy Balances are cross-checked against the data provided to IEA/Eurostat.
- In addition, the AGEB member associations carry out supporting checks.
- Furthermore, at early stages data and results are exchanged and discussed with responsible experts of the Federal Environment Agency (UBA), also in consultation with AGEE-Stat.
- Statistical questions pertaining to the Energy Balance are also discussed by the "Working Group on methods" ("Arbeitskreis Methodik" – AKM) within the Federal Ministry for Economic Affairs and Energy (BMWi).

Only when the completed Energy Balance has successfully passed through all controlling bodies is it published on the AGEB's Web site and are provisional Energy Balance data provided to the Federal Environment Agency for further processing within the system for the national greenhouse-gas inventory.

With a view to effective prevention of errors in data calculation and estimation for the Energy Balances, the annual balances are prepared via standardised procedures. To that end, a broad range of instruments has been developed that automate proven estimation procedures, and formal calculation methods, within the context of Energy Balance preparation. This approach, which often permits simple entry of statistical raw data into the suitable calculation tools, largely eliminates calculation and transformation errors. What is more, its use of consistent, standardised methods plays an important role in assuring time-series consistency.

18.4.1.1.6 Documentation and archiving

DIW Berlin, the EEFA research institute and the Centre for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW) keep careful, detailed documentation relative to the annual Energy Balances. The documentation covers every Energy Balance entry, lists the statistical sources and surveys used and precisely describes the calculation methods and procedures used. The purpose of the documentation is to ensure that all steps can be retraced, both by Energy Balance staff and by the Federal Ministry for Economic Affairs and Energy (BMWi) and the Federal Environment Agency. Furthermore, regular updating of the documentation contributes to data quality and helps to assure consistency in time series and methods.

All statistical data, calculation methods and estimation procedures used in preparation of Energy Balances for the Federal Republic of Germany are archived. The pertinent electronic data are backed up at DIW Berlin and at ZSW – both automatically, by central data systems, on dedicated server space, and manually, at regular intervals. For electronic archiving, the EEFA institute uses portable media (CD-ROMs, DVD), external drives and network-based server systems. Data back-ups are carried out both automatically and manually (at regular intervals).

18.4.1.1.7 Qualified staff

For execution of the service project "Preparation of Energy Balances for the Federal Republic of Germany" ("Erstellen von Energiebilanzen für die Bundesrepublik Deutschland"), DIW Berlin, the EEFA research institute and ZSW rely on experienced staff with solid backgrounds in the areas of statistics, economics and the energy sector.

18.4.1.1.8 Explanations regarding the currentness and availability of data for preparation of Energy Balances

Official statistics

The final annual data from the monthly survey 066 (electricity generation for the public supply), for 2016, became available in March 2017. Other annual surveys became available as follows: 064 (heat generation), November 2017; 067 (electricity generation systems of industry), October 2017; 070 (electricity feed-in), October 2017; and 073 (sewage gas), August 2017. Nos. 082/082P became available in January 2018. The results of surveys 066 (electricity generation systems for the public supply) and 067 (electricity generation systems for industry) have to be converted via the "Finnish" method. Calculations, checking and processes of consultation with the German Association of Energy and Water Industries (BDEW), Working Group on Renewable Energy Statistics (Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat), Energy Environment Forecast and Analysis (EEFA) institute, and Association of the German Petroleum Industry (MWV) take at least three weeks. The results of survey 060 (energy use by industry), which account for a significant component of the Energy Balances, became available in October 2017 (and the Federal Statistical Office provided corrections in January 2018). Calculations for individual sectors, plausibility checks, checking requests submitted to the Federal Statistical Office (which has to forward the requests to the Länder) and consultations with participating associations take at least three weeks. The results of survey 062 (geothermal energy) became available in November 2017.

As a result of such time constraints, an estimated Balance is prepared in July (in a process first carried out for the 2009 report) that incorporates the available official data from survey 066. The remaining data are first estimated and agreed on in cooperation with the AGEB member associations.

The following table presents an overview of publication times for statistics used in the Energy Balance for the Federal Republic of Germany:

Table 515: Data for the year 2016

Surveying institution	Statistics no.	Publication date
Federal Statistical Office	060	Oct. 2017; correction in Jan. 2018
	062	Oct. 2017
	064	Nov. 2017
	066	March 2017
	067	Oct. 2017
	070	Oct. 2017
	073	Aug. 2017
	075	Aug. 2017
	082/082P	Jan. 2018
BAFA	Official Mineral Oil Statistics (Amtliche Mineralölstatistik)	April 2017

Table 516: Data for the year 2015

Surveying institution	Statistics no.	Publication date
Federal Office for Statistics	Energy tax 2016, Tab. 2.3 Natural gas	June 2017

Association statistics

Data from associations (see above), which become available early, enter into the final Energy Balance.

Because quarterly estimates of primary energy consumption in Germany are carried out, provisional data in the relevant areas also become available quickly. The BDEW provides important provisional data, dated as of August, that are also of relevance to final energy consumption as recorded in the estimate Balance. Every summer, that organisation publishes data under the heading "The German energy market – facts and figures on the gas, electricity and district-heating sectors" ("Energiemarkt Deutschland – Zahlen und Fakten zur Gas-, Strom- und Fernwärmeversorgung"). In addition, the estimated Balance incorporates BDEW data on gross electricity generation, data of Statistik der Kohlenwirtschaft coal-industry statistics, data of the Association of the German Petroleum Industry (MWV) and data of the Deutsche Atomforum nuclear-energy association.

Other data

For the final Energy Balance, data on electricity generation from wind energy, photovoltaics and geothermal energy are used that are based on the quantities certified by auditors of transmission system operators (TSO), relative to electricity feed-in and relevant compensation, pursuant to the Renewable Energy Sources Act (EEG). Those data become available in August of each year.

The figures on electricity generation from biomass, and on biomass-fuel inputs in decentralised CHP systems, are based on internal calculations of the Working Group on Energy Balances (AGEB). In this connection, a method is used that was developed by ZSW and EEFA in the framework of reporting to IEA and Eurostat. With regard to wood consumption in the Residential and Commercial / Institutional sectors, figures of RWI/forsa and of the Thünen Institute were used. Data in the areas of solar thermal energy and environmental heat are based on model calculations.

Figures for electricity generation and fuel inputs in small CHP systems fired with natural gas and HEL (< 1 MW) were calculated with data the BHKW (compact combined heat-and-power (CHP) generating systems) database of the Öko-Institut e.V. Institute for Applied Ecology. The same data are used for reporting in the IEA/Eurostat context.

Table 517: Federal Statistical Office surveys used in preparation of Energy Balances for the Federal Republic of Germany

Survey	No.	Survey period	Currentness, pursuant to quality report	Type of data	Group surveyed	Units surveyed
Survey of energy use by manufacturing, mining and quarrying companies	060	Annually	End of the following year *(available as of the end of October / beginning of November)*	Electricity generation, deliveries and consumption **Fuels / energy sources, orders and consumption, by energy source / fuels** **Fuels / energy sources, deliveries and stocks, by energy source / fuels** Average net calorific value	Sections B "Mining and quarrying" and C "Manufacturing"	**Producing companies** (currently, at least 40,000) with **at least 20 employees** **Exception:** Plants of manufacturing sector companies with **10 or more persons active in the relevant economic sectors**
Survey on coal imports	061E	Monthly; annually	end of April of the following year	**Coal imports**	Companies that import lignite, lignite products, hard coal, hard-coal coke and hard-coal briquettes.	**Exhaustive survey** (but does not include units located abroad)
Survey on geothermal energy	062	Annually	About 9 weeks after the end of the reporting period	**Net heat generation** and output by type of system, and by domestic customer groups being supplied with heat.		The survey covers a maximum of **100 operators of systems for use of geothermal energy**
Survey of heat generation, demand, use and supply,	064	Annually	End of the following year *(available usually at the end of September)*	District heating: Net heat generation, demand, deliveries and network losses. No information on energy sources / fuels is provided Heating plants: **Fuel inputs and heat production, by energy sources / fuels**	Operators of **heating plants** with outputs of at least 1 MWth, and operators of **district heating networks** (only large networks that have grown "historically"). No **"island networks" for district heating** are surveyed.	**Max. of 1,000 operators** of heating plants, including absorption systems for refrigeration, and with outputs of **at least 2 MW_{th}.**
Survey of electricity and heat generation of electricity generation systems serving the public grid	066K	Monthly; annually	6 weeks after the end of the reporting period; end of June of the following year *(available in May)*	Number, net-electricity and net-heat production, by plant type, **Electricity and heat production, by energy sources / fuels** **Fuel inputs for electricity and/or heat production, by energy sources / fuels** (separate survey of CHP systems)	Companies and plants in the **electricity sector (public grid)**	**Max. of 1,000 operators of plants with outputs of at least 1 MW_{el}.**
Survey of electricity generation systems of manufacturing, mining and quarrying companies	067	Annually	9 weeks after the end of the reporting period *(available usually at the end of September)*	**Number and bottleneck capacity, by plant type** **Net-electricity and net-heat production (separate survey of CHP systems)** **Fuel inputs for electricity and/or heat production, by energy sources / fuels (separate survey of CHP systems)** Own consumption of electricity and heat	Sections B "Mining and quarrying" and C "Manufacturing"	Operators (currently, about 500) of systems **serving their own requirements**. Surveys cover systems for generating electricity, including systems for co-generation of electricity and heat (CHP) with **outputs of at least 1 MW_{el}**
Survey of network operators relative to electricity feed-in	070	Annually	12 weeks after the end of the reporting period *(available usually at the end of September)*	**Electricity feed-in, by Länder and energy sources / fuels** **Power statistics, separately for Länder and energy sources / fuels**	Operators of electricity grids for the public supply	**Exhaustive survey**
Survey of production, use and supply of sewage gas	073	Annually	8 weeks after the end of the reporting period *(available at the end of June / beginning of July)*	**Anaerobic sewage-gas collection** **Fuel inputs in power stations** **Fuel inputs for heating only or motors (drive units) only** **Electricity feed-in** **Own consumption**	Operators of wastewater-treatment plants	Max. of 6,000 operators of wastewater-treatment plants (currently, **about 1,300 operators**)
Survey on provision of liquefied petroleum gas	075	Annually	8 weeks after the end of the reporting period *(available at the end of June / beginning of July)*	**Provision of liquefied petroleum gas, by domestic customer groups and German Länder (states); and exports**	Companies that provide liquefied petroleum gas to end users and resellers	A maximum of 130 companies that provide liquefied petroleum gas to end users or resellers
Survey of production, supply, import and export of gas, and of revenue of gas utilities and gas sellers	082	Annually	National results become available 12 months after the end of the period covered by the report	**Extraction and production of gas, demand for gas, and value of relevant imports** **Deliveries and exports of gas, and relevant revenue** **Gas production, by gas types** **Gas deliveries, and revenue, by Länder**	Gas-sector companies	Exhaustive survey
Survey of supply, import and export of natural gas and petroleum gas, and of revenue of producers	082P	Annually	National results become available 12 months after the end of the period covered by the report	**Imports and exports; sales by domestic customer groups**	Natural gas producers	Exhaustive survey

Link to the nomenclature for classification of industrial sectors (Nomenklatur der Wirtschaftszweige; WZ 2008): https://www.destatis.de/DE/Methoden/Klassifikationen/Klassifikationen.html

Link to the quality reports on energy statistics, and to a pertinent questionnaire: https://www.destatis.de/DE/Publikationen/Qualitaetsberichte/Energie/EnergieWasserversorgung.html

18.5 REGULAR COMPARISONS OF ENERGY BALANCES

18.5.1 Comparison of the 2016 Energy Balance with the 2015 Energy Balance

The AGEB normally publishes the final Energy Balances in the spring of the next calendar year but one. With a view to providing data at earlier times, as of 2009 estimated Energy Balances are being prepared along with the evaluation tables. In some cases, those balances are based on different data sources (cf. the quality report of DIW and EEFA).

The following comparisons were carried out in the framework of the UNFCCC's review of the Energy Balances with regard to quality control and assurance:

- Comparison of the estimated Energy Balance with the Energy Balance for the previous year
- Comparison of the Energy Balance with the estimated Energy Balance for the same year
- Comparison of the Energy Balance with the Energy Balance for the previous year

In such comparisons, both absolute and relative discrepancies are calculated, to make it possible to identify any significant discrepancies between final and provisional Energy Balances. Such significant discrepancies have to be individually explained. Positions with discrepancies are analysed, by Energy Balance lines and Energy Balance columns, in light of a combination of the criteria "discrepancies in TJ" and "discrepancies in %". Discrepancies of 10,000 TJ and 20 % are used as thresholds.

With these criteria, the comparison of the 2016 Estimated Balance with the 2015 Energy Balance yields 43 positions (including sum fields). These are shown in the overview below and explained in the following.

The differences between the 2016 estimated Energy Balance and the 2015 Energy Balance 2010 are in keeping with the differences, with respect to the previous year, that were foreseeable at the time the estimated Energy Balance was prepared. The general reasons for such differences include economic trends, structural changes, changes in prices, weather-related effects and special developments such as the decision to discontinue use of nuclear power. Such general trends in energy consumption and its determining factors in 2016, in comparison to the corresponding aspects in 2015, are discussed in the annual reports of the Working Group on Energy Balances (AG Energiebilanzen; 2012).[213]

In addition, it must be noted that data discrepancies can occur in that other data sources have to be used to prepare the estimated Energy Balances, in some cases, than are used to prepare the final Energy Balances. Furthermore, differences can occur as a result of changes in methods.

The comparison of the Energy Balances serves the primary purpose of checking and documenting the plausibility of noticeable changes. In some Balance positions, changes determined via the aforementioned criteria are simply not unusual, however. For example, this applies to changes in stocks, which by nature differ significantly from year to year.

[213] AG Energiebilanzen (Working Group on Energy Balances): Energieverbrauch in Deutschland im Jahr 2017 (energy consumption in Germany in 2011). Slightly increasing energy consumption in 2017. February 2018. www.ag-energiebilanzen.de.

Table 518: Overview: Positions of note in the comparison of the 2016 Energy Balance with the 2015 Energy Balance

EB column	EB line	TJ	%	Explanatory remarks:
Hard coal	Domestic production	-69,485	-37.7	Development pursuant to coal industry statistics
Hard coal	Removals from stocks	-14,825	-100.0	
Hard coal	Additions to stocks	28,894		
Hard coal	Industrial thermal power stations (only for electricity)	19,593	278.0	Development pursuant to official statistics
Hard coal	Statistical differences	-22,178	-50.7	Formula
Hard coal	Primary chemicals	-20,672	-76.7	Development pursuant to official statistics
Hard coal	Other chemical industry	14,454	724.9	Development pursuant to official statistics
Coke	Exports	10,547	105.5	Development pursuant to official statistics
Coke	DOMESTIC PRIMARY ENERGY CONSUMPTION	-23,998	-32.5	Sum (formula)
Petroleum	Removals from stocks	22,526	219.5	Official Mineral Oil Statistics (AMS), Table 4
Gasoline fuels	Imports	-17,216	-21.1	AMS Tab 5b
Gasoline fuels	Domestic energy production	-17,216	-21.1	Sum (formula)
Gasoline fuels	DOMESTIC PRIMARY ENERGY CONSUMPTION	-43,522	35.7	Sum (formula)
Jet fuel	Exports	-15,149	-29.1	AMS Tab 6a
Diesel	Exports	59,391	21.2	AMS Tab 6a
Diesel	Additions to stocks	-19,936	-68.5	AMS Tab 6j
HEL	Removals from stocks	12,339	192.8	AMS Tab 6j
HEL	NON-ENERGY-RELATED CONSUMPTION	15,286	135.3	AMS Tab 7j
HS	Imports	23,763	30.3	AMS Tab 5b
HS	Domestic energy production	23,763	30.3	Sum (formula)
HS	Exports	-36,662	-29.7	AMS Tab 6a
HS	Bunker fuels	16,944	29.3	AMS Tab 6j
HS	DOMESTIC PRIMARY ENERGY CONSUMPTION	42,032	-40.0	Formula
HS	Manufacture of refined petroleum products	18,631	59.2	AMS Tab 5j
HS	Total transformation inputs	18,762	45.2	Sum (formula)
HS	Manufacture of refined petroleum products	-89,527	-26.0	AMS Tab 5j
HS	Total transformation emissions	-84,716	-24.0	Sum (formula)
HS	DOMESTIC ENERGY SUPPLY, PURSUANT TO TRANSORMATION BALANCE	-65,708	-37.4	Formula
HS	NON-ENERGY-RELATED CONSUMPTION	-69,753	-46.9	AMS Tab 7j
Petrol coke	Statistical differences	11,080	-125.9	Formula
LP gas	Residential, commercial and institutional	10,329	23.2	Comparison with BAFA report for JAQ 2015 and 2016
Refinery gas	Manufacture of refined petroleum products	31,724	21.5	AMS Tab 5j
Refinery gas	Total energy consumption in the transformation sector	31,724	21.5	Sum (formula)
AMP	DOMESTIC PRIMARY ENERGY CONSUMPTION	-17,919	36.0	Formula
AMP	Manufacture of refined petroleum products	93,891	34.5	AMS Tab 5j
AMP	Other energy producers	21,477	41.3	AMS Tab 5j + IKW + industry
AMP	Total transformation emissions	115,368	35.6	Sum (formula)
AMP	DOMESTIC ENERGY SUPPLY, PURSUANT TO TRANSFORMATION BALANCE	105,482	111.5	Sum (formula)
AMP	NON-ENERGY-RELATED CONSUMPTION	52,697	38.1	AMS Tab 7j– waste oil from transformation-related uses
AMP	Statistical differences	-51,725	-101.1	Formula

EB column	EB line	TJ	%	Explanatory remarks:
Blast furnace gas & basic oxygen furnace gas	Flaring and line losses	11,334	50.5	Residual account
Blast furnace gas & basic oxygen furnace gas	DOMESTIC ENERGY SUPPLY, PURSUANT TO TRANSFORMATION BALANCE	-22,112	-31.1	Sum (formula)
Blast furnace gas & basic oxygen furnace gas	FINAL ENERGY CONSUMPTION	-22,110	-31.1	Sum (formula)
Blast furnace gas & basic oxygen furnace gas	Metals production	-22,110	-31.1	Pursuant to BGS
Blast furnace gas & basic oxygen furnace gas	Mining, non-metallic minerals, manufacturing sector overall	-22,110	-31.1	Sum (formula)
Natural gas	Removals from stocks	-22,256	-81.3	Federal Statistical Office
Natural gas	Exports	-332,255	-29.1	Federal Statistical Office
Natural gas	Thermal power stations for the public supply	105,026	53.6	Federal Statistical Office and Finnish method
Natural gas	Total transformation inputs	138,775	23.9	Sum (formula)
Natural gas	Statistical differences	-60,648	-121.9	Formula
Natural gas	Other chemical industry	10,661	33.5	Federal Statistical Office
Electricity	Imports	-31,211	-23.4	Development pursuant to official statistics
Electricity	Domestic energy production	-31,211	-23.4	Sum (formula)
District heating	Commercial and institutional, and other consumers	-12,369	-21.3	Residual account
PET	Removals from stocks	-14,819	-28.1	The discrepancies in the sums become apparent here.
PET	Exports	-353,909	-28.6	The discrepancies in the sums become apparent here.
PET	Additions to stocks	32,452	1,359.5	The discrepancies in the sums become apparent here.
PET	Statistical differences	-78,725	-84.0	The discrepancies in the sums become apparent here.
PET	Other chemical industry	31,449	81.5	The discrepancies in the sums become apparent here.
SET	Removals from stocks	16,730	68.9	The discrepancies in the sums become apparent here.
SET	Additions to stocks	-17,284	-22.2	The discrepancies in the sums become apparent here.
SET	Statistical differences	-26,296	89.7	The discrepancies in the sums become apparent here.
Total	**Statistical differences**	**-105,021**	**-163.1**	**The discrepancies in the sums become apparent here.**
Total	**Other chemical industry**	**39,722**	**47.9**	**The discrepancies in the sums become apparent here.**

18.6 Energy-Data Action Plan for inventory improvement

Also in 2012, the Federal Environment Agency, working in cooperation with the Federal Ministry for Economic Affairs and Energy (BMWi), the Working Group on Energy Balances (AGEB) and the Federal Statistical Office, prepared an "Energy-Data Action Plan for inventory improvement" that outlined actions to be taken to address the criticism that emerged from the inventory review. This action plan fulfills the action-plan requirement set forth in Paragraph 39 of the 2011 review report (FCCC/ARR/2011/DEU).

Table 519: Energy-Data Action Plan for inventory improvement

No.	Issue	Responsibility	Responsibility for execution	Reference (paragraph)	Quotation from 2011 review report (FCCC/ARR/2011/DEU)	Instrument for implementation / publication	Activity for improvement	Result planned / achieved	Time perspective	Remark
1	Energy-Data Action Plan for inventory improvement	Federal Ministry for Economic Affairs and Energy (BMWi) / UBA / AGEB / Federal Statistical Office	UBA	39	*address review relevant issues in an action plan in the 2011 submission. […] The ERT reiterates the recommendation of the previous review report that Germany prepare a plan for the remaining abovementioned issues, and to report on it and on any progress achieved in its next annual submission*	Action plan; NIR	The pertinent action plan is being prepared, for the first time, for the 2013 inventory report	A coordinated Energy-Data Action Plan for inventory improvement is available for the 2012 inventory review process and will be updated annually	Ongoing	
2.1	Deadline compliance of the final Energy Balance	BMWi/AGEB/Federal Statistical Office/Statistical offices of the Länder	BMWi	39	*timeliness of reporting […]*	Process analysis, energy data; NIR	For the 2013 inventory report, a process analysis is presented. Inter alia, it covers reporting channels (these are described more precisely than in the past), the efforts made to shorten such channels and the relevant success achieved.	Process analysis, describing applicable reporting channels more precisely than in the past, and describing efforts made to shorten such channels and the relevant success achieved, enables review experts to determine that Germany has made use of all available possibilities for optimisation; The status of such work is documented in the NIR 2013	Completed	
2.2	Deadline compliance of	BMWi/AGEB/Federal Statistical	BMWi/AGEB (not for official	137	*In the course of the review, the ERT formulated a number*	Process analysis, energy data; NIR	Organisational improvements in	In future, official statistics are to be transmitted at an		

No.	Issue	Responsibility	Responsibility for execution	Reference (paragraph)	Quotation from 2011 review report (FCCC/ARR/2011/DEU)	Instrument for implementation / publication	Activity for improvement	Result planned / achieved	Time perspective	Remark
	the final Energy Balance	Office/Statistical offices of the Länder	data)/Federal Statistical Office and statistical offices of the Länder (for official data);		*of recommendations relating to the transparency of background and methodological information (e.g. in the energy[...] sectors), justification and documentation of recalculations (e.g. in the energy[...] sectors)[...] The key sectoral recommendations are that Germany: [...] (b) Improve the timeliness of reporting of the NEB (energy);*		the statistical offices of the Länder. In rapporteurs' meetings with the Länder, the Federal Statistical Office discusses possibilities and ways of improving the cooperation.	earlier time than has been the case to date.		
3.1	Discrepancies between provisional and final EB	BMWi/AGEB/Federal Statistical Office/Statistical offices of the Länder	AGEB; UBA	39	*significant differences between the preliminary and final NEB*	QC report; NIR	Energy data consistency analysis (EDKA)	Identification and clarification of discrepancies, along with differentiation and addressing of a) Informational deficits b) Documentation requirements c) Data problems d) Methodological changes	Ongoing	
3.2	Discrepancies between provisional and final EB	AGEB	AGEB	39	*significant differences between the preliminary and final NEB*	QC	The AGEB is working to reduce estimation errors. The contract for preparation of the Energy Balances for the years 2018 through 2020, which is currently in the tendering process, will stipulate that the existing estimation procedures and transition models are to be continually	AGEB reports on plausibility checks The AGEB reviews new procedures and methods for preparing the estimated Energy Balance. Specific proposals in this regard have been made (cf. the report of the EEFA research institute regarding approaches in estimation and modelling for the preparation of provisional Energy Balances.	Ongoing	

No.	Issue	Responsibility	Responsibility for execution	Reference (paragraph)	Quotation from 2011 review report (FCCC/ARR/2011/DEU)	Instrument for implementation / publication	Activity for improvement	Result planned / achieved	Time perspective	Remark
							optimised and recorded in writing.			
3.3	Discrepancies between provisional and final EB	AGEB, UBA	UBA	39	*significant differences between the preliminary and final NEB*	Inventory description	In the framework of work on the inventory and the 2015 National Inventory Report (NIR), discrepancies are described, and the results are presented in a "differences discussion".	The status of this work is documented in the 2015 inventory description: Documentation, revision of data for earlier years, reduction of estimation errors	Ongoing since 2012	
4	Complex National System	Federal Ministry of Economics and Technology (BMWi) / UBA / AGEB	UBA	39	*The previous review report noted several issues related to Germany's NEB (such as [...] the complexity of the NEB compiling process that may contribute to the problems with regard to timeliness and quality.*	NaSE	Exchange regarding the results of the inventory review and derivation of requirements for action;	Energy-data workshop on 16 Nov. 2010 Energy-data workshop on 5 August 2011 Energy-data workshop on 27 April 2012 Energy-data workshop on 7 August 2012 2013 Energy-data workshop on 7 May 2013 2014 Energy-data workshop on 5 June 2014 2016 Energy-data workshop on 3 May 2016		
5	Quality assurance	EEFA / German Institute for Economic Research (DIW) / Federal Statistical Office / AGEB / UBA	AGEB / UBA	39	*lack of QA/QC procedures in place for some data sources used to compile the NEB*	NIR	Joint AGEB quality report in the new Annex 2 of the NIR 2012 and in subsequent inventory reports	the NEB is subject to QA/QC procedures in accordance with the national system	Ongoing since 2012	
6.1	Discrepancies between EB and IEA data	BMWi, AGEB, persons responsible for questionnaires	BMWi	39	*low comparability with the IEA data*		To be jointly defined in the framework of the action plan	Introduction of a transition procedure for assuring compatibility between the Energy Balance and surveys in the areas of electricity and heat (cf. in this regard	Completed or ongoing	

No.	Issue	Responsibility	Responsibility for execution	Reference (paragraph)	Quotation from 2011 review report (FCCC/ARR/2011/DEU)	Instrument for implementation / publication	Activity for improvement	Result planned / achieved	Time perspective	Remark
								the report of the EEFA research institute to the AGEB and the Federal Ministry for Economic Affairs and Energy (BMWi). The transition has been successfully carried out as part of comprehensive revision of the questionnaires. Efforts to minimize discrepancies are being continued in other areas of the surveys and the Energy Balance. AGEB reports on plausibility checks Revision of the questionnaire for 2003-2011. Planned revision of the NEB	Completed Spring 2014	
6.2	Discrepancies between EB and IEA data	BMWi, AGEB, persons responsible for questionnaires	BMWi	45	*The ERT also noted differences between the inventory data and the corresponding IEA data (e.g. for solid fuels exports, the data show differences of over 60 per cent in some recent years […] Germany has provided some explanations for the divergences and informed the ERT that it is continuing to investigate these differences. The ERT considers that the differences cause no underestimation of emissions, but reiterates the recommendation of the previous review report that Germany explain the reasons for these differences between*		To be jointly defined in the framework of the action plan	See 6.1		

No.	Issue	Responsibility	Responsibility for execution	Reference (paragraph)	Quotation from 2011 review report (FCCC/ARR/2011/DEU)	Instrument for implementation / publication	Activity for improvement	Result planned / achieved	Time perspective	Remark
					its inventory data and the corresponding IEA data in its next annual submission.					
6.3	Discrepancies between EB and IEA data	BMWi, Working Group on Energy Balances (AG Energiebilanzen)	BMWi		*The ERT also noted differences between the inventory data and the corresponding IEA data (e.g. for solid fuels exports, the data show differences of over 60 per cent in some recent years […] Germany has provided some explanations for the divergences and informed the ERT that it is continuing to investigate these differences. The ERT considers that the differences cause no underestimation of emissions, but reiterates the recommendation of the previous review report that Germany explain the reasons for these differences between its inventory data and the corresponding IEA data in its next annual submission.*		Study on reduction of discrepancies between national and international energy statistics	Since the Member States' NECPs must lend themselves to comparison, they draw to a large extent on Eurostat data. In the interest of preventing inconsistencies, the existing discrepancies between national and international energy data (IEA, Eurostat) are to be minimised. For this reason, a study was commissioned for the purposes of a) producing a complete picture of the existing data discrepancies and their causes and b) developing strategies for reducing the discrepancies. The results of the study are now available. The tender for the contract for preparation of the Energy Balances for the years 2018 through 2020 takes account of the findings of the discrepancies study. As of the final 2020 EB, an evaluation is to be carried out with the aim of preventing the occurrence of unjustified new discrepancies to the greatest possible extent.	End of 2018 Beginning of 2022	
7.1	Improvement of the balance sheet for gases	BMWi / Federal Statistical Office	Federal Statistical Office	39	*significant amount of flaring/losses of natural gas in*	NIR, EB	Meeting involving all participating energy experts;	The significant amount of flaring/losses of natural gas are taken into account	Apr 12	Completed

No.	Issue	Responsibility	Responsibility for execution	Reference (paragraph)	Quotation from 2011 review report (FCCC/ARR/2011/DEU)	Instrument for implementation / publication	Activity for improvement	Result planned / achieved	Time perspective	Remark
		/ DIW / UBA / and others			*the NEB that were not transparently accounted for*		review and adjustment of the data source			
7.2	Improvement of the balance sheet for gases	BMWi / Federal Statistical Office / DIW / UBA / and others	Federal Statistical Office	39	*significant amount of flaring/losses of natural gas in the NEB that were not transparently accounted for*	NIR, EB	Updating of the gas balance sheets in the positions relative to flaring losses, and in positions relative to production, foreign trade, changes in stocks, non-energy-related consumption and energy-related consumption, in the Energy Balances for 2005 and for subsequent years	The significant amount of flaring/losses of natural gas are taken into account with regard to the time series Revision of the NEB	Completed	

18.7 Uncertainties in the activity data for stationary combustion systems

See NIR 2007, Chapter 13.6.

18.8 CO_2 emissions

The CO_2 emission factors have been completely revised for the 2015 report. For the first time, such work was able to draw extensively on data from emissions trading. Emissions trading data were available on relevant calorific values, emission factors, fuel quantities and data quality. The data were subjected to thorough quality control. For example, only factors on level 3 or 4 (measurement) entered into the calculations. In addition, emission factors were replaced if it was clear that they had simply been taken from lists. In emissions trading, some substance flows are not unambiguously named, and this can lead to erroneous material allocations in solid fuels categories. With regard to coal, it was possible to identify such misallocations, via the pertinent net calorific values, and then carry out the necessary resorting. Lignite and hard coal can be clearly differentiated via net calorific values. Annually weighted average values were calculated from the quality-checked data. To make it possible to determine whether the resulting factors are representative, the underlying fuel quantities were compared with the corresponding quantities in the Energy Balance. In addition, every effort was made to achieve the greatest possible consistency between net calorific values and emission factors.

Other data sources, in addition to the data from emissions trading, were evaluated as well. Furthermore, archive data were reviewed and measurements of our own were carried out. The recalculations through 1990 were carried out with widely differing procedures, chosen in each case in accordance with the specific subject area. This was done with a view to assuring time-series consistency and to obtaining the most realistic solutions possible. The task of finding well-documented archive data for the year 1990 presented a special challenge, since the documents from that period are available only in paper form and are housed at various different institutions. What is more, data are seldom kept for a period of longer than 20 years.

Since no reliable and representative data are available on the carbon content remaining in ash, an oxidation factor of 1 has been assumed. That figure is also the default value in the 2006 IPCC Guidelines (IPCC, 2006).

18.8.1 Hard coal

For hard coal, an inter-sectoral emission factor has been calculated. In the present case, this ensures that the total emissions are determined as precisely as possible. One exception in this case consists of the coking coal for the iron and steel industry, which differs considerably from steam coal. Another exception consists of the anthracite coal used in the residential sector and in other small combustion plants; that coal has considerably higher calorific values and carbon-content levels.

For the other types of hard coal, emissions trading data from the years 2005 – 2014 were evaluated. For each type, there are substance flows that can be correlated with specific areas of origin. This makes it possible to determine origin-specific CO_2 emission factors and calorific values. Apart from the coal for which origin-specific data are available, there are quantities of mixed coal, and of coal of uncertain origin, to consider. CO_2 emission factors and calorific values were determined for all individual coal fractions (Germany, South Africa, Australia, Indonesia, Columbia, Norway, Poland, Czech Republic, Russia, the U.S. and Venezuela). In addition, weighted averages were calculated for the other hard-coal types for which specific values cannot be obtained. Two different methods for recalculating the emission factors for hard coal were reviewed. On the one hand, a weighted average for each year was calculated with the help of the data on the various individual areas of origin and the import-flow figures from hard-coal statistics. On the other, a weighted average was formed from all of the emission factors reported and checked in the emissions trading framework. The following figure shows the results of this comparison:

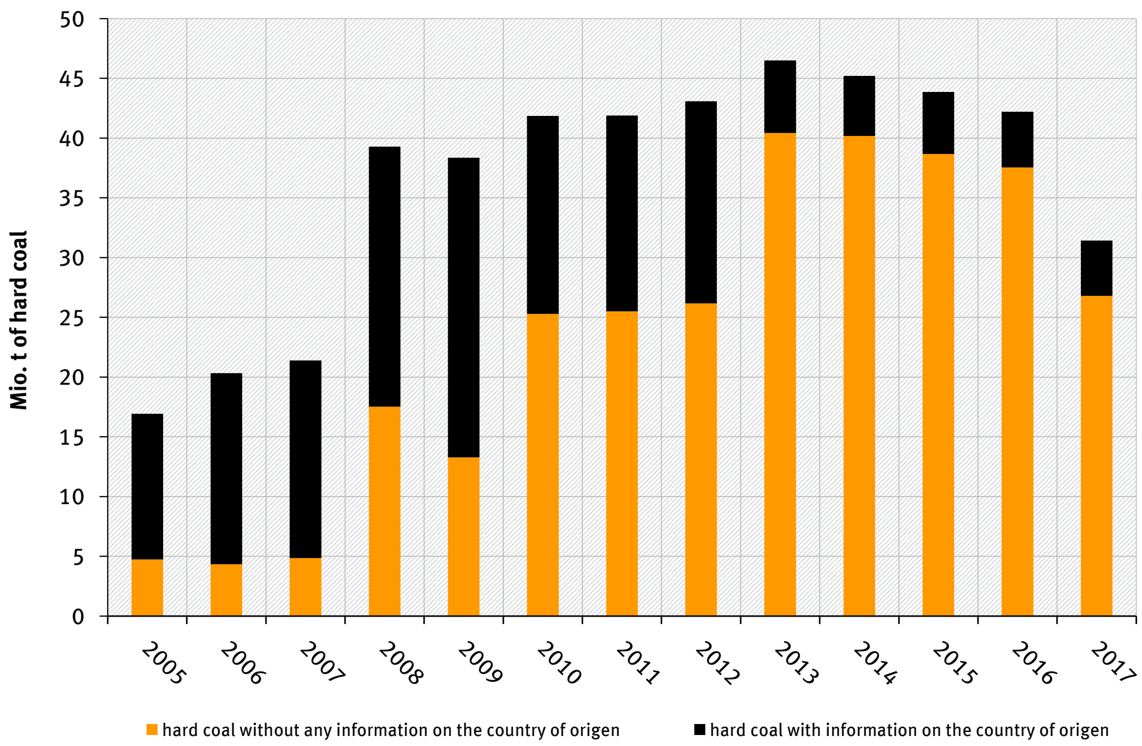
Table 520: Comparison of CO_2 emission factors for hard coal

[t CO2/TJ]	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Calculation via imports	93.874	93.976	93.865	93.924	93.993	94.003	94.181	93.652	93.276	93.888
Weighted EF from all ETS data	93.606	93.940	93.792	94.317	94.121	94.032	94.228	93.675	93.363	93.560
Difference	**0.29%**	**0.04%**	**0.08%**	**-0.42%**	**-0.14%**	**-0.03%**	**-0.05%**	**-0.02%**	**-0.09%**	**0.35%**

Since the differences are very small in most years, as of the year 2006 the weighted emission factors for all hard coal reported in the emissions trading framework (apart from that in the iron and steel sector) can be used – regardless of the area of origin involved. For the recalculation through 1990, the origin-specific emission factors calculated from emissions trading data are combined with the relevant import flows. This produces a consistent time series.

The following figure shows the evaluatable hard-coal quantities for which emission factors and calorific values were available that were measured in the emissions trading framework.

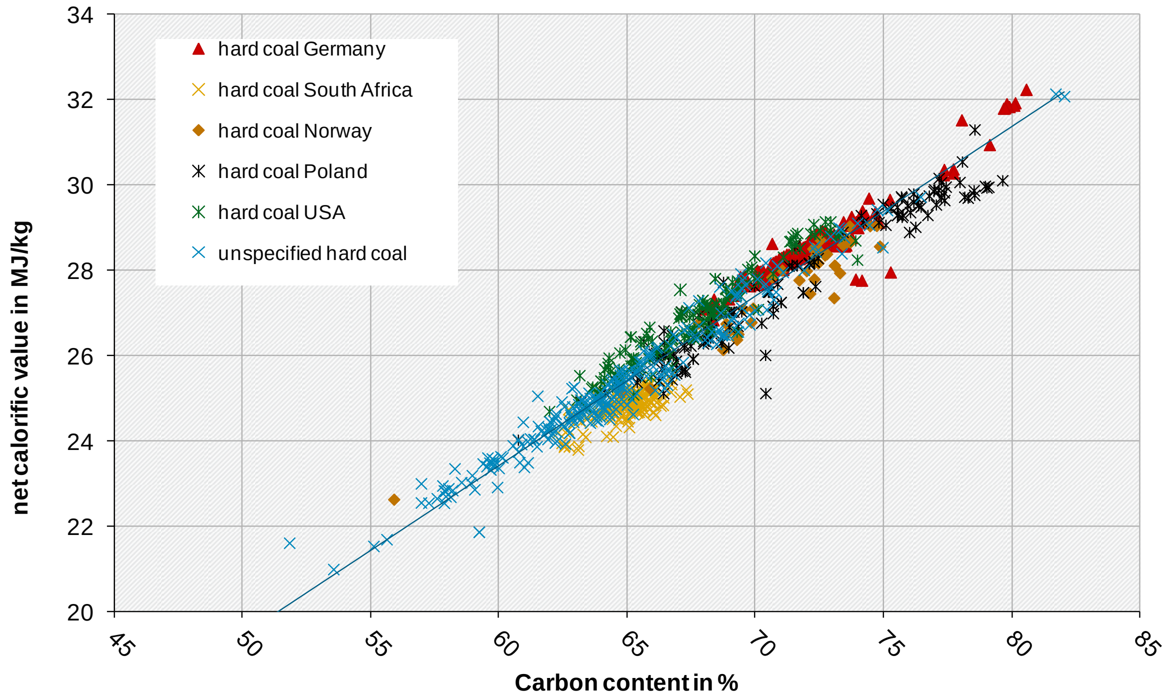
Figure 85: Hard-coal quantities for the emission factors and calorific values measured in the emissions trading framework



It emerges that the quality of the values increases – especially so as of the year 2008 – due to changes in regulations. Furthermore, the quantity of hard coal that can be clearly allocated to a specific mining area decreases noticeably. For this reason, the most sensible approach, from a technical standpoint, is to form a weighted average for all hard coal, regardless of area of origin. This is the only way to ensure that the emission factors are representative.

All in all, very thorough quality checks were conducted, and numerous evaluations were carried out. As the following figure illustrates, it is possible to develop fairly clear origin profiles, and there is a clear relationship between carbon content and net calorific value.

Figure 86: Relationship between carbon content and calorific values, for various qualities of hard coal



Most types of hard coal have a carbon content (with respect to the original substance) of between 60 and 75 %. The average, depending on the year concerned, lies between 65 and 66 %. The hard coal in the lower range, with a carbon content as low as 56 %, and a net calorific value of no more than 22 MJ/kg, can be referred to as "high-ballast coal". The hard coal in the upper range, as of a net calorific value of about 30 MJ/kg, is of coking-coal quality. The highest carbon-content levels are found in anthracite.

The figure does not include values for the **coking coal** used in Germany. Coking coal was evaluated separately, due to its special characteristics. In addition, no evaluatable net calorific values are reported, with regard to coal in the emissions trading framework, for the iron and steel industry. As a result, only weight-based emission factors have been determined for that area. Consequently, the coal quantities in that area have also been recorded in terms of tonnes. Since the available statistics give virtually no pertinent calorific-value figures, it seems useful to calculate with natural units. With the help of intensive discussions with the responsible experts of the German Emissions Trading Authority (DEHSt), it proved possible to determine representative emission factors for the hard coal used in the iron and steel industry. From the same data set, combined emission factors were developed for **hard-coal coke, hard-coal tar and benzene**, which in the Energy Balance are listed under "other hard-coal products".

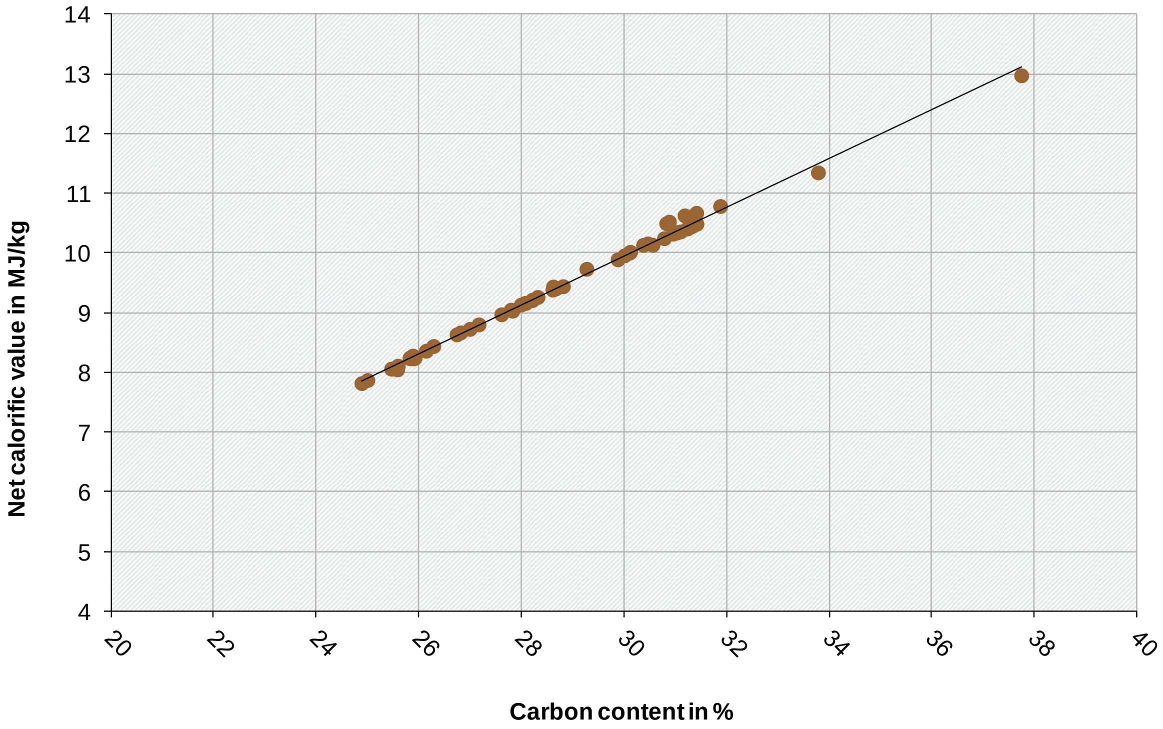
With regard to **hard-coal coke**, an average, energy-based CO_2 emission factor was calculated, for all other industrial sectors, from the emissions trading data for the years 2005 – 2013. The emission factors for the subsequent years differ only slightly, and thus calculations can continue to use the average value.

Since emissions trading statistics do not cover the **hard-coal briquettes** used in small combustion plants, we carried out our own analyses for that area, in the framework of a project. The resulting values have been entered back through the year 1990, since no representative values are available for the base year.

18.8.2 Lignite

The raw lignite used for electricity generation for the public grid can be allocated, via lignite statistics, to specific coalfields. For the period as of the year 2005, the CO_2 emission factors are determined from emissions trading data. The carbon content figures (with respect to the original substance) are also available in mining-district-specific form. The following figure provides an illustrative example:

Figure 87: Relationship between carbon content and net calorific values, illustrated with the example of crude-lignite quality



The variances in sulphur content are larger in lignite than they are in hard coal. Since sulphur content has a noticeable effect on net calorific value and, thus, on the relationship between carbon content and net calorific value, lignite has to be evaluated mining-district-specifically. As Figure 87 shows, there is a clear correlation between net calorific value and carbon content. Consequently, for each relevant year the carbon content, and the energy-related CO_2 emission factor, can be calculated, via a resulting formula, from the net calorific value as known for that year. This makes it possible to recalculate the figures back through 1990 – and thus to form a consistent time series. Some uncertainties do remain, however, since it is likely that a number of small mines were in operation in 1990 that produced coal with other sulphur-content levels. That supposition can no longer be checked, however. Hardly any carbon analyses were carried out in 1990, because carbon content was not an issue at that time. Only a few individual analyses were carried out, and their results are not necessarily representative. For example, only net-calorific-value data are available for lignite from the state of Hesse (Hessische Braunkohle), which was mined until 2003. For recalculation purposes, a mid-level sulphur content was assumed, a level between those found in the Mitteldeutsch ("central German") and Rhenish coalfields. That coal is of little relevance in terms of quantity, however. Between 1991 and 1992, the applicable emission factor changed sharply, because two power stations in that district went offline during that period, and they had been fired for some time with low-quality coal.

For raw-lignite inputs in district heating stations, a weighted emission factor is calculated from lignite inputs for the public electricity supply. For industry and the residential, institutional and commercial (small consumers) sectors, a weighted emission factor was calculated, from sales statistics of the DEBRIV Federal German association of lignite-producing companies and their affiliated organisations, that reflects the distribution of the relevant coalfields.

The emission factors for **lignite briquettes** were determined on the basis of emissions trading data for the period as of 2005. From those data, mining-district-specific averages, for each specific year, were formed. Then a weighted average was calculated from those averages, with the help of DEBRIV sales statistics. The emissions trading data cannot be used directly, since they do not completely reflect and cover the areas being reported on. The residential, institutional and commercial sectors do not take part in emissions trading. To ensure that the fuel-quality figures are the same, the ETS-based data evaluations were compared with our own analyses for briquettes in the residential sector. The two data sets show good agreement. While lignite briquettes are a standardized product, for which certain quality requirements apply, mining-district-specific differences still occur, in the form of carbon-content and sulphur-content variances in the raw lignite used. The recalculation back to 1990 proved to be considerably more complicated than the calculation for raw lignite. From the ETS data for the period 2005 – 2013, it was possible to calculate an average CO_2 emission factor only for Rhenish lignite briquettes. That factor can also be used for the years 1990 – 2004. In the new German Länder, a great many briquette factories were closed in the early 1990s. This considerably changed fuel quality levels in that region. No briquettes are now produced from central German (Mitteldeutsch) lignite. Consequently, no current relevant measurements are available. For this reason, we had to rely on archive data in this area. Data from analyses carried out by Mohry in 1986, and data from the 1986 "Jahresbericht der Kohleindustrie der DDR" ("annual report on the coal industry of the GDR") were available. It emerged that the carbon content previously assumed for central German (Mitteldeutsch) briquettes was too high, by a considerable amount. In calculation of the average values, care was taken to ensure that the resulting emission factors agreed with the net calorific values published by DEBRIV. As a result, it was possible to calculate an annual CO_2 emission factor for each coalfield. From those factors, it was then possible, with the help of DEBRIV sales statistics, to calculate weighted annual CO_2 emission factors.

Data on **lignite dust and fluidised-bed coal** are easier to obtain, since emissions trading data are available from all relevant coalfields. For the recalculations through 1990, average values from the years 2005, and 2008 – 2013, were used, depending on data quality. In an approach similar to that used for raw lignite and briquettes, a weighted CO_2 emission factor was calculated for lignite dust and fluidised-bed coal with the help of DEBRIV sales statistics. As of the year 2005, the CO_2 emission factors from emissions trading are entered directly into the calculation. Then, via the customary procedure, weighted factors are calculated with the help of mining-district-specific sales statistics.

Lignite coke is currently being produced in only one coalfield. In general, hearth furnace coke is used primarily for its properties as a material. Since fuel quality in this category fluctuates very little, an average was formed from the ETS data for the period 2008 – 2013 and then used for recalculations back through 1990. For the new German Länder, only one data source was available. That source consists of analyses carried out by the Ingenieurschule für Bergbau und Energetik "Ernst Thälmann" (the "Ernst Thälmann" school of engineering, specialising in mining and energy technology), located in Senftenberg. It seems plausible, however, that the coke studied in those analyses, in comparison to Rhenish coke, had a considerably lower carbon content and considerably higher ash and sulphur content. Consequently, the emission factor calculated for the new German Länder is lower.

The emission factor determined for 2014, from emissions trading data, at 109.317 t CO_2/TJ, is very close to the average value calculated for 2005 – 2013, 109.578 t CO_2/TJ.

The data set from the Ingenieursschule für Bergbau und Energetik "Ernst Thälmann" in Senftenberg also included analyses for **air-dried peat**. The net calorific value given agrees with the corresponding value used in the Energy Balance. The values for the **lignite tar oil** used in refineries in the new German Länder come from the same data source.

No data were available for the **lignite tar** used in the new German Länder. As an alternative, analysis data from the research report Vertrag Nr. (contract no.) 7220-EB/106 (DEBRIV 1980) were used. Lignite tar has not been used since 1991.

The ETS data can be used to generate CO_2 emission factors for **meta-lignite** for the period as of 2008. At present, only very small quantities of meta-lignite are used in Germany. To make it possible to calculate the applicable emission factors for the period back through 1990, the relevant carbon / net calorific value relationship was determined from the available ETS data. It was then possible, with the help of the net calorific values known from the DEBRIV lignite statistics, to produce a consistent time series.

18.8.3 Petroleum

Crude oil and **naphtha** are not used in combustion systems in Germany. For this reason, the emissions trading data do not include any carbon-content figures for these raw materials. In addition, no analysis values are available from other sources. For this reason, the default values from the 2006 Guidelines have been used. The relevant factors have been used only for the Reference Approach and for the transformation balance for refineries. Default values have also been used for **avgas** and **lubricants**.

For calculation of the CO_2 emission factors for **gasoline**, research report 502-1 of the German Society for Petroleum and Coal Science and Technology (DGMK), "Zusammensetzung von Ottokraftstoffen aus deutschen Raffinerien" ("composition of gasolines produced by German refineries") (DGMK, 2002) was comprehensively evaluated. That study studied the components of the fuels involved in great detail. As a result, data are available on the average concentrations of 113 individual substances, and of 16 substance groups, in the categories regular gasoline, super (premium) and super plus (premium plus), for all German refineries. Via the carbon-content levels in the substances listed, and the pertinent concentrations, it was possible to calculate weighted carbon-content levels for each of the 3 grades of gasoline involved. This was because it was possible to calculate weight-based emission factors from carbon content. The following table presents the average values and fluctuation ranges ranges for the CO_2 factors:

Table 521: Composition of, and emission factors for, gasoline

		average CO_2 EF	Minimum	Maximum	Units
Regular gasoline		**3.183**	**3.160**	**3.206**	**t CO_2/ t**
Super (premium)		**3.185**	**3.152**	**3.211**	**t CO_2/ t**
Super plus (premium plus)		**3.141**	**3.102**	**3.176**	**t CO_2/ t**
With the following composition:					
Regular gasoline	Kerosenes	45.30	52.06	41.64	%
	Aromatic compounds	37.14	28.68	48.12	%
	Oxygen compounds	0.30	0.32	0.19	%
Super (premium)	Kerosenes	40.23	23.32	32.22	%
	Aromatic compounds	43.44	47.99	46.30	%
	Oxygen compounds	2.54	11.52	0.01	%
Super plus (premium plus)	Kerosenes	33.95	41.60	33.29	%
	Aromatic compounds	44.33	34.43	49.19	%
	Oxygen compounds	10.49	13.44	6.80	%

The naphthenes and olefins in the gasolines, while worthy of mention as additional components, have virtually no influence on CO_2 factors. In the case of regular gasoline, levels of aromatic compounds are the main factor that affects the size of CO_2 emission factors. On average, aromatic compounds tend to have higher carbon-content levels than kerosenes do. The levels of aromatic compounds found in a gasoline depend primarily on whether the refinery that produces the gasoline also produces basic chemical compounds. Where refineries do produce such compounds, efforts are made to make the highest possible fractions of aromatic compounds available for chemical production processes. The levels of aromatic compounds found in premium-grade gasolines fluctuate only very slightly. The CO_2 factors for such gasolines are determined primarily by the gasolines' content of oxygen compounds (MTBE). In the case of super plus (premium plus) grades, the levels of aromatic compounds and of oxygen compounds both play a role.

A weighted CO_2 emission factor has been calculated from the figures on annual sales of regular gasoline (Normalbenzin), premium (Super) and premium plus (Super Plus) (Official Mineral Oil Statistics). No figures for the new German Länder are available for the year 1990. For this reason, the breakdown by individual fuel qualities for the year 1991 has been applied to 1990. In the interest of consistency, an energy-related CO_2 emission factor has been calculated from the calculated weight-based emission factor and the lower net calorific value listed in the Energy Balance. So-calculated emission factors hardly fluctuate at all over the years concerned. The only year in which the emission factor changed more significantly was 2011, when the factor was unusually low. When the "E10" fuel was introduced (with a 10% biofuel fraction in premium grade fuel), greater quantities of Super Plus (premium plus) were sold.

The basis for calculation of the emission factor for **diesel fuel** is research report (Forschungsbericht) 583 of the German Society for Petroleum and Coal Science and Technology (DGMK): "Zusammensetzung von Dieselkraftstoffen aus Deutschen Raffinerien 1999-2002" ("Composition of diesel fuels from German refineries, 1999-2002"). For that study, winter and summer samples from 13 refineries were studied. From the analysis results, an average value for the fuel quality in summer and an average value for the fuel quality in winter were calculated. In Germany, the availability of "winter diesel" is regulated by law. The law requires service stations to offer winter diesel from 15 November to 28 February. In addition, a transition phase has to be taken into account, and thus a usage period of about 4 months can be expected for winter diesel. Consequently, diesel-powered vehicles operate with summer diesel for 8 months. Via this distribution, a weighted emission factor was calculated from the analysis results relative to summer and winter diesel.

The CO_2 emission factors for **light fuel oil, petroleum coke, heavy fuel oil** and **other petroleum products** have been calculated from emissions trading data. The relevant average values for the years 2005 – 2013 have been applied to the years back through 1990. As of 2005 (or 2008, as relevant), year-specific, weighted average values from emissions trading will be used for petroleum coke, heating oil (heavy) and other petroleum products. It is difficult to draw a precise line between heavy fuel oil and other petroleum products. In keeping with Mineral Oil Statistics (Mineralölstatistik), "other petroleum products" have been defined as residual substances from refineries, and the pertinent emission factor has been calculated accordingly.

For **refinery gas**, a weight-based CO_2 emission factor has been calculated from the ETS data. Since the annual fluctuations for such gas are small, the same factor, formed from the average values for the years 2005 – 2013, has been used for all years. While the lower net calorific values given in the context of emissions trading show only slight annual fluctuations, the calorific values used in the Energy Balance vary significantly, in some cases, and show discrepancies with the ETS data. The refinery-gas quantities reported in the Energy Balance come from the Mineral Oil Statistics. Those values agree well with the ETS data. In the interest of consistency, the lower net calorific values used in the Energy Balance were chosen for inventory preparation. The pertinent emission factor has been adjusted accordingly.

For determination of the CO_2 emission factors for **LP gas**, first the applicable carbon content levels for butane and propane were calculated via molar masses. The pertinent fractions for the two components are published in the annual report of the German Liquid Petroleum Gas Association (Deutscher Verband Flüssiggas e.V.). The data through 1990 have also been provided by that association. Via the applicable fractions for the two components, a weighted emission factor years was calculated, and then that factor was divided by the lower net calorific value used in the Energy Balance. The LP gas emission factors published in the NIR apply only to energy-related consumption. The data for material-related use differ, since the relevant mixtures contain more butane than propane on average. Gas for energy-related use tends to contain more propane than butane. Unfortunately, the ratios between the two fuels are no longer available as of reported year 2017. For this reason, the existing butane-to-propane ratio will be carried forward in future. This is not expected to have a major impact. The fractions for the two fuels varied only insignificantly over the years.

18.8.4 Gases

Some gaseous fuels are allocated to the solid fuels category, in keeping with a) the IPCC fuel definitions and b) the Guidelines' emphasis on the fact that they originate in solid fuels or are produced from such fuels. This approach is taken for coke oven gas, town gas, blast furnace gas and basic oxygen furnace gas. The other relevant produced gases are allocated to the liquid fuels category, since those gases are produced primarily by the chemical industry, in non-energy-related consumption of naphtha and other petroleum products. These allocations play a necessary role in enabling the Reference Approach to achieve useful results.

For determination of CO_2 emission factors for **coke oven gas, blast furnace gas, basic oxygen furnace gas** and **petroleum gas**, emissions trading data are used. For the recalculations back through 1990, average values were calculated from the ETS data for the period 2005 – 2013 and then used for the years 1990 – 2004. In energy statistics, blast furnace gas and basic oxygen furnace gas are reported only as a gas mixture. For this reason, a weighted emission factor for such mixtures has been calculated from the individually determined emission factors for the two gases and from produced quantities of blast furnace gas and basic oxygen furnace gas. In all likelihood, the mixing ratios of such mixtures vary throughout the different specific areas in which the mixtures are used. Emissions trading data only partially cover combustion of blast furnace gas and basic oxygen furnace gas, but the calculation method used here ensures that the total emissions of such gases are still calculated correctly.

Until 1996, town gas was still used in Germany. In in the Energy Balance, it is combined with coke oven gas. The applicable fractions of **coke oven gas and town gas** cannot be determined on the usage side (the situation is similar to that for combustion of blast furnace gas and basic oxygen furnace gas). For this reason, here as a well a weighted emission factor is calculated – in this case from the produced quantities of coke oven gas and town gas. The values for **town gas** have been obtained from the firms of GASAG and DBI Gas- und Umwelttechnik GmbH Leipzig. Detailed analyses are available for the years 1989 through 1991. The different gases have been mixed so as to yield mixtures with fairly constant town-gas quality. DBI Gas- und Umwelttechnik GmbH Leipzig has also provided information regarding the mixing ratios in which the gas fractions are combined to produce summer-quality and winter-quality grades. The emission factors have been weighted accordingly. The figures for **fuel gas**, which is used exclusively in the new German Länder, have been obtained from a data set provided by the Ingenieurschule für Bergbau und Energetik "Ernst Thälmann" (the "Ernst Thälmann" school of engineering, specialising in mining and energy technology), located in Senftenberg. The term "fuel gas" has not been clearly defined. Since that gas has been used primarily in mine-mouth power plants, it may be assumed to be lignite-based. Such gases can vary widely in composition, however. Consequently, the applicable emission factors can also vary widely. They lie within the range 118.6 – 131 t CO_2/TJ. To ensure that the base-year emissions are not overestimated, a conservative approach is applied, and the lowest emission factor is used. The 1989 annual report for the energy sector (Energiewirtschaftlicher Jahresbericht 1989) gives a net calorific value of 5.3 MJ/Nm^3 for "other gas", a figure that points to a higher emission factor. Since coke oven gas, town gas and fuel gas are reported in combined form in the Energy Balance, the net calorific values for those individual gases can no longer be determined.

Other produced gases are used primarily in the chemical industry. The category to which that term refers includes both a) gases with high calorific values and with large hydrogen fractions and b) flare gases with low calorific values and with large nitrogen fractions. The pertinent emission factor has been calculated from emissions trading data for the chemical industry. In the process, an average value for the years 2008 – 2013 was formed. Although the calorific-value figures given in energy statistics differ considerably from those used in emissions trading, the applicable cubic-metre quantities listed in the two contexts show good agreement. Consequently, an emission factor based on those natural units (cubic metres) was calculated for this category. In the interest of consistency, the net calorific value used in energy statistics has been used for calculations for inventory preparation. An analysis of the energy consumption in large combustion plants has shown that the generated electricity quantities were considerably larger than had been previously thought. As a result of this discrepancy, a decision has been made calling for use of a different net calorific value in future calculations. The CO_2 emission factor will decrease as a result.

For **mine gas**, a methane content figure was calculated with the help of the methane-utilization data provided by the Gesamtverband Steinkohle (GVSt) hard-coal-mining association and the total methane quantities listed (in cubic metres) in the Energy Balance. A CO_2 emission factor was then calculated via the corresponding gas composition. Statistical differences result in some years, and thus calculations are carried out with the lowest methane-content figure, in the interest of applying a conservative approach.

Since the **natural gas** quantities recorded in the emissions trading context are not representative, and since default emission factors are often used in this category, the firm of DBI Gas- und Umwelttechnik GmbH Leipzig carried out its own analyses in the framework of the project "Messungen der Erdgasqualität an verschiedenen Stellen im Netz zur Ableitung bzw. Verifizierung von durchschnittlichen Emissionsfaktoren und Heizwerte von Erdgas" (2014; measurements of natural gas quality at various locations within the network, for purposes of derivation and verification of average emission factors and net calorific values for natural gas). In that effort, measurements were carried out at 32 locations throughout Germany. The measurement points were selected so as to ensure that all important imported gases and the country's own in-country production were taken into account. In addition, a mixture distributed in Germany was analysed. Alternative measuring sites were found for selected border handover points at which measures proved unfeasible. Within the relevant gas-quality ranges, the CO_2 emission factors fluctuate only very slightly. And the values fluctuate very little overall. In an approach similar to that used for other fuels, no sector-specific emission factors were determined for natural gas. As it is, the data do not allow determination of such factors. It thus seemed advisable, and more feasible, to determine weighted emission factors at the national level. They were calculated on the basis of the measurements carried out, of import flows and of the country's own production. Since 2015, it has no longer been possible to use this calculation method, since large quantities of imports are subject to confidentiality. As a result, for the period as of 2015, the weighted average values calculated from emissions trading data have been used, even though such average values are not fully representative of the actual situation. In previous years, the different factors were very similar.

18.8.5 Waste and special fuels

For **waste**, a carbon content pursuant to VDI 3460 is assumed. Energy statistics serve as the data source for the calorific values. The data for **special fuels** were obtained from the project "Einsatz von Sekundärbrennstoffen" ("use of secondary fuels"; Lechtenböhmer et al. (2006c), FKZ 204 42 203/02). These data still need to be reviewed, with the help of emissions trading data, and corrected as necessary. In general, it is difficult to compare data on fuels with relevant biomass fractions with ETS data, since the emission factors for such fuels do not always take account of the biomass fractions. What is more, the terms used in the ETS context are not always unambiguous. And since the net calorific values of special fuels vary considerably more strongly than those of conventional fuels do, net calorific values cannot be used for unambiguous identification of special fuels. All of these factors considerably complicate such comparisons. While for conventional fuels inter-sectoral emission factors are determined in most cases, for special fuels the factors have to be calculated sector-specifically.

For a few special fuels, emissions trading data have already been evaluated. This applies to **waste oil** and **waste plastics**. The relevant values are used in the carbon balance for the iron and steel industry. The emission factor for **waste tyres** has been calculated from ETS data from the year 2010.

18.8.6 Biomass fuels

The emission factors for the biomass fuels that are used as **substitute fuels** in industry have also been obtained via the project "Einsatz von Sekundärbrennstoffen" ("use of secondary fuels"; Lechtenböhmer et al. (2006c), FKZ 204 42 203/02). The CO_2 emission factors for **wood** have been obtained from the research report "Effiziente Bereitstellung aktueller Emissionsdaten für die Luftreinhaltung" ("Efficient provision of current emissions data for purposes of air quality control"; (Struschka et al., 2008)).

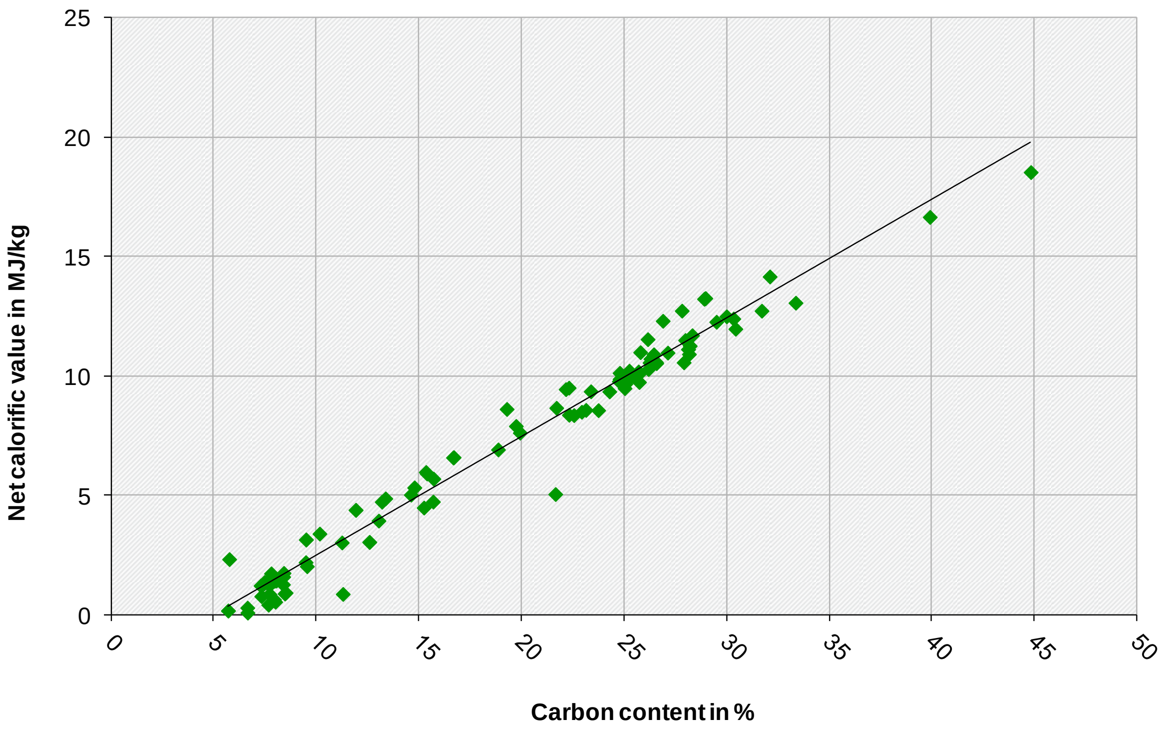
With regard to **black liquor** from wood pulp production, emission factors for spent sulphate liquor and for spent sulphite liquor were calculated on the basis of operator information relative to liquor composition. A weighted mean is formed annually by applying those two values to the produced quantities of sulphite and sulphate wood pulp.

The process for calculation of the CO_2 emission factors for **biogas, landfill gas** and **sewage gas** began with evaluation of relevant net calorific values from energy statistics. Averages of those calorific values were then calculated for each category from the values for the years 2009 – 2011. Then, corresponding methane quantities were determined from each such average calorific value. Apart from methane, these gases consist mainly of carbon dioxide and a small nitrogen fraction. As a result, the net calorific value is determined via the methane content. The biogases also contain other hydrocarbons, in fractions totalling about 1 %. A CO_2 emission factor was then calculated via this known gas composition.

The emission factor for **bioethanol** was calculated on the basis of the number of carbon atoms, and of the molar mass, of ethanol. The relevant net calorific value is published by the Bundesverband der Deutschen Bioethanolwirtschaft German bioethanol industry association. For **bodiesel**, we did not carry out any analyses of our own. For this reason, the default emission factor given in the 2006 IPCC Guidelines (IPCC, 2006) has been used.

For determination of the CO_2 emission factors for **sewage sludge, waste wood and animal meal**, data from emissions trading were evaluated. For animal meal and waste wood, a median was formed from data on carbon content and net calorific value available for the period 2005 through 2014. For sewage sludge, data from municipal waste-management companies were also included in the evaluation. Since sewage sludges are used both in their original condition and in a dry condition, the spectrum of net calorific values ranges from < 1 MJ/kg to 18 MJ/kg. Consequently, the standard deviation for the CO_2 emission factors is so high that it would not be useful to form an average or median. Since the carbon content correlates very well with the net calorific value, a suitable formula can be derived from the graphic representation (cf. the following figure).

Figure 88: Relationship between carbon content and calorific values, for various sewage sludges



As a result, the pertinent carbon content and emission factors can be calculated with the help of the net calorific values, as given in energy statistics, for co-incineration and for mono-incineration.

18.8.7 List of carbon dioxide emission factors derived for energy & industrial processes

The following tables provide an overview of the carbon dioxide emission factors used in the inventory.

Table 522: CO_2 emission factors derived for emissions reporting for the period as of 1990; energy

Fuel-based emission factors	Units	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Coal																	
Hard coal																	
Raw hard coal (power stations, industry)	t CO2/TJ	93.1	93.1	93.2	93.2	93.2	93.1	93.2	93.4	93.4	93.4	93.5	93.8	93.8	93.9	93.9	93.9
Hard-coal briquettes	t CO2/TJ	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9	95.9
Hard-coal coke (not including that for the iron & steel industry)	t CO2/TJ	108.1	108.1	108.1	108.1	108.1	108.1	108.1	108.1	108.1	108.1	108.1	108.1	108.1	108.1	108.1	108.1
Hard-coal coke for the iron & steel industry	t CO2/ t	3.29	3.29	3.28	3.27	3.27	3.26	3.25	3.25	3.24	3.23	3.23	3.22	3.21	3.21	3.20	3.19
Anthracite (heat market for households, commerce, trade, services)	t CO2/TJ	97.6	97.6	97.6	97.6	97.6	97.6	97.6	97.6	97.6	97.6	97.6	97.6	97.6	97.6	97.6	97.6
Ballast hard coal, *old German Länder*	t CO2/TJ	95.2	95.2	95.2	95.2	95.2											
Coking coal, *Germany*	t CO2/ t	2.96	2.96	2.95	2.94	2.94	2.93	2.93	2.92	2.91	2.91	2.90	2.89	2.89	2.88	2.88	2.87
Hard coal for the iron & steel industry	t CO2/ t	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.92	2.95
Other hard-coal products	t CO2/ t	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30
Hard-coal tar	t CO2/ t	3.27	3.27	3.27	3.27	3.27	3.27	3.27	3.27	3.27	3.27	3.27	3.27	3.27	3.27	3.27	3.28
Benzene	t CO2/ t	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38	3.38
Lignite																	
Raw lignite																	
Public district heating stations, *Germany*	t CO2/TJ						111.7	111.5	111.5	111.3	111.1	110.8	110.6	110.9	110.7	110.7	111.1
Old German Länder	*t CO2/TJ*	113.8	113.5	113.5	113.6	113.4											
New German Länder	*t CO2/TJ*	110.0	110.0	110.2	110.4	110.3											
Industry, commercial and institutional and residential ("small consumers"), *Germany*	t CO2/TJ						106.0	108.6	111.2	111.1	110.8	109.8	108.5	108.9	109.1	109.2	108.2
Old German Länder	*t CO2/TJ*	114.7	114.5	113.7	113.8	113.5											
New German Länder	*t CO2/TJ*	107.7	107.2	107.2	107.5	106.5											
Public power stations; coalfield:																	
Rheinland	t CO2/TJ	114.8	114.5	114.5	114.6	114.3	113.9	113.8	113.8	113.5	113.3	113.1	112.7	112.9	112.7	112.6	113.2
Helmstedt	t CO2/TJ	98.7	98.7	98.7	98.7	98.7	98.7	98.7	98.7	98.7	98.7	98.7	98.7	98.7	98.7	98.7	98.7
Hesse	t CO2/TJ	112.2	114.7	103.7	102.4	103.0	103.2	103.7	102.4	102.7	103.4	103.5	104.0	103.9	102.5	NO	NO
Lausitz	t CO2/TJ	111.2	111.2	111.3	111.3	111.4	111.3	111.2	111.3	111.3	111.4	111.5	111.5	111.4	111.4	111.3	111.2
Mitteldeutschland	t CO2/TJ	105.7	105.2	104.9	105.2	103.8	103.9	103.7	103.7	103.7	103.4	102.9	103.4	103.6	103.7	103.7	104.0
Lignite briquettes, Germany	t CO2/TJ						98.3	98.5	98.5	98.7	98.9	99.0	99.1	99.1	99.0	99.3	99.3
Old German Länder	*t CO2/TJ*	99.5	99.5	99.5	99.5	99.5											
New German Länder	*t CO2/TJ*	96.6	96.1	95.5	95.9	96.9											
Lignite tar, *New German Länder*	t CO2/TJ	82.9	82.9	82.9	82.9	82.9											
Lignite tar oil, *New German Länder*		78.6	78.6	78.6	78.6	78.6											
Lignite dust and fluidised bed coal, Germany	t CO2/TJ						97.6	97.8	97.9	97.9	98.0	98.1	98.1	98.0	98.0	98.0	98.1
Old German Länder	*t CO2/TJ*	98.3	98.3	98.3	98.3	98.3											
New German Länder	*t CO2/TJ*	96.1	95.5	95.6	95.9	95.8											
Lignite coke, *Germany*	t CO2/TJ						109.6	109.6	109.6	109.6	109.6	109.6	109.6	109.6	109.6	109.6	109.6
Old German Länder	*t CO2/TJ*	109.6	109.6	109.6	109.6	109.6											

Fuel-based emission factors	Units	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
New German Länder	*t CO2/TJ*	100.2	100.2	100.2													
Peat, *old German Länder, Germany*		101.8	101.8	101.8	101.8	101.8	101.8	101.8	101.8	101.8	101.8	101.8	101.8	101.8	101.8	101.8	101.8
Meta-lignite ("hard lignite")	t CO2/TJ	96.4	96.3	96.4	96.4	96.3	96.4	96.4	96.4	96.4	96.3	96.5	96.4	96.9	97.7	NO	NO
Petroleum																	
Crude oil [4]	t CO2/TJ	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3
Gasoline	t CO2/t	3.181	3.181	3.181	3.181	3.182	3.182	3.182	3.182	3.182	3.182	3.183	3.183	3.183	3.183	3.183	3.183
Naphtha, *Germany*[4]	t CO2/TJ						73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3
Old German Länder[4]	*t CO2/TJ*	73.3	73.3	73.3	73.3	73.3											
New German Länder[4]	*t CO2/TJ*	73.3	73.3	73.3	73.3	73.3											
Kerosene[4]	t CO2/TJ	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3
Avgas[4]	t CO2/TJ	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0
Diesel fuel, *Germany*	t CO2/TJ						74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0
Old German Länder	*t CO2/TJ*	74.0	74.0	74.0	74.0	74.0											
New German Länder	*t CO2/TJ*	74.0	74.0	74.0	74.0	74.0											
Light heating oil, *Germany*	t CO2/TJ						74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0
Old German Länder	*t CO2/TJ*	74.0	74.0	74.0	74.0	74.0											
New German Länder	*t CO2/TJ*	74.0	74.0	74.0	74.0	74.0											
Heavy fuel oil	t CO2/TJ	79.8	79.8	79.8	79.8	79.8	79.8	79.8	79.8	79.8	79.8	79.8	79.8	79.8	79.8	79.8	79.6
Petroleum	t CO2/TJ	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0	74.0
Petroleum coke (not including coke burn-off in catalyst regeneration)	t CO2/TJ	94.8	94.8	94.8	94.8	94.8	94.8	94.8	94.8	94.8	94.8	94.8	94.8	94.8	94.8	94.8	94.8
LP gas, *Germany (energy-related consumption)*	t CO2/TJ						65.3	65.2	65.2	65.2	64.0	64.4	64.5	64.4	65.0	65.3	65.3
Old German Länder	*t CO2/TJ*	65.6	65.6	65.5	65.4	65.3											
New German Länder	*t CO2/TJ*	65.6	65.6	65.5	65.4	65.3											
Refinery gas, *Germany*	t CO2/TJ						56.9	56.2	56.8	56.3	60.9	56.7	62.0	58.1	57.0	57.6	57.0
Old German Länder	*t CO2/TJ*	54.6	54.6	57.8	57.1	58.5											
New German Länder	*t CO2/TJ*	54.6	54.6	54.6	57.1	58.5											
Other petroleum products, *Germany*	t CO2/TJ						82.1	82.1	82.1	82.1	82.1	82.1	82.1	82.1	82.1	82.1	82.1
Old German Länder	*t CO2/TJ*	82.1	82.1	82.1	82.1	82.1											
New German Länder	*t CO2/TJ*	82.1	82.1	82.1	82.1	82.1											
Lubricants[4]	t CO2/TJ	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3

Fuel-based emission factors	Units	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Gases																	
Coke oven gas, *Deutschland*	t CO_2/TJ						41.0	41.0	41.0	41.0	41.0	41.0	41.0	41.0	41.0	41.0	40.7
Old German Länder	*t CO_2/TJ*	41.0	41.0	41.0	41.0	41.0											
New German Länder	*t CO_2/TJ*	43.6	43.6	43.6	43.6	43.6											
Coking-plant and city gas, *Germany*	t CO_2/TJ						42.6	42.0									
Old German Länder	*t CO_2/TJ*	43.2	43.7	43.8	44.0	43.3											
New German Länder	*t CO_2/TJ*	58.3	59.9	61.4	61.6	62.4											
Blast furnace gas and basic oxygen furnace gas, *Germany*	t CO_2/TJ						257.1	259.0	258.9	258.7	258.6	258.7	258.8	258.6	258.7	258.7	252.9
Old German Länder	*t CO_2/TJ*	264.6	264.6	264.6	255.3	257.1											
New German Länder	*t CO_2/TJ*	264.6	264.6	264.6	258.5	258.2											
Fuel gas, *New German Länder*	t CO_2/TJ	118.4	118.4	118.4	118.4	118.4											
Other produced gases, *Germany*	t CO_2/1000 m^3	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77
Natural gases																	
Natural gas, *Germany*	t CO_2/TJ						55.8	55.8	55.8	55.8	55.8	55.8	55.9	55.9	55.9	55.9	55.9
Old German Länder	*t CO_2/TJ*	55.7	55.8	55.8	55.8	55.8											
New German Länder	*t CO_2/TJ*	55.5	55.5	55.4	55.4	55.4											
Petroleum gas	t CO_2/TJ	61.9	61.9	61.9	61.9	61.9	61.9	61.9	61.9	61.9	61.9	61.9	61.9	61.9	61.9	61.9	61.9
Pit gas	t CO_2/TJ	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1	68.1
Waste																	
Household waste / municipal waste	t CO_2/TJ	109.6	107.0	104.6	100.1	98.0	96.9	95.8	94.7	93.6	92.5	91.5	91.5	91.5	91.5	91.5	91.5
Industrial waste, *Germany*	t CO_2/TJ						71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1
Old German Länder[2)]	*t CO_2/TJ*	73.9	73.9	74.0	74.1	74.3											
New German Länder[2)]	*t CO_2/TJ*	74.9	74.8	74.7	74.6	74.6											
Special waste, Germany	t CO_2/TJ						83.0	83.0	83.0	83.0	83.0	83.0	83.0	83.0	83.0	83.0	83.0
Special fuels[1)]																	
Used oil	t CO_2/TJ	75.7	75.7	75.7	75.7	75.7	75.7	75.7	75.7	75.7	75.7	75.7	75.7	75.7	75.7	75.7	75.7
Waste plastics	t CO_2/TJ	80.9	80.9	80.9	80.9	80.9	80.9	80.9	80.9	80.9	80.9	80.9	80.9	80.9	80.9	80.9	80.9
Waste tyres	t CO_2/TJ	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4	88.4
Bleaching clay	t CO_2/TJ	NO	NO	NO	NO	NO	78.2	78.2	78.2	78.2	78.2	78.2	78.2	78.2	78.2	78.2	78.2
Sewage sludge (2 MJ/kg)	t CO_2/TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	168.9	168.9	168.9
Sewage sludge (4 MJ/kg)	t CO_2/TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	120.4	120.4	120.4
Sewage sludge (6 MJ/kg)	t CO_2/TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	104.2	104.2	104.2
Sewage sludge (8 MJ/kg)	t CO_2/TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	96.1	96.1	96.1
Sewage sludge (10 MJ/kg)	t CO_2/TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	91.3	91.3	91.3
Solvents (waste)	t CO_2/TJ	74.2	74.2	74.2	74.2	74.2	74.2	74.2	74.2	74.2	74.2	74.2	74.2	74.2	74.2	74.2	74.2

Fuel-based emission factors	Units	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Biomass fuels[3)]																	
Spent liquors from pulp production	t CO2/TJ	121.1	121.1	121.1	121.1	121.1	121.1	121.1	121.1	121.1	121.1	110.3	108.7	108.4	109.7	104.7	104.8
Fibre/de-inking residues	t CO2/TJ	54.9	54.9	54.9	54.9	54.9	54.9	54.9	54.9	54.9	54.9	54.9	54.9	54.9	54.9	54.9	54.9
Firewood, untreated	t CO2/TJ	102.1	102.1	102.1	102.1	102.1	102.1	102.1	102.1	102.1	102.1	102.1	102.1	102.1	102.1	102.1	102.1
Waste wood, wood scraps (industry)	t CO2/TJ	107.8	107.8	107.8	107.8	107.8	107.8	107.8	107.8	107.8	107.8	107.8	107.8	107.8	107.8	107.8	107.8
Waste wood, wood scraps (commercial/institutional)	t CO2/TJ	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4	101.4
Bark	t CO2/TJ	80.6	80.6	80.6	80.6	80.6	80.6	80.6	80.6	80.6	80.6	80.6	80.6	80.6	80.6	80.6	80.6
Animal meals and fats	t CO2/TJ	85.8	85.8	85.8	85.8	85.8	85.8	85.8	85.8	85.8	85.8	85.8	85.8	85.8	85.8	85.8	85.8
Biogas	t CO2/TJ	90.6	90.6	90.6	90.6	90.6	90.6	90.6	90.6	90.6	90.6	90.6	90.6	90.6	90.6	90.6	90.6
Landfill gas	t CO2/TJ	111.4	111.4	111.4	111.4	111.4	111.4	111.4	111.4	111.4	111.4	111.4	111.4	111.4	111.4	111.4	111.4
Sewage gas	t CO2/TJ	104.9	104.9	104.9	104.9	104.9	104.9	104.9	104.9	104.9	104.9	104.9	104.9	104.9	104.9	104.9	104.9
Bioethanol	t CO2/TJ	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	71.6	71.6
Biodiesel[4)]	t CO2/TJ	NO	NO	NO	NO	NO	70.8	70.8	70.8	70.8	70.8	70.8	70.8	70.8	70.8	70.8	70.8
Other factors, units [kg/t]																	
Flue-gas desulphurisation	kg/t	440.0	440.0	440.0	440.0	440.0	440.0	440.0	440.0	440.0	440.0	440.0	440.0	440.0	440.0	440.0	440.0

1) Designations of fuels as defined for the inventory data can diverge from other standards, and they are listed as such, and given EF as such, only in the inventory.

2) Annual changes in EF as a result of varying fractions for combustion systems and plants' own systems. 1990 through 1994 – for each year, separately for old German Länder / new German Länder

3) Listed for selected fuels; calculated CO_2 emissions are reported only as memo items, and do not enter into the total inventory quantities; biomass fractions from special fuels (see above) are not listed separately, because their CO_2 EF are not differentiated.

4) Default values

Remark: The information and FAQ provided by the German Emissions Trading Authority (DEHSt) must be taken into account in any use of substance data from the NIR in the context of the ETS.

Table 523: Emission factors for CO_2 as of 1990, as derived for emissions reporting: industrial processes

Units [kg CO_2 / t (raw material or product)]	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
2.A.1 Production of cement clinkers	530.00	530.00	530.00	530.00	530.00	530.00	530.00	530.00	530.00	530.00	530.00	530.00
2.A.2 Production of burnt lime	746.00	746.00	746.00	746.00	746.00	746.00	746.00	746.00	746.00	746.00	746.00	746.00
2.A.2 Production of dolomite lime	867.00	867.00	867.00	867.00	867.00	867.00	867.00	867.00	867.00	867.00	867.00	867.00
2.A.3 Production of container glass	193.00	193.00	193.00	193.00	193.00	193.00	193.00	193.00	193.00	193.00	193.00	193.00
2.A.3 Production of flat glass	208.00	208.00	208.00	208.00	208.00	208.00	208.00	208.00	208.00	208.00	208.00	208.00
2.A.3 Production of household and table glassware	120.00	120.00	120.00	120.00	120.00	120.00	120.00	120.00	120.00	120.00	120.00	120.00
2.A.3 Production of special glass	113.00	113.00	113.00	113.00	113.00	113.00	113.00	113.00	113.00	113.00	113.00	113.00
2.A.3 Production of glass fibres	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00	198.00
2.A.3 Production of rock wool	299.00	299.00	299.00	299.00	299.00	299.00	299.00	299.00	299.00	299.00	299.00	299.00
2.A.3 Production of glass (all glass types, including cullet inputs)	118.94	115.64	112.76	115.53	115.70	113.80	116.30	118.50	119.60	123.90	123.50	122.70
2.A.4.a Production of ceramics (all relevant product types)	71.92	74.57	72.56	68.78	70.70	71.26	71.58	72.62	72.22	71.52	73.22	72.51
2.A.4.b Use of soda ash	415.00	415.00	415.00	415.00	415.00	415.00	415.00	415.00	415.00	415.00	415.00	415.00
2.B.1 Production of ammonia*	2227.63	2246.17	2160.68	2190.69	2171.33	2091.96	2195.60	2107.36	1654.47	1507.97	1415.79	1396.84
2.B.5 Production of calcium carbide	C	C	C	C	C	C	C	C	C	C	C	C
2.B.7 Production of soda ash	C	C	C	C	C	C	C	C	C	C	C	C
2.B.8 Petrochemicals	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00	28.00
2.B.8.f Production of carbon black	1,960	1,960	1,960	1,960	1,960	1,960	1,960	1,960	1,960	1,960	1,960	1,960
2.C.1 Production of electrical steel	8.50	7.37	7.37	7.37	7.37	7.37	7.37	7.37	7.37	7.37	7.37	7.37
2.C.1 Production of oxygen steel; limestone input	440.00	440.00	440.00	440.00	440.00	440.00	440.00	440.00	440.00	440.00	440.00	440.00
2.C.2 Ferroalloys production	1500.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00
2.C.3 Production of primary aluminium	1367.00	1367.00	1367.00	1367.00	1367.00	1367.00	1367.00	1367.00	1367.00	1367.00	1367.00	1367.00
2.C.5 Production of refined lead (D)		371.00	220.00	220.00	220.00	220.00	220.00	220.00	220.00	220.00	220.00	220.00
2.C.5 Production of refined lead (old German Länder)	434.00											
2.C.5 Production of refined lead (new German Länder)	200.00											
2.C.6 Zinc production: primary and resmelted zinc	1720.00	1720.00	1720.00	1720.00	1720.00	1720.00	1720.00	1720.00	1720.00	1720.00	1720.00	1720.00

C Confidential data

ABL/NBL/D = reference: old German Länder / new German Länder / Germany as a whole

* 2.B.1 Production of ammonia: CO2-EF = (EM - Recovery amount)/AR

Remark: **The information and FAQ provided by the German Emissions Trading Authority (DEHSt) must be taken into account in any use of substance data from the NIR in the context of the ETS.**

18.9 Analysis of CO_2 emissions from non-energy-related use of fuels

The great majority of the coal, oil and gas that Germany uses is used for energy-related purposes. The remainder of the coal, oil and gas is used as feedstock for production processes. This consumption enters into the balance as "non-energy use" (NEU).

In the German Energy Balance, this consumption is listed separately, in line 43. The chemical industry is the leading user of fossil fuels for non-energy-related purposes. It uses fossil fuels in steam crackers, in reforming processes, in synthetic-gas production and in the produciton of graphite electrodes. For cracking and reforming, the most important downstream products are ethylene, propylene, 1,3-butadiene, benzene, toluene and xylenes; for production of synthetic gases, the most important such products are ammonia and methanol. Bitumen, lubricants and paraffin waxes are produced in refineries. Bitumen is used in a range of applications, including road surfaces and bitumen sheeting for roofs. Lubricants are used in road vehicles and machines (inter alia). Without suitable adjustments, the consumption figures listed in Energy Balance line 43 cannot be compared with the CO_2 and NMVOC emissions from use of fossil fuels, in non-energy-related uses, that are reported in the inventory under industrial processes. The reason is that for the industrial processes, only emissions from production or use of products are taken into account, while line 43 takes account of entire feedstocks, thereby including both product-specific emissions and the carbon quantities stored in products. The latter account for far and away the largest share of the feedstocks. Another important difference is that calculation of emissions from product use takes account of imported and exported quantities. In the interest of complete accounting, the carbon quantities stored in the relevant fossil fuel products were taken into account in Table 525 (see below). The correlation between material-related applications and products and the various relevant fuels is oriented to Table 1.3 from Volume 3 of the 2006 IPCC GL, and is based on information provided by relevant associations, producers and experts. In some cases, we had to make our own estimates of the applicable correlation with individual fuels.

The produced quantities of the products listed in the table have been obtained from data reported by the Federal Statistical Office and by the Federal Office of Economics and Export Control (BAFA) and have been converted into CO_2 equivalents. For petrochemical products, the conversion was made on the basis of a) specific carbon content pursuant to Table 3.10 in Volume 3 of the 2006 IPCC-GL (IPCC, 2006) and b) the molar mass of CO_2. The pertinent CO_2 equivalent emissions were split among the three feedstocks used in Germany (naphta, LP gas and other petroleum products), in keeping with (internal) data provided by associations.

In the case of carbon black, the product is assumed to consist of pure carbon. That carbon was also converted into CO_2 equivalents.

The production quantities for bitumen, lubricants and paraffin waxes were obtained from the Official Mineral Oil Statistics, and they are based on gross refinery production. The production quantities have been converted into CO_2 equivalents with the help of the following IPCC standard values (Table 1.2 and Table 1.4 from Vol. 2 of the 2006 IPCC GL).

Table 524: IPCC standard values for EF & lower net calorific value

	EF t CO_2/TJ	Lower net calorific value TJ/kt
Bitumen	80.6	40.2
Paraffin wax	73.3	40.2
Lubricating oil	73.3	40.2

For the year 2016, the last year for which a final Energy Balance is available (situation as of 18 April 2018), the sum of the carbon from the pertinent emissions and of the carbon stored in products amounts to 108 % of the non-energy-related consumption given in line 43 of the Energy Balance. Consequently, the relevant material-related use can clearly be shown to include the quantities listed in the Energy Balance as non-energy-related consumption. No gaps in determination of non-energy-related CO_2 emissions are apparent in the inventory.

Table 525: Verification of the completeness of reported CO_2 from non-energy-related use of fossil fuels

Year	2016	Units	Coal: Hard coal + hard-coal coke	Coal: Lignite + lignite products	Coal: Total, solid fuels	Petroleum: Raw benzene (naphtha)	Petroleum: Petrol coke	Petroleum: LP gas	Petroleum: Other petroleum products	Petroleum: Total, liquid fuels	Gas: Natural gas	Gas: Total, gas
A: Listed NEU quantity (Energy Balance line 43)		TJ	3,286	13,862	17,148.3	441 126	7 071	55 971	310 341	814,509.0	121 687	121,687.0
B: Carbon content		kg C/GJ	29.2	30.2		20.0	26.0	17.8	22.4		15.3	
C: Total input as feedstock / non-energy use		kt C	96.0	397.0	492.9	8,818.1	183.5	998.5	6,948.5	16,948.7	1,861.8	1,861.8
D: Total input as feedstock / non-energy use		**kt CO_2**	**351.9**	**1,455.6**	**1,807.5**	**32,333.1**	**672.8**	**3,661.2**	**25,478.0**	**62,145.1**	**6,826.6**	**6,826.6**
E: Implied oxidised carbon fraction		%	**132%**			**113%**	**112%**	**101%**	**112%**	**112%**	**99%**	**99%**

Year	2016	Units	Coal: Hard coal + hard-coal coke	Coal: Lignite + lignite products	Coal: Total, solid fuels	Petroleum: Raw benzene (naphtha)	Petroleum: Petrol coke	Petroleum: LP gas	Petroleum: Other petroleum products	Petroleum: Total, liquid fuels	Gas: Natural gas	Gas: Total, gas
	AD [kt]	EM [kt CO_2]	Activity data + emissions (C in Gg CO_2)			Activity data + emissions (C in Gg CO_2)						
F: Total reported fossil IPPU CO_2		**7,263**	**464**			**36,409**	**755**	**3,687**	**28,546**	**69,397**	**6,756**	**6,756**
2 Industrial processes		**7,263**	**464**			**36,409**	**755**	**3,687**	**8,026**	**48,877**	**6,756**	**6,756**
2B: Chemical industry		**6,052**				**36,409**	**7**	**3,687**	**8,026**	**48,130**	**6,756**	**6,756**
2B1: Ammonia production	2,954	5,321									5,321	5,321
2B5: Carbide production	C	7					7			7		
2B6: Titanium dioxide production		NE										
2B8: Petrochemical industry (1)												
Methanol	*1,044*										*1,435*	1,435
Ethylene	*5,156*					*12,784*		*1,295*	*2,104*	*16,182*		
Propylene	*4,010*					*9,947*		*1,007*	*1,637*	*12,592*		
Butene and 1,3-Butadiene	*2,209*					*5,682*		*575*	*935*	*7,192*		
Benzene	*1,888*					*5,045*		*511*	*830*	*6,386*		
Toluene	*594*					*1,570*		*159*	*258*	*1,988*		
Xylene	*526*					*1,381*		*140*	*227*	*1,748*		
Carbon black	*369*	*724*							*2,035*	*2,035*		
2C: Metal industry		1,211	**464**				**747**			**747**		
2C1: Iron and steel production (2)		IE										
2C2: Production of ferroalloys	55	6	6									
2C3: Primary aluminium production	547	747					747			747		
2C5: Lead production (2)	C	IE										
2C6: Zinc production (2)	C	IE										

Year	2016	Units	Coal: Hard coal + hard-coal coke	Coal: Lignite + lignite products	Coal: Total, solid fuels	Petroleum: Raw benzene (naphtha)	Petroleum: Petrol coke	Petroleum: LP gas	Petroleum: Other petroleum products	Petroleum: Total, liquid fuels	Gas: Natural gas	Gas: Total, gas
	AD [kt]	EM [kt CO_2]	Activity data + emissions (C in Gg CO_2)			Activity data + emissions (C in Gg CO_2)						
2D: Non-energy-related products from fuels and solvents (1)									***20,520***	**20,520**		
Lubricants	*2367*								*6,978*	*6,978*		
Waxes, paraffins, vaseline, etc.	*122*								*360*	*360*		
Bitumen	*4,065*								*13,182*	*13,182*		
Solvents and other product use (3)	IE	IE				IE						

(1) To ensure that a complete carbon balance is obtained, a departure is made here from the report format used for the categories in the inventory. For this reason, the production quantities listed here cannot be compared with the inventory figures in 2.B.8 and 2.D. The emissions given in the table refer to complete transformation of products into CO_2 – instead of, as in the inventory categories – to emission in production or use.

(2) For reasons of confidentiality, these data are reported in aggregated form.

(3) Since over 90% of solvents from basic chemicals are produced in steam crackers, it is assumed that carbon emitted from NMVOCs comes from products of such crackers.

19 Annex 3: Other detailed methodological descriptions for individual source or sink categories, including KP-LULUCF activities

19.1 Other detailed methodological descriptions for the source category "Energy" (1)

19.1.1 Revision of the activity rates for stationary combustion systems of the new German Länder for the year 1990 and for subsequent years (1.A.1 and 1.A.2)

Problems with the GDR's official statistics in 1990, the year of German reunification, along with the creation of a standardised system of official statistics for all of Germany, had a noticeable effect on the quality of figures, as reported in past inventories, for activity rates of stationary combustion systems of the new German Länder for the year 1990 (and for subsequent years). For this reason, these figures have been revised, completed and corrected as necessary and suitably recorded. This work was carried out by the Institute for Energy and Environment (Institut für Energetik und Umwelt gGmbH; IE gGmbH), in the research project "Base year and update" ("Basisjahr und Aktualisierung"; :(Zander and Merten (2006): FKZ 20541115). For a detailed description of the procedure for revising the activity data for stationary combustion systems, see the 2010 NIR.

19.1.2 Energy industry (1.A.1)

19.1.2.1 Methodological aspects of determination of emission factors (Chapter 3.2.6.2)

This section of the Annex describes the main steps carried out in the research projects Rentz et al. (2002) and Fichtner et al. (2011) for determination of emission factors. (This description does not apply to the CO_2 emission factors whose determination is described in Annex 2 (Chapter 18.8).)

Determination of emission factors requires detailed analysis of all operational facilities with regard to technologies used and design-specific emission behaviour. Three overarching categories are formed: large combustion systems, combustion systems within the scope of application of the Technical Instructions on Air Quality Control (TA Luft) and gas turbines. Existing plants are classified in terms of emissions-relevant characteristics, and the pertinent emission factors are determined. These so-called "technology-specific" factors can then be aggregated in an adequate manner. This database also provides the basis for estimating future emissions (changes in the overall make-up of the entire group of facilities, in terms of percentage shares for various facility types). This procedure thus consists of the following steps:

7. Characterisation of the technology-specific emissions behaviour of combustion systems. In a first step, the combustion and emissions-reduction technologies used in Germany are briefly described, and the relevant emissions-determining factors are explained. On the basis of this characterisation, emission factors are derived for the various different relevant technologies, differentiated by size class and fuel type. The chosen classification is also oriented to applicable provisions under immissions-control law, an orientation that permits derived emission factors to be compared with limits applicable now or in the future.
8. Analysis of the relevant category structure
   Emissions calculations must be carried out using emission factors that have the same references as the pertinent energy-input data. The latter (data) are broken down by categories that are derived from the national energy balance – cf. Chapter 3.2 – and are not based on the combustion technologies used. The project has defined and analysed the following categories: Public electricity and heat production (CRF 1.A.1a), Industrial power stations (CRF 1.A.1c for mining-sector power stations; otherwise CRF 1.A.2), District-

heating stations (CRF 1.A.1a), Refinery power stations (CRF 1.A.1b), Industrial combustion systems (CRF 1.A.1c and 1.A.2) and Residential and Institutional and commercial (small consumers) (CRF 1.A.4 and 1.A.5).

In the analysis, the various technologies' contributions to total energy use must be determined. The most important data sources for this include the power-station database of the DFIU (now the KIT), relevant statistics, communications of industry associations (VGB, VDEW, VIK), operator information and technical publications. Furthermore, excerpts of emissions declarations from the years 1996 and 2004, as provided by some Länder authorities, were also evaluated in the present context.

9. Aggregation of emission factors

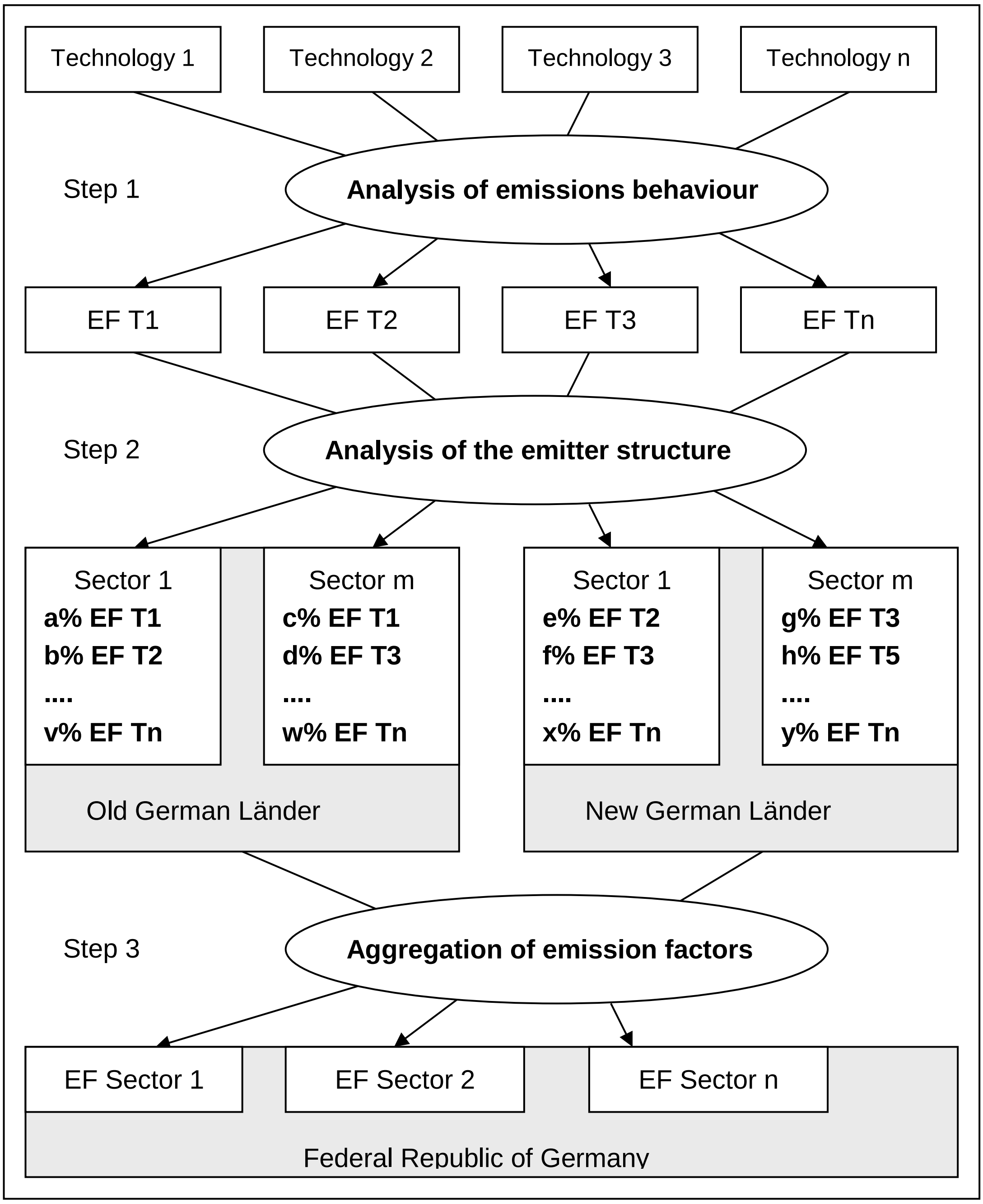
   On the basis of the percentage contributions for the various technologies – which were determined separately for the old and new Länder – the technology-specific emission factors are aggregated to form category-specific factors. Finally, factors for Germany as a whole are formed. The category-specific factors are sub-divided in accordance with the categories "large combustion systems", "TA Luft combustion systems" and "gas turbines", as well as by fuel type. The aggregated emission factors are formed first for the reference year 1995 (Rentz et al., 2002) and for the reference year 2004 (Fichtner et al., 2011).

10. Projections are made for the years 2000 and 2010 (Rentz et al., 2002) and for the years 2010 and 2020 (Fichtner et al., 2011). Technology-specific emission factors are defined for the purpose of describing ongoing technical progress. These are derived from characterisation of modern technologies. An increasing contribution of low-emissions technologies to total relevant activity, thus, can be represented by suitably changing the percentage shares for the technologies under consideration. The framework for such carrying forward consists of the relevant applicable provisions under immissions-control law. For the reference year 2010, it is assumed that requirements from the amended Technical Instructions on Air Quality Control (TA Luft) from 2002 and the EU Large Combustion Plants Directive of 2001 have been implemented; for the reference year 2020, we assume that the requirements of Directive 2010/75/EU of the European Parliament and of the Council on industrial emissions have been implemented.

The above-described methods, beginning with characterisation of the emissions behaviour of relevant combustion technologies and gradually leading to aggregated factors at various regional and category-specific levels, make it possible to represent the required factors transparently.

The chosen methods for deriving emission factors for a given reference year are shown in Figure 89 below.

Figure 89: Methods for calculating emission factors



The origins and quality of the data are described in detail in the project reports Rentz et al. (2002) and Fichtner et al. (2011). A large part of the data has been taken from the emissions declarations of the German Länder (states) Baden-Württemberg, Brandenburg, North Rhine – Westphalia and Thuringia for 1996, and from the emissions declarations of all Länder (except for Berlin) for the year 2004. The annual pollutant-load data included in those data are based, depending on the pollutant in question, on measurements from continuous monitoring, on individual measurements or on calculations based on physical laws, mass balances or emission factors. In the following, the emissions declarations of the state of Baden-Württemberg are used to show, by way of illustration, what data-determination methods tend to be used for the various types of combustion systems and substances in question. Such analysis makes it possible to classify the quality of the underlying data with regard to the derived technology-specific emission factors. At the same time, the description illustrates the data-evaluation procedure. Where a sufficient amount of data for a source category is available, the relevant value range is characterised via the median and the percentile is characterised at 25 % and 75 %[214]. This produces a robust estimate that, unlike characterisation via the mean value, is not distorted by extreme values. In general, percentiles at 5 % and 95 % are also listed, to describe the distribution of values. Similar percentile evaluations were also carried out for the emissions declarations of the other Federal Länder.

In the following, a distinction is made between measured data (either continuous measurements or individual measurements) and data based on calculations or emission factors. In evaluation, therefore, individual data items are first classified as either "measurements" (M) or "assumptions" (A). This general overview, in turn, is divided into the categories of large combustion systems, TA Luft combustion systems and gas turbines. These are then further subdivided, with regard to declaration obligations, into facilities subject to abbreviated (K) or complete (V) declarations. For each of the three groups of systems, evaluation and derivation of emission factors is carried out, using the sample data from Baden-Württemberg and with classification by "measurements" and "assumptions".

Table 526 provides an overview of the facility types considered, grouped on the basis of their numbers under the 4th Ordinance Implementing the Federal Immission Control Act (BImSchV) and of the type of declaration concerned.

Table 526: Facility types pursuant to Annex of 4th BImSchV (4th Ordinance on Execution of the Federal Immission Control Act)

Index	**Large combustion systems (Großfeuerungsanlagen)**		**Type of declaration required**
1 01 1	Power stations	≥ 50 MW for solid, liquid and gaseous fuels	V
1 02A 1	Combustion systems	≥ 50 MW for solid and liquid fuels	V
1 02B 1	Combustion systems	≥ 50 MW for gaseous fuels	V
Index	**TA Luft installations**		**Type of declaration required**
1 02A 2	Combustion systems heating oil EL)	1 - < 50 MW, solid and liquid fuels (except for	V
1 02B 2	Combustion systems	5 - < 50 MW heating oil EL	K
1 02C 2	Combustion systems	10 - < 50 MW for natural gas	K
	Combustion systems installations	10 - < 50 MW, except for natural gas	V
1 03 1	Combustion systems	> 1 MW, other fuels	V
Index	**Gas turbine systems**		**Type of declaration required**
1 05 1	Gas turbines	≥ 50 MW for natural gas	K
	Gas turbines	≥ 50 MW, except for natural gas installations	V
1 05 2	Gas turbines	< 50 MW for natural gas	K
	Gas turbines	< 50 MW, except for natural gas installations	V

214 For the entire value range of a variable X, the sum-frequency distribution can be used to estimate what percentage of all units considered will have a maximal value of x. That value is referred to as a *quantile* or, when percentage values are being considered, as a *percentile*. The best-known percentile, the one that separates the lower half of all values from the upper half, is the 50th percentile, the so-called *median*. The 25th and 75th percentiles cut off the upper and lower quarters of the distribution. They are thus also referred to as upper and lower *quartiles* or as the first and third *quartile* (with the median being a sort of second quartile).

In the analyses, emissions data are differentiated by combustion technologies. Table 527 provides an overview of this technology classification based on types. Categories 110 to 118 apply mainly to solid fuels, while 120 to 125 apply to liquid fuels and 130 to 132 apply to gaseous fuels.

Table 527: Classification of sources by type of combustion system

Technology	
Type	**Meaning**
110	Combustion systems for solid fuels / waste
111	Filled-shaft combustion systems
112	Combustion with throw feed
113	Combustion systems with pneumatic feed
114	Under-thrust combustion
115	Combustion with mechanically moved grids
116	Dust incineration with dry-ash ventilation
117	Dust incineration with wet-ash ventilation
118	Fluidised-bed combustion
120	Combustion systems for liquid fuels / waste
121	With evaporative burner
122	With pressure-atomising burner
123	With steam-atomising burner
124	With rotation-atomising burner
125	With air-atomising burner
130	Combustion systems for gaseous fuels / waste
131	With atmospheric gas burner
132	With gas-blower burner
141	Multiple-substance combustion systems
142	Mixed combustion
815	Gas turbines

19.1.2.2 CO_2 emissions from flue-gas desulphurisation (CRF 1.A.1, Limestone balance)

In the framework of the research project "limestone balance" ("Kalksteinbilanz"; Lechtenböhmer et al. (2006c), FKZ 20541217/02), data for CO_2 emissions from flue-gas desulphurisation were determined for the category Electricity and heat production in public power stations (cf. 3.2.6.2). Flue-gas desulphurisation systems have the task of converting sulphur dioxide in combustion gases, via chemical and physical processes, into substances that are less harmful. Limestone is commonly used as a reagent in flue-gas desulphurisation. Desulphurisation systems are tailored to the applicable requirements under immissions-control law and to the economic value of the resulting residual substances (plaster). The predominant process used in electricity generating plants is limestone scrubbing. Some 87 % of all power stations in Germany, in terms of installed output, use this process (Rentz et al., 2002).

Desulphurisation with $CaCO_3$ consists of several sub-reactions. For stoichiometric calculation of limestone inputs in the limestone-scrubbing process, the relevant chemical gross-reaction equation for the process is used (Strauß, 1998):

$$CaCO_3 + SO_2 + 1/2O_2 + 2H_2O \Longrightarrow CaSO_4.2H_2O + CO_2$$

This equation can be used to derive the limestone/plaster molar mass ratio. Such derivation shows that 581.39 kilograms of limestone are used per produced tonne of plaster. Plaster-production figures thus can be used to obtain the theoretically maximal limestone inputs for flue-gas desulphurisation in hard-coal-fired and lignite-fired power stations. The plaster-production figures do not indicate whether limestone or lime has been used, however. This problem was resolved with the help of statistics of the German Lime Association (BV Kalk) relative to sales of burnt and unburnt lime for the air-quality-control sector. Using the above reaction equation, the pertinent process-related CO_2 emissions can be determined from the mass relationship between $CaCO_3$ and CO_2. The results of the calculation are shown in the following table. They take account of the data on plaster production in all years between 1990 and 2011 and for the year 2014. For the years 2012 and 2013, we have carried forward the plater-production value for 2011, as a provisional input value. For the years 2015, 2016 and 2017, on the other hand, we have used the value for the year 2014, since current statistical data were not yet available.

Table 528: CO_2 emissions from flue-gas desulphurisation in public power stations

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CRF 1.A.1					Figures in kt					
CO_2 from flue-gas desulphurisation in public power stations	618	652	629	662	616	683	867	878	1,005	966
Year	2001	2001	2002	2003	2004	2005	2006	2007	2008	2009
CRF 1.A.1					Figures in kt					
CO_2 from flue-gas desulphurisation in public power stations	1,135	1,069	1,094	1,156	1,162	1,142	1,076	1,017	985	995
Year	2010	2011	2012	2013	2014	2015	2016	2017		
CRF 1.A.1					Figures in kt					
CO_2 from flue-gas desulphurisation in public power stations	1,003	1,028	1,019	979	974	984	968	1,002		

Source: Calculation on the basis of of the "limestone balance" project (Lechtenböhmer et al. (2006c), FKZ 20541217/02); updated in 2008 (cf. NIR 2009)

In the inventory, these CO_2 emissions were assigned to emissions from use of solid fuels, because such use is the reason for operation of the flue-gas desulphurisation systems and for the systems' CO_2 emissions. Pursuant to expert estimates of the group carrying out the pertinent research, the uncertainty for limestone use and, thus, the uncertainty for related CO_2 emissions, is +/- 10 %.

19.1.3 Transport (1.A.3)

19.1.3.1 Transport – Civil aviation (1.A.3.a)

19.1.3.1.1 Derivation of additional emission factors (1.A.3.a)

Kerosene

Emissions of *sulphur dioxide* depend directly on the sulphur content of the jet kerosene being used. That, in turn, is subject to regional and chronological fluctuations. IPCC (2006) gives an EF of 1 kg SO_2/t kerosene, which is based on a sulphur content of 0.05 % by weight. According to current information of the Fachausschuss für Mineralöl- und Brennstoff-Normung[215] (FAM; technical committee for petroleum and fuels standardisation), jet kerosene in Germany typically has a total sulphur content of about 0.01 % by weight, i.e. one-fifth of the content given by the IPCC. The 2009 inventory report uses a sulphur-content figure of 0.021 % by weight for jet kerosene, on the basis of measurements from the year 1998 (Döpelheuer, 2002). It seems plausible that the emission factor would decrease over time as a result of improved procedures and reduced maximum permitted levels. Consequently, a linear reduction is included here between the framework years 1990 (1.08 g SO_2 / kg kerosene), 1998 (0.4 g) and 2009 (0.2 g). In addition, it is assumed that all of the sulphur in the fuel is converted into sulphur dioxide. Because the emission factor depends

[215] Personal e-mail communication with Dr. Feuerhelm, FAM Hamburg, 9 June 2009

directly and solely on the sulphur content of the jet kerosene, this emission factor is used for both flight phases.

NO_X and *CO emissions* are calculated with the help of implied emission factors based on TREMOD-AV calculations. Those results, in turn, are based on aircraft-type-specific and operational-state-specific emission factors taken largely from the EMEP/EEA database. Adjusted emission factors have to be used in some cases, when specific aircraft types cannot be directly allocated to the proper categories, even with the help of data on technically similar aircraft types. Those emission factors were determined via emissions functions, in the context of regression calculations, that calculate the emission factor for each engine type as a function of take-off weight. The basis for those functions consisted of the emission factors for existing aircraft types pursuant to Knörr et al. (2012).

In each case, the *NMVOC* emission factors are obtained from the difference between the emission factor for hydrocarbons and that for methane.

Avgas

In (IPCC (2006): Vol. 2, p. 3-64), the emission factors for *nitrous oxide* are explicitly defined as equal to the relevant values given for jet-kerosene use. That assumption has been adopted here – along with the forecasts for jet-kerosene use in cruise phases of national air transports.

As to fuel properties, there are no fundamental differences between avgas and automobile gasoline[216]. Consequently, values for specific SO_2 emissions from automobile gasoline may be used for avgas. Pursuant to the Fachausschuss für Mineralöl- und Brennstoff-Normung (FAM; technical committee for petroleum and fuels standardisation), the maximum permitted level for total sulphur content in gasoline-station fuel is 10 mg/kg, or 0.001 % by weight, which is one-tenth of the figure given for jet kerosene. As a result, the 2008 emission factor for SO_2 from jet kerosene, reduced by 90 %, is used in the present context.

In each case, the *NMVOC* emission factors are obtained from the difference between the emission factor for hydrocarbons and that for methane.

The other emission factors are not available as special values for average small aircraft. For this reason, they are assumed to be the same as the relevant jet-kerosene emission factors (national, cruise).

Table 529: Emission factors for avgas, 2017

	[g/kg]	[kg/TJ]	Remarks regarding the source or calculation
CO_2	3,048.00	70,000.00	Tier 1 default EF pursuant to (IPCC, 2006a; Table 3.6.4)
CH_4	0.36	8.21	same as Tier 2 EF for kerosene, LTO/national
N_2O	0.10	2.33	same as Tier 2 EF for kerosene, Cruise/national
SO_2	0.02	0.51	derived from the maximum permitted level of 10 mg / kg fuel
NO_X	11.27	256.86	Tier 3 EF, calculated in TREMOD-AV
NMVOC	8.21	187.26	Tier 3 EF, calculated in TREMOD-AV
CO	679.94	15,502.55	Tier 3 EF, calculated in TREMOD-AV

Source: (Gores, 2018)

[216] E-mail communication with Mr Winkler of the Mineralölwirtschaftsverband e.V. Association of the German Petroleum Industry, 8 June 2009

Table 530: Overview of emission factors for kerosene; in g/kg

	1990	1995	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1.A.3.a/ 1.D.1a – overarching																
CO_2								3,150								
SO_2	1.08	0.66	0.36	0.27	0.25	0.24	0.22	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
1.A.3.a – domestic flights within Germany: LTO																
CH_4								0.35								
N_2O								0.12								
NO_X	12.92	14.28	12.92	12.29	12.26	12.41	12.85	13.31	13.56	13.68	13.89	13.88	13.81	14.04	14.27	14.36
NMVOC	0.85	0.86	0.79	0.89	0.95	0.98	0.95	0.85	0.77	0.81	0.85	0.96	1.00	0.83	0.87	0.96
CO	7.84	7.90	10.23	10.94	10.96	10.68	10.32	9.72	9.31	9.24	9.05	9.1371	9.20	8.88	8.63	8.55
1.A.3.a – domestic flights within Germany: Cruise																
CH_4								0.00 [a]								
N_2O								0.10								
NO_X	14.73	16.38	15.08	14.55	14.57	14.89	15.41	15.76	15.98	16.11	16.34	16.55	16.50	16.69	17.01	17.27
NMVOC	0.40	0.50	0.45	0.52	0.57	0.57	0.56	0.56	0.56	0.57	0.57	0.59	0.61	0.58	0.58	0.59
CO	3.68	3.79	4.80	4.77	4.77	4.53	4.40	4.51	4.55	4.52	4.39	4.24	4.32	4.48	4.22	3.94
1.D.1.a – international flights: LTO																
CH_4								0.13								
N_2O								0.09								
NO_X	13.01	13.34	13.19	13.86	13.92	14.10	14.18	14.45	14.78	14.82	15.00	15.17	15.28	15.41	15.57	15.62
NMVOC	3.09	1.68	1.39	1.15	1.14	1.11	1.08	1.04	1.00	1.00	0.97	0.94	0.92	0.89	0.88	0.90
CO	10.55	9.53	10.11	9.62	9.47	9.24	9.12	8.94	8.67	8.62	8.47	8.33	8.22	8.07	7.93	7.90
1.D.1.a – international flights: Cruise																
CH_4								0.00 [a]								
N_2O								0.10								
NO_X	13.45	13.62	14.15	14.42	14.46	14.60	14.64	14.78	15.06	15.13	15.43	15.65	15.81	16.07	16.27	16.35
NMVOC	0.58	0.39	0.24	0.22	0.22	0.21	0.21	0.20	0.20	0.20	0.19	0.19	0.19	0.19	0.19	0.19
CO	3.09	2.57	1.91	1.73	1.69	1.64	1.60	1.58	1.57	1.56	1.54	1.53	1.51	1.51	1.51	1.53

Source: (Gores, 2018)

[a] pursuant to IPCC (2006): Volume 2, Chapter 3.6, Table 3.6.5: Methane emissions during cruise flight are negligibly low.

19.1.3.1.2 Detailed overview of the uncertainties underlying the pertinent activity data and emission factors (1.A.3.a)

Table 531: Overview of the applicable partial uncertainties for activity rates and emission factors

Individual components		Partial uncertainties		AD (kerosene & avgas)		SF (LTO / cruise)		AD (kerosene) LTO and cruise		EM(CO_2) LTO and cruise		EM (CH_4) LTO and cruise		EM (N_2O) LTO and cruise		Source / reason for assumptions
		%		Total	n / i	n	i	n	i	n	i	n	i	n	i	
AD of AGEB and BAFA		-5	5	x	x											Öko-Institut / DIW 2007 Here, the higher uncertainties of the Energy Balance are used. The uncertainties for the BAFA data are +3, -1% (conservatively estimated, using the approach for the uncertainties of mineral-oil statistics, which are based on BAFA data.)
Split factor, national/international																Results, since v42, from the TREMOD calculations relative to national air traffic in relation to the Energy Balance. No longer an influencing variable in its own right.
Kerosene consumption	n & i	-5.0	5					x	x							Calculated
Data of the Federal Statistical Office relative to aircraft movements	n	-0.1	0.1			x										Aviation statistics are based on the Transport statistics act (Verkehrsstatistikgesetz - VerkStatG). The data specified by Arts. 12, 13 VerkStatG are recorded. Pursuant to that act, all civil aviation craft, including aircraft, helicopters, airships, motorised gliders, sailplanes and manned balloons, are to be included in relevant surveys, as long as airports/airfields in Germany are involved.
	i	0	0.1				x									
Real-distance surcharge	n & i	-3	3			x	x									The data of the Federal Statistical Office are oriented to great-circle distances. A detour factor for cruise flight has been used, as a means of estimating the distances actually flown (cf. IFEU and Öko-Institut 2010).
Allocation of kerosene consumption data to aircraft types	n	-5	5			x										Aircraft types pursuant to the Federal Statistical Office are assigned emission factors from the EMEP-EEA database. There are four different quality levels for such assignment: a) direct, b) via similar types, c) via regression functions depending on take-off weight, and d) lump-sum EF.
	i	-5	5				x									
LTO/cruise split	n	-6	6					x								Calculated
	i	-6	6						x							Calculated
Kerosene consumption LTO and cruise	n	-8	8							x		x		x		Calculated
	i	-8	8								x		x		x	Calculated
Emission factors	CO_2	5	5							x	x					IPCC 2006, p.3.69; low uncertainty, since the EF depends only on the C content of the fuel.
	CH_4	-57	100									x	x			IPCC 2006, p.3.69; depends on technology and is thus subject to large uncertainty in combination via the Tier 1 approach
	N_2O	-70	150											x	x	IPCC 2006, p.3.69; depends on technology and is thus subject to large uncertainty in combination via the Tier 1 approach
The total uncertainty is above				+5%	+5%	+6%	+6%	+8%	+8%	+9%	+9%	+58%	+58%	+70%	+70%	
The total uncertainty is below				-5%	-5%	+6%	-6%	-8%	-8%	-9%	-9%	-100%	-100%	-150%	-150%	

n = national share; i = international share

Source: (Gores, 2018)

19.1.3.2 Derivation of activity rates for road transport (1.A.3.b)

19.1.3.2.1 Harmonisation with the Energy Balance

The basis for CSE data collection for the road-transport sector consists of energy consumption data provided by the Working Group on Energy Balances (AGEB). For each year, the sum of the activity rates for the various individual structural elements must be equivalent to the Energy Balance data, in terajoules (TJ). The relevant basic Energy Balance data are shown in Table 532 below.

Table 532: Energy inputs in road transports, 1990-2017

	Gasoline	Diesel	Biofuels	Natural gas & LP	Petroleum	Lubricants [a]
Energy inputs pursuant to Energy Balances 1990-2017 (last revision: 10/2018), in TJ						
1990	1,330,479	735,920	0	138	0	2,416
1991	1,332,285	785,174	0	137	0	1,387
1992	1,344,129	853,502	0	229	0	1,284
1993	1,350,617	907,787	0	184	473	885
1994	1,276,637	932,060	0	184	559	365
1995	1,299,982	964,013	1,504	138	610	335
1996	1,299,879	964,580	2,046	115	638	295
1997	1,297,487	979,586	3,652	106	357	233
1998	1,300,463	1,022,794	4,081	106	637	201
1999	1,300,602	1,097,036	5,370	100	637	123
2000	1,237,055	1,108,105	12,276	94	414	89
2001	1,199,318	1,097,416	16,740	98	471	86
2002	1,166,381	1,105,842	20,460	607	472	82
2003	1,108,989	1,078,352	29,948	694	0	83
2004	1,072,720	1,110,931	39,950	1,887	0	88
2005	992,377	1,078,620	78,641	5,484	0	88
2006	930,834	1,082,042	143,583	9,051	0	92
2007	892,982	1,073,987	155,297	14,787	0	87
2008	854,002	1,102,623	125,721	22,796	0	90
2009	829,227	1,114,939	113,066	32,285	0	91
2010	791,416	1,168,063	119,463	30,591	0	88
2011	787,803	1,197,252	115,102	32,384	0	91
2012	742,000	1,223,718	119,832	32,401	0	88
2013	741,150	1,283,637	108,736	30,466	0	88
2014	744,661	1,296,828	113,280	28,936	0	90
2015	708,672	1,348,789	105,101	26,370	0	86
2016	709,179	1,393,481	105,516	22,647	0	87
2017	711,674	1,422,567	106,980	18,768	0	87

Sources: Evaluation tables of the Energy Balances, "Mineralöl-Zahlen" ("Petroleum Data") of the Association of the German Petroleum Industry (MWV, 2018) and "Amtliche Mineralöldaten" ("Official Mineral Oil Statistics") (BAFA, 2018a).

[a] as components of 1:50 two-stroke fuel mixtures

The Energy Balance is also used to model transport-quantity structures in TREMOD. For example, the German Economic Institute (DIW) carries out a fuel-consumption calculation in order to derive total mileage travelled Heilwig (2002). Some of the results of the calculation, for automobile transports, are entered into TREMOD. The DIW uses a fuel-consumption calculation in order to determine total domestic mileage; TREMOD uses some other sources and assumptions to estimate total domestic mileage – especially for goods transports (cf. the detailed description in Knörr et al. (2002)). This estimate also takes the basic figures of the Energy Balance into account.

On the other hand, due to the many dependencies and uncertainties in the model, and to the basic data that must be taken into account, no feasible means is available for comparing mileage and energy consumption, for each year and each vehicle layer, in such a manner that the results yield the Energy Balance sum and the mileage and mean energy consumption figures in the time series are plausible. For this reason, the TREMOD results for the energy consumption are corrected, at the end of the process, in such a manner that the total for each reference year corresponds to the relevant figure in the Energy Balance.

Since TREMOD calculates energy consumption in tonnes, the results first have to be converted into TJ. For this purpose the net calorific values provided by the Working Group on Energy Balances (AGEB) are used (cf. Table 533).

Table 533: Mean net calorific values for gasoline and diesel fuel

Validity period	Gasoline	Diesel fuel
1990-1992	43.543 MJ/kg	42.704 MJ/kg
since 1993	43.543 MJ/kg	42.960 MJ/kg
since 2014	42.280 MJ/kg	

Source: Working Group on Energy Balances (AGEB)

The correction factors are derived in TREMOD separately for the various vehicle categories, as follows:

- Firstly, a correction factor for gasoline is derived from the calculated gasoline consumption for all vehicle categories and from gasoline sales pursuant to the Energy Balance.
- The correction factor for gasoline is then also used to bring fuel consumption of vehicles with diesel engines, among automobiles and other vehicles ≤ 3.5 t (light duty vehicles (LNF), and of motor homes and motorcycles (MZR)), into line with the Energy Balance.
- The difference between the corrected diesel-fuel consumption of automobiles and of other vehicles ≤ 3.5 t and the Energy Balance is then allocated to heavy duty vehicles and buses.
- The correction factor for heavy duty vehicles and buses is then calculated from their energy consumption, as calculated in accordance with the domestic principle, and the pertinent difference, as calculated for this group, from the Energy Balance.

The following table summarises the correction factors used.

Table 534: Correction factors for harmonisation with the Energy Balance

	Applicability range	Gasoline fuels[a]	Diesel fuel[a]	
		Automobiles, light utility vehicles, motorcycles	*Automobiles, light utility vehicles*	*Heavy utility vehicles, buses*
1990	Old German Länder	1.035	1.035	1.126
1990	New German Länder	1.051	1.051	1.390
1995	D	0.993	0.993	1.205
2000	D	0.957	0.957	1.334
2005	D	0.923	0.923	1.074
2006	D	0.921	0.921	1.090
2007	D	0.918	0.918	1.032
2008	D	0.919	0.919	1.021
2009	D	0.913	0.913	1.056
2010	D	0.902	0.902	1.088
2011	D	0.913	0.913	1.060
2012	D	0.893	0.893	1.134
2013	D	0.916	0.916	1.147
2014	D	0.936	0.936	1.084
2015	D	0.904	0.904	1.143
2016	D	0.918	0.918	1.152
2017	D	0.927	0.927	1.170

[a] In each case, including biogenic admixtures

Source: TREMOD 5.81 (Knörr et al., 2018a)

19.1.3.2.2 Allocation of biofuels, petroleum, natural gas and LP gas to the structural elements

The Energy Balance includes data on biomass and other fuels, broken down by individual vehicle categories. Those data are allocated as follows:

- The figures for biodiesel and bioethanol are divided in accordance with the various vehicle categories' shares of consumption of the corresponding fossil fuels.
- Petroleum is allocated to buses (on roads outside urban areas) in keeping with the buses' percentage shares of consumption of conventional diesel fuel.

19.1.3.2.3 Activity rate for evaporation

The activity rate for evaporation emissions is set as total gasoline consumption, on *municipal roads (= city)*; the corresponding figure for mopeds is the *total consumption*. The values corrected to the Energy Balance are used.

19.1.3.3 Derivation of emission factors

19.1.3.3.1 Emission factors from TREMOD

In the Central System of Emissions (CSE), implied emission factors, in [kg/TJ] or [kg/t], generated from more-specific TREMOD data, are given for the categories *engine type* and *evaporation*. For gasoline and diesel fuel, those values can be derived directly from TREMOD. To that end, emissions in [t] and energy consumption in [TJ] (converted from the results "energy consumption in t", using the net calorific values pursuant to Table 533) are derived from the TREMOD results and allocated to the relevant structural elements. The implied emission factors (IEF) result as the quotient of specific emissions in [t] divided by the specific energy consumption in [TJ].

$$IEF\ [kg\ pro\ TJ]_{inventory} = EM\ [kg]_{specific,\ TREMOD} \div AR\ [TJ]_{specif.\ consumption,\ TREMOD}$$

A similar procedure is used for the implied emission factors for evaporation:

$$IEF\ [kg\ pro\ t]_{inventory} = EM\ [kg]_{specific,\ TREMOD} \div AR\ [t]_{specif.\ consumption,\ TREMOD}$$

In general, TREMOD data that have not been corrected in accordance with the Energy Balance are used for this derivation. Use of the so-corrected figures for emissions and energy consumption would lead to the same results, however, since the correction factor cancels out when the IEF is calculated.

$$EM_{corr.} \div AR_{corr.} = EM_{TREMOD} \div AR_{TREMOD}$$

.

19.1.3.3.2 Emission factors for biodiesel, bioethanol, petroleum, natural gas and LP gas

In all cases, the emission factors for biodiesel and petroleum are set to the same values as those for conventional diesel fuel. The emission factors for bioethanol are set to the same values as those for conventional gasoline.

Exceptions:

- The EF(CO_2) used for biodiesel, 70.8 t/TJ, is a default pursuant to the IPCC (2006): Volume 2, Chapter 2 – Stationary Combustion, p. 2.20, Tab. 2.4.
- The EF (SO_2) for petroleum is set to 24 kg/TJ for those years in which diesel fuel has a higher value. In all other years, the lower value for diesel fuel is used.

Now, the emission factors for LP gas and natural gas, like those for diesel fuel and gasoline, are being taken from the "Handbook for emission factors of road transports 3.3" ("Handbuch für Emissionsfaktoren des Straßenverkehrs 3.1"; (Keller et al., 2017)).

19.1.3.4 Derivation of data for western and eastern Germany, 1994

TREMOD distinguishes between old and new German Länder only until 1993. Since the CSE also requires such differentiation for 1994, a relevant breakdown must be made using simplifying assumptions. The framework conditions include:

- The sum total of activity rates for engine-type categories (Antrieb) must correspond to the relevant Energy Balance values (in each case, for old and new German Länder).
- In the overall result, emissions resulting from linking activity data with emission factors must correspond to the TREMOD results for Germany.

With these framework conditions, a relevant breakdown is possible only under the following assumptions:

- The EF (CSE) for the old and new German Länder are set to the relevant values for all of Germany (TREMOD) in 1994.
- The individual CSE vehicle layers' percentage shares of the activity rates are considered to be the same in each case in the old and new German Länder, and they are the same as the relevant values for all of Germany in 1994.

With these assumptions, the aforementioned conditions are fulfilled. A third framework condition is not fulfilled: the plausibility of emissions results in the time series, in each case, for the old/new German Länder.

19.1.4 CO_2 emissions from lubricant co-incineration in two-stroke gasoline engines

The German greenhouse-gas inventory covers CO_2 emissions from co-incineration of lubricants for all mobile sources. In keeping with emissions reporting requirements, emissions from two-stroke gasoline engines are allocated directly to the pertinent emission sources, since in those cases lubricants are seen as part of the relevant two-stroke fuel mixtures. On the other hand, all co-incineration emissions not caused by two-stroke engines are reported under CRF 2.D.1 (product use). (Cf. Chapter 4.5.1)

For the entire time series as of 1990, it is assumed, as a simplification, that the two-stroke fuel mixture used in Germany consists of 49 parts gasoline and one part lubricants (mixture of 1:50). Since the 1980s, this mixing ratio has been the standard for most vehicles with two-stroke engines. No reliable usage data are available on motors that use mixtures of 1:100 (newer mobile devices such as chainsaws, lawnmowers, etc.).

Mopeds and small motorcycles are now virtually the only types of *vehicles with two-stroke engines* that are found on German roads. Until the end of the 1990s, the automobile and utility vehicle fleet included a fraction of vehicles with two-stroke engines produced in the former GDR.

TREMOD contains pertinent separate sets of consumption data for automobiles and light utility vehicles (through 1999) and for two-wheel vehicles.

TREMODD MM contains current figures on use of *mobile devices with two-stroke engines* for both the Residential (1.A.4.b ii) and Forestry (1.A.4.c ii) sectors.

The figures on gasoline consumption in road transports and by mobile sources in the Commercial and Institutional, and Residential, sectors agree with the corresponding figures in the Energy Balance.

To obtain a complete picture of the fuel consumption that must be assigned to two-stroke engines, the relevant quantities of lubricants added to fuel have been calculated, in accordance with the mixing ratio of 1:50. On the basis of an r_V 2 % fraction by volume, the fraction r_E applying to the pertinent energy quantity in terajoules has to be determined, via the relationship of the two components' average densities (ρ) and net calorific values (H_i):

$$r_{E\%} = r_{V\%} \times \frac{\rho_{lubricant}}{\rho_{fuel}} \times \frac{\mathrm{H_{i_{lubricant}}}}{\mathrm{H_{i_{fuel}}}}$$

$$r_{E\%} = 2\ \% \times \frac{0.875\ \frac{\mathrm{kg}}{\mathrm{l}}}{0.750\ \frac{\mathrm{kg}}{\mathrm{l}}} \times \frac{40.000\ \frac{\mathrm{kJ}}{\mathrm{kg}}}{43.543\ \frac{\mathrm{kJ}}{\mathrm{kg}}} = 2.1435\ \%$$

The lubricant quantities in [TJ] that are co-combusted as part of two-stroke fuel mixtures are then calculated from the annual energy inputs in [TJ] that are assigned to two-stroke engines and the pertinent fraction r_E.

The CO_2 emissions from lubricant co-incineration in two-stroke engines in road transports can thus be listed separately (cf. Chapters 3.2.10.2 & 19.1.3.2). In the CRF tables, this is done under CRF *1.A.3.b v – Other (please specify): CO_2 from lubricant co-incineration in 2-stroke road vehicles.*

In the category of mobile machines and devices, no separate lubricant quantities are calculated in terajoules. Instead, in a simplification the energy inputs applying to these two-stroke engines are upwardly corrected by 2.1435 %. The CO_2 emissions from lubricant co-incineration in two-stroke engines in mobile machines and devices are thus included in the total emissions of the relevant sectors (cf. Chapter 3.2.12). Consequently, the emissions are also not listed separately within the CRF tables.

Emission factors

To make it possible to show CO_2 emissions from combusted two-stroke fuel mixtures in the inventory, weighted implied emission factors were formed for the entire time series. These consist of a 49/50ths fraction based on the year-specific EF(CO_2) for gasoline ((or the Tier 1 EF for bioethanol) and a 1/50th fraction based on the default value 73,300 kg CO_2/TJ for lubricants pursuant to (IPCC, 2006): Volume 2, Chapter 2 – *Stationary Combustion*, page 2.20, Table 2.4.

These IEF, which include 2 % by vol. for lubricants, are thus slightly higher than the values used for the relevant pure fuels (gasoline, bioethanol).

Table 535: Derivation of the EF(CO_2) for two-stroke fuel mixtures, in kg/TJ

<table>
<tr><th></th><th>1990</th><th>1995</th><th>2000</th><th>2005</th><th>2010</th><th>2011</th><th>2012</th><th>2013</th><th>2014</th><th>2015</th><th>2016</th><th>2017</th></tr>
<tr><td>Gasoline</td><td>73,069</td><td>73,075</td><td>73,094</td><td>73,103</td><td>73,119</td><td>73,025</td><td>73,088</td><td>73,091</td><td>73,091</td><td>75,287</td><td>75,285</td><td>75,285</td></tr>
<tr><td>Bioethanol</td><td colspan="12">71,607</td></tr>
<tr><td>Lubricants [a]</td><td colspan="12">73,300</td></tr>
<tr><td>Two-stroke mix
fossil</td><td>73,074</td><td>73,079</td><td>73,098</td><td>73,107</td><td>73,123</td><td>73,030</td><td>73,093</td><td>73,095</td><td>73,095</td><td>75,247</td><td>75,245</td><td>75,245</td></tr>
<tr><td>biogenic</td><td colspan="12">71,641</td></tr>
</table>

Source: own calculations

[a] Default emission factor pursuant to IPCC (2006): Volume 2, Chapter 2 – *Stationary Combustion*, page 2.20, Table 2.4

Table 536: CO_2 from lubricants co-incinerated in two-stroke gasoline engines, in kilotonnes

	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017
1.A.3.b	177.12	24.56	6.55	6.46	6.43	6.64	6.43	6.45	6.57	6.31	6.35	6.38
1.A.4.b ii	2.29	1.77	1.18	1.10	1.40	1.65	1.56	1.41	1.48	1.57	1.56	1.54
1.A.4.c ii	4.53	4.40	4.87	4.48	2.38	2.17	0.61	0.60	0.64	2.60	2.47	2.89
Total	**183.95**	**30.73**	**12.60**	**12.05**	**10.21**	**10.46**	**8.60**	**8.46**	**8.70**	**10.48**	**10.38**	**10.81**

Source: Own calculations, based on Knörr et al. (2018a, 2018b)

Carbon dioxide from lubricant co-combustion in four-stroke gasoline engines, and in other engines in vehicles and in mobile machinery and equipment, on the other hand, is reported separately under CRF 2.D.1, as emissions from product use. (Cf. Chapter 4.5.1)

19.2 Other detailed methodological descriptions for the category "industrial processes" (2)

This chapter is currently not required.

19.3 Other detailed methodological descriptions for the category "Agriculture" (3)

19.3.1 Calculation of the emissions for additional animal categories

The CRF tables under IPCC (2006): Vol. 4 call for emissions reporting on additial animal categories that are not included in Chapter 5:

- Deer,
- Rabbits,
- Reindeer,
- Ostriches,
- Fur-bearing animals.

No reindeer are kept in Germany. In the following, the GHG emissions from the other four categories are calculated, by way of example, and using Tier 1 methods, for one year. Table 537 summarises the results of these calculations. These data serve as the basis for concluding that the relevant emissions are insignificant and thus do not have to be reported in the NIR; cf. Chapter 21.

Table 537: Total GHG emissions of deer, rabbits, ostriches and fur-bearing animals

	CH_4 [kt a^{-1}]	N_2O [kt a^{-1}]	CO_{2eq} [kt a^{-1}]
Total	**5.635**	**0.108**	**172.91**
Deer	5.348	0.085	159.11
Rabbits	0.194	0.011	7.98
Ostriches	0.043	0.003	1.83
Fur-bearing animals (mink)	0.050	0.009	3.99

19.3.1.1 Animal-place figures

In Germany, no official counts are taken of populations of deer, rabbits, ostriches and fur-bearing animals. Table 538 presents estimates of the Federal Statistical Office concerning the average animal populations (Federal Statistical Office, Section G 105, C. Schreiner, personal communication, 2012). These figures are interpreted as continuously occupied animal places (AAP) (cf. Chapter 5.1.3.2). The FAO also provides figures for rabbits, but those figures are far lower than the national figures. For this reason, the approach used here may be considered a conservative one.

Table 538: Average annual animal populations, pursuant to estimates of the Federal Statistical Office

	Population	Source
Deer	264,500	Landesverbände für landwirtschaftliche Wildtierhaltung (state associations for agricultural husbandry of wild animals); survey conducted in the period 2008/2009
Rabbits	440,000	Bundesverband deutscher Kaninchenfleisch- und –wollerzeuger e.V. (national association of German producers of rabbit meat and rabbit fur)
Ostriches	7,632	Tierseuchenkasse (animal diseases fund; 2012)
Fur-bearing animals (mink)	63,500	Länderabfrage zur Haltung von Pelztieren (State survey on husbandry of fur-bearing animals; last revision March 2012)

19.3.1.2 CH_4 emissions from enteric fermentation

No CH_4 emissions from enteric fermentation are calculated for ostriches, since IPCC (2006): Vol. 4) does not specify any relevant methods. The emissions for the categories deer, rabbits and fur-bearing animals are calculated by multiplying the relevant numbers of animals by the pertinent emission factors.

For reserve game, the CH_4 default emission factor in IPCC (2006): Vol. 4, 10.28, Tab. 10.10, is used (20 kg pl^{-1} a^{-1}).

On the other hand, IPCC (2006): Vol. 4) does not give any emission factor for rabbits. Pursuant to footnote 1 under Table 10.10 on p. 10.28 in IPCC (2006): Vol. 4), the emission factor can be approximated by selecting an emission factor for an animal with a similar digestive system and then scaling that emissions factor using the ratio of the weights of the animals raised to the 0.75 power. For such estimation, the horse was chosen as the comparison animal, since it is neither a ruminant (cattle, sheep, goats) nor an omnivore (swine). Pursuant to (IPCC (2006): Vol. 4, 10.28, Table 10.10), a horse weight of 550 kg per animal should be used for the calculation. The specified weight for rabbits is 3.0 kg (final live weight of a fattening rabbit, pursuant to LfL Bayern (Bavarian state office for agriculture)[217]). With the CH_4 emission factor for horses (18 kg pl^{-1} a^{-1}, IPCC (2006): Vol. 4, 10.28, Table 10.10) taken as a basis, a CH_4 emission factor of 0.36 kg pl^{-1} a^{-1} results for rabbits.

[217] http://www.lfl.bayern.de/itt/tierhaltung/37339/

For fur-bearing animals, we have adopted the CH_4 emission factor used by other countries (Estonia, Iceland, Latvia, Lithuania, Norway; the 2017 NIR applies in each case), 0.1 kg pl^{-1} a^{-1}.

Table 539 shows, by way of example, the annual emissions from enteric fermentation calculated for deer, rabbits and fur-bearing animals.

Table 539: CH_4 emissions from enteric fermentation for deer, rabbits and fur-bearing animals

	EF [kg pl^{-1} a^{-1}]	CH_4 [kt a^{-1}]	CO_{2eq} [kt a^{-1}]
Total		5.45	136.37
Deer	20.00	5.29	132.25
Rabbits	0.36	0.16	3.96
Fur-bearing animals (mink)	0.10	0.0064	0.16

19.3.1.3 CH_4 emissions from manure management

The default emission factors in IPCC (2006): Vol. 4, 10.83, Tab. 10A-9) are used. The resulting emissions are shown in Table 540.

Table 540: CH_4 emissions from manure management for deer, rabbits, ostriches and fur-bearing animals

	EF [kg pl^{-1} a^{-1}]	CH_4 [kt a^{-1}]	CO_{2eq} [kt a^{-1}]
Total		**0.180**	**4.50**
Deer	0.22	0.058	1.45
Rabbits	0.08	0.035	0.88
Ostriches	5.67	0.043	1.08
Fur-bearing animals (mink)	0.68	0.043	1.08

19.3.1.4 N_2O emissions from manure management

To calculate N_2O emissions from manure management, one must know the relevant N excretions. It is also useful to know how the relevant animal population is divided among the applicable housing systems. The latter factor is not known for deer, rabbits, ostriches and fur-bearing animals in Germany. As a simplification, therefore, year-round free-range management is assumed for deer, while year-round housing in solid-manure-based stable systems is assumed for rabbits, fur-bearing animals and ostriches. With regard to the N excretions, cf. Chapter 19.3.1.4.1. The resulting N_2O emissions are listed in Chapter 19.3.1.4.2.

19.3.1.4.1 N excretions

Neither IPCC (2006): Vol. 4) nor EMEP (2016) specify a default value for the N excretions of deer. The German calculations have been carried out with the value used by Denmark (16 kg pl^{-1} a^{-1}; (UNFCCC, 2018a)), since it can be assumed that the average N excretions of deer in Denmark do not differ significantly from those of deer in Germany.

For rabbits, IPCC (2006): Vol. 4, p. 10.59, Tab. 10.19) specifies a default N-excretion value of 8.1 kg pl^{-1} a^{-1}. That value seems unrealistically high, since it is of the same order of magnitude as the total weight gain per animal place and year. Assuming about four rounds of fattening per year (n_{round}, derived from a 87-day duration of fattening pursuant to LfL Bayern[218] (Bavarian state office for agriculture) and a final live weight of about 3 kg $animal^{-1}$ (cf. also LfL Bayern), the latter works out to about 12 kg pl^{-1} a^{-1}. For this reason, the N excretions of rabbits are estimated on the basis of the relevant N balance for the animals; cf. Equation58:

[218] http://www.lfl.bayern.de/itt/tierhaltung/37339/

Equation58: Calculation of the N excretions of rabbits (N balance)

$$N_{\text{excr, rabbit}} = n_{\text{round}} \cdot \Delta w_{\text{round}} \cdot (x_{\text{N}} \cdot x_{\text{XP, feed}} \cdot x_{\text{feed}} - x_{\text{N, ret}})$$

Where

$N_{\text{excr, rabbit}}$	N excretions (in kg place^{-1} a^{-1})
n_{round}	Number of fattening rounds per year (in rounds a^{-1})
Δw_{round}	Weight gain per fattening round (in kg round^{-1} place^{-1})
x_{N}	N content of raw protein (1 / 6.25 kg kg^{-1})
$x_{\text{XP, feed}}$	Raw protein content of feed (fresh matter) (in kg kg^{-1})
x_{feed}	Feed input (fresh matter) per kg of weight gain (in kg kg^{-1})
$x_{\text{N, ret}}$	Specific N retention (kg kg^{-1})

In a conservative approach, and as a simplifying approximation, Δw_{round} is considered to be equal to the end weight after fattening (see above). The raw protein content of the feed, $x_{\text{XP,feed,}}$ pursuant to [219], is about 0.17 kg kg^{-1}. The feed input x_{feed} is about 3.5 kg kg^{-1} (LfL Bayern). Pursuant to DLG (2005), p.12, $x_{\text{n,ret}}$ = 0.03 kg kg^{-1}. Equation58 then yields an N-excretion value of 0.8 kg pl^{-1} a^{-1}.

For ostriches, neither (IPCC (2006): Vol. 4) nor EMEP (2016) provide default values for N excretions. For the German calculations in this category, we again use the relevant Danish value (UNFCCC, 2018a): 15.6 kg pl^{-1} a^{-1}.

For mink, IPCC (2006): Vol. 4, 10.59, Tab. 10.19 specifies a default N-excretion value of 4.59 kg pl^{-1} a^{-1}.

19.3.1.4.2 Direct N_2O emissions from manure management

For rabbits, fur-bearing animals and ostriches, the direct N_2O emissions from manure management are obtained by multiplying the relevant animal-place figures by the annual N excretions per place, the relevant N_2O-N emission factor (0.005 kg kg^{-1} for rabbits and fur-bearing animals, and 0.001 kg kg^{-1} for ostriches; cf. Chapter 5.3.4.2.2) and the molar ratio of N_2O to N (44/28). No N_2O emissions occur in the area of manure management for deer, since free-range management may be considered equivalent to "grazing" in this regard. The resulting emissions are reported together with the direct N_2O emissions from soils; cf. Chapter 19.3.1.6.

Table 541: Direct N_2O emissions from manure management for deer, rabbits, ostriches and fur-bearing animals

	N_{excr} [kg pl^{-1} a^{-1}]	N_2O [kt a^{-1}]	CO_{2eq} [kt a^{-1}]
Total		**0.005**	**1.56**
Deer	16	NO	NO
Rabbits	0.8	0.003	0.82
Ostriches	15.6	0.0002	0.06
Fur-bearing animals (mink)	4.59	0.002	0.68

19.3.1.5 Indirect N_2O emissions from manure management

As for other animals (cf. Chapter 5.3.1), indirect N_2O emissions from leaching / surface runoff are not calculated. The following section describes the calculation of indirect N_2O emissions from deposition of reactive nitrogen from NH_3 and NO emissions from housing and storage. Due to a lack of relevant data, nitrogen inputs from bedding material cannot be taken into account.

First, the NH_3 and NO emissions from housing and storage are determined. The procedure for calculating the NO emissions is similar to that for calculating direct N_2O emissions from housing and storage (cf. Chapter 19.3.1.4.2). As was the case for the other animals (cf. Chapter 5.3.4.2.2),

[219] http://www.meissner-widder-kaninchen.de/F_WERT_TAB1.html

the emission factor is set to ten percent of the N_2O emission factor: 0.0013 kg kg^{-1} for rabbits and fur-bearing animals, and 0.0001 kg kg^{-1} for ostriches.

The NH_3 emissions from housing are calculated by multiplying the excreted quantity of TAN (total ammoniacal nitrogen) by the relevant emission factor. The applicable TAN quantity is obtained as the product of N excretions and the excretions' relative TAN content. The NH_3 emissions from storage are proportional to the TAN quantity that remains following deduction of N losses due to NH_3 emissions from the stable. The pertinent proportionality factor is the emission factor for storage. For rabbits and ostriches, no data on TAN content and emission factors are in keeping with. For this reason, the relevant default values for horses and geese given in EMEP (2016)-3B-29 are used. The data so used are listed in Table 542, with the emission factors given in kg NH_3-N per kg TAN. For deer, the calculation is not required, since deer are assumed to remain outdoors year-round.

Table 542: Input data for calculation of NH_3 emissions (emission factors [EF] in kg NH_3-N per kg TAN)

	TAN content [%]	EF stable [kg kg^{-1}]	EF storage [kg kg^{-1}]	Remarks
Rabbits	60	0.22	0.35	Default for horses, (EMEP, 2016)-3B-29
Ostriches	70	0.57	0.16	Default for geese, (EMEP, 2016)-3B-29
Fur-bearing animals (mink)	60	0.27	0.09	Default, (EMEP, 2016)-3B-29

The resulting deposition of reactive nitrogen (N_{reac}), and the then-resulting indirect N_2O emissions, are given in Table 543. Here, pursuant to IPCC (2006): Vol. 4, 11.24, Tab. 11.3, an emission factor of EF_4 = 0.01 kg N_2O-N per kg N_{reac} has been used.

Table 543: Indirect N_2O emissions from deposition of reactive nitrogen from NH_3 and NO emissions from housing and storage

	N_{reac}[kt a^{-1}]	N_2O [kt a^{-1}]	CO_{2eq} [kt a^{-1}]
Total	**0.2164**	**0.00340**	**1.01**
Rabbits	0.0000	0.00000	0.00
Ostriches	0.1043	0.00164	0.49
Fur-bearing animals (mink)	0.0533	0.00084	0.25

19.3.1.6 Direct N_2O emissions from agricultural soils

Application of manure of rabbits, ostriches and fur-bearing animals, and free-range husbandry of deer, leads to direct N_2O emissions from agricultural soils.

The emissions from manure application are calculated by multiplying the N quantity that remains, following N losses (as NH_3, N_2O, NO and N_2) from housing and storage, by the IPCC default emission factor EF_1 (0.01 kg N_2O-N per kg N, IPCC (2006): Vol. 4, 11.11, Tab. 11.1) and the molar ratio 44/28.

The N_2O emissions caused by deer are obtained by multiplying the number of animals by the TAN excretions, the N_2O-N emission factor for grazing and the molar ratio 44/28. The applicable TAN quantity is obtained as the product of N excretions and the excretions' relative TAN content. Since the latter factor is unknown, the relevant value for sheep pursuant to EMEP (2016)-3B-29 (50 %) is used. Pursuant to IPCC (2006): Vol. 4, 11.11, Tab. 11.1, the $EF_{3PRP,SO}$ for sheep and other animals (0.01 kg N_2O-N per kg N excretions) is used as the emission factor.

Table 544 shows the pertinent emissions, along with the N quantities used to obtain them, via multiplication by the relevant emission factors and the molar ratio 44/28.

Table 544: Direct N_2O emissions from soils as a result of free-range husbandry of deer and of application of manure of rabbits, ostriches and fur-bearing animals.

	N [kt a^{-1}]	N_2O [kt a^{-1}]	CO_{2eq} [kt a^{-1}]
Total	**4.765**	**0.0749**	**22.31**
Deer	4.232	0.0665	19.82
Rabbits	0.241	0.0038	1.13
Ostriches	0.065	0.0010	0.31
Fur-bearing animals (mink)	0.227	0.0036	1.06

19.3.1.7 Indirect N_2O emissions from agricultural soils

To calculate the indirect emissions from deposition of reactive nitrogen, one must know the NH_3-N emissions from free-range husbandry of deer and from manure application, along with the relevant NO-N emissions. Table 546 shows the emission factors that are used to calculate the NH_3 emissions.

Table 545: Parameters for calculation of indirect N_2O emissions from deposition of reactive nitrogen as a result of free-range husbandry and of application (emission factors [EF] in kg NH_3-N per kg TAN)

	EF_{NH3-N} Free-range	EF_{NH3-N} application	Remarks
Deer	0.09		Default for sheep, (EMEP, 2016)-3B-29
Rabbits		0.90	Default for horses, (EMEP, 2016)-3B-29
Ostriches		0.45	Default for geese, (EMEP, 2016)-3B-29
Fur-bearing animals (mink)		0.90	Default for horses, (EMEP, 2016)-3B-29

In a procedure similar to that described in Chapter5.3.4.2.2, the NO-N emissions from free-range husbandry of deer, and from application of manure of rabbits, ostriches and fur-bearing animals are calculated with the emission factor derived by Stehfest and Bouwman (2006), 0.012 kg NO-N per kg of available nitrogen.

The resulting deposition of reactive nitrogen (N_{reac}), and the then-resulting indirect N_2O emissions, are given in Table 546. Here, pursuant to IPCC (2006): Vol. 4, 11.24, Tab. 11.3, an emission factor of EF_4 = 0.01 kg N_2O-N per kg N_{reac} has been used.

Table 546: Indirect N_2O emissions from deposition of reactive nitrogen (N_{reac}) from NH_3 and NO emissions from free-range husbandry of deer and from manure application

	N_{reac}[kt a^{-1}]	N_2O [kt a^{-1}]	CO_{2eq} [kt a^{-1}]
Total	**0.456**	**0.0072**	**2.13**
Deer	0.241	0.0038	1.13
Rabbits	0.096	0.0015	0.45
Ostriches	0.014	0.0002	0.07
Fur-bearing animals (mink)	0.104	0.0016	0.49

The indirect emissions from leaching / surface runoff are calculated by multiplying the N quantity applied to the soil, ($N_{applied}$), by $FRAC_{Leach}$ (0.3 kg kg^{-1} pursuant to IPCC (2006a)-11.24, Table 11.3) and the emission factor EF_5 = 0.0075 kg N_2O-N (kg N leaching/runoff) (IPCC (2006): Vol. 4, 11.24, Tab.11.3).

Table 547: Indirect N_2O emissions from the soil as a result of leaching / surface runoff

	$N_{applied}$ [kt a^{-1}]	N_2O [kt a^{-1}]	CO_{2eq} [kt a^{-1}]
Total	**4.765**	**0.0168**	**5.02**
Deer	4.232	0.0150	4.46
Rabbits	0.241	0.0009	0.25
Ostriches	0.065	0.0002	0.07
Fur-bearing animals (mink)	0.227	0.0008	0.24

19.3.2 Distributions of housing, storage and application procedures, and of grazing data (CRF 3.B, 3.D)

Table 548 through Table 551 show the applicable distributions, aggregated at the national level (and rounded to whole-number percentages), of housing, storage and application procedures. They also include data on grazing. Buffalo, and mules and asses, are not listed separately in the following tables, because buffalo data are reported together with cattle data, and data for mules and asses are reported together with data for horses (cf. Chapter 5.1.3.2.2).

The relevant emissions were calculated not with the data shown in Table 548 through Table 551, but with the data underlying those data. Those underlying data have state-level (German-Länder-level) resolution. Cf. Chapter 3.4.3 in Rösemann et al. (2019b). The tables also include information relative to emission factors (including that for NH_3). For further details, cf. chapters 3.4.4, 4.2.2, 5.2.2, 6.2.2, 7.2.2, 8.2.2 and 8.3.8.3 in Rösemann et al. (2019b).

Table 548: Frequency distributions of animal housing procedures (in %), and pertinent litter quantities and NH_3 emission factors

livestock category	housing type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	bedding material (straw) kg place d^{-1}	NH3-N EF for housing, kg NH3-N per kg TAN in excreta
Dairy cows	tied systems, straw based	31	31	31	31	15	15	15	15	13	13	13	12	12	12	11	11	10	10	10	9	9	9	9	9	9	9	9	9	5.0	0,066
	tied systems, slurry based	39	39	39	39	36	36	36	36	34	34	33	31	30	28	27	25	24	23	21	20	18	18	18	18	18	18	18	18		0,066
	loose housing, straw based	2	2	2	2	3	3	3	3	3	3	4	4	5	5	6	6	7	7	8	8	9	9	9	9	9	9	9	9	5.0	0,197
	loose housing, slurry based	28	28	28	28	46	46	46	46	49	49	50	52	53	55	56	57	59	60	61	63	64	64	64	64	64	64	64	64		0,197
	loose housing, deep bedding	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8.0	0,197
	time spent on pastures (in % of year)	18	18	18	18	14	14	14	14	13	13	13	13	12	12	12	11	11	11	11	11	10	11	11	11	11	11	11	11		
male beef cattle	tied systems, straw based	4	4	4	4	2	2	2	2	2	2	2	3	3	4	4	5	5	6	6	6	7	7	7	7	7	7	7	7	2.0	0,066
	tied systems, slurry based	7	7	7	7	4	4	4	4	4	4	4	5	5	6	7	7	8	8	9	10	10	10	10	10	10	10	10	10		0,066
	loose housing, slurry based	85	85	85	85	89	89	89	89	91	91	87	84	81	77	74	71	67	64	61	57	54	54	54	54	54	54	54	54		0,197
	loose housing, sloped floor	4	4	4	4	4	4	4	4	3	3	6	8	10	13	15	17	19	22	24	26	29	29	29	29	29	29	29	29	2.5	0,213
	time spent on pastures (in % of year)	4	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3	3	4	4	3	3	3	3	3	3	3		
heifers	tied systems, straw based	8	8	8	8	8	8	8	8	8	8	9	9	9	9	9	9	10	10	10	10	10	10	10	10	10	10	10	10	2.0	0,066
	tied systems, slurry based	17	17	17	17	17	17	17	17	17	17	16	16	15	14	14	13	12	12	11	10	10	10	10	10	10	10	10	10		0,066
	loose housing, slurry based	49	49	49	49	49	49	49	49	50	50	49	49	48	48	47	47	47	46	46	45	45	45	45	45	45	45	45	45		0,197
	loose housing, straw based	26	26	26	26	26	26	26	26	25	25	26	27	28	29	30	31	31	32	33	34	35	35	35	35	35	35	35	35	3.0	0,197
	time spent on pastures (in % of year)	20	20	19	19	19	19	20	20	20	20	20	19	19	19	19	19	19	19	20	20	20	20	20	20	20	20	20	20		
calves	tied systems, straw based	50	50	50	50	50	50	50	50	50	50	50	50	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.5	0,066
	loose housing, deep bedding	50	50	50	50	50	50	50	50	50	50	50	50	50	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	2.5	0,197
	time spent on pastures (in % of year)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
suckler cows	tied systems, straw based	7	7	7	7	6	6	6	6	6	6	7	8	9	10	11	12	13	14	15	16	17	17	17	17	17	17	17	17	5.0	0,066
	tied systems, slurry based	3	3	3	3	3	3	3	3	2	2	3	3	3	3	4	4	4	4	5	5	5	5	5	5	5	5	5	5		0,066
	loose housing, slurry based	10	10	10	10	8	8	8	8	7	7	8	9	9	10	11	11	12	13	13	14	14	14	14	14	14	14	14	14		0,197
	loose housing, deep bedding	80	80	80	80	83	83	83	83	85	85	83	81	79	77	75	73	71	69	67	65	63	63	63	63	63	63	63	63	8.0	0,197
	time spent on pastures (in % of year)	42	41	42	42	42	42	43	43	44	44	44	44	45	44	45	45	45	46	46	47	47	47	47	47	47	47	47	47		

livestock category	housing type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	bedding material (straw) kg place d^{-1}	NH3-N EF for housing, kg NH3-N per kg TAN in excreta
mature males > 2 years	tied systems, straw based	15	15	15	15	15	15	15	15	14	14	14	14	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	2.6	0,066
	tied systems, slurry based	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8		0,066
	loose housing, slurry based	34	34	34	34	35	35	35	35	36	36	36	36	35	35	35	35	34	34	34	34	33	33	33	33	33	33	33	33		0,197
	loose housing, straw based	43	43	43	43	42	42	42	42	41	41	41	42	42	42	43	43	43	43	44	44	44	44	44	44	44	44	44	44	2.6	0,197
	time spent on pastures (in % of year)	35	33	33	34	33	33	33	32	33	33	32	32	32	32	32	33	33	33	34	34	34	34	34	34	34	34	34	34		
fattening pigs	fully slatted floor, slurry	49	49	49	49	57	57	57	57	62	62	63	64	64	65	66	67	68	69	70	71	72	72	72	72	72	72	72	72		0.3
	partly slatted floor, slurry	40	40	40	40	34	34	34	34	31	31	31	30	29	28	27	26	26	25	24	23	22	22	22	22	22	22	22	22		0.3
	plane floor with bedding	8	8	8	8	6	6	6	6	5	5	5	5	5	5	5	5	5	4	4	4	4	4	4	4	4	4	4	4	0.3	0.4
	deep bedding	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1.0	0.4
	time spent on pastures (in % of year)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
weaners	fully slatted floor, slurry	45	45	45	45	57	57	57	57	62	62	63	64	64	65	66	67	68	68	69	70	71	71	71	71	71	71	71	71		0.3
	partly slatted floor, slurry	41	41	41	41	33	33	33	33	28	28	28	27	27	26	26	25	25	24	24	23	23	23	23	23	23	23	23	23		0.3
	plane floor with bedding	10	10	10	10	7	7	7	7	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	5	5	5	5	0.15	0.4
	deep bedding	4	4	4	4	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0.2	0.4
	time spent on pastures (in % of year)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
sows	straw based	42	42	42	42	26	26	26	26	24	24	23	22	22	21	20	19	18	17	16	15	14	14	14	14	14	14	14	14	0.5	0.34
	slurry based	58	58	58	58	74	74	74	74	76	76	77	78	78	79	80	81	82	83	84	85	86	86	86	86	86	86	86	86		0.34
	time spent on pastures (in % of year)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
boars	straw based	32	32	32	32	23	23	23	23	21	21	21	21	20	20	19	19	18	18	17	17	16	16	16	16	16	16	16	16	0.5	0.34
	slurry based	68	68	68	68	77	77	77	77	79	79	79	79	80	80	81	81	82	82	83	83	84	84	84	84	84	84	84	84		0.34
	time spent on pastures (in % of year)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
laying hens	cages; ≥2010: small group housing systems	95	95	95	95	95	94	92	90	89	88	87	85	84	81	77	73	70	68	62	38	18	14	13	11	11	10	10	9		*)
	floor management, aviary	4	4	4	4	4	5	5	7	7	7	7	7	7	9	12	14	15	17	22	45	63	64	64	64	64	64	63	65	0.5 kg per place and year	*)
	free range, organic farming	1	1	1	1	1	2	2	4	4	5	7	8	9	10	11	13	14	15	16	18	19	22	23	24	26	26	27	26	0.5 kg per place and year	*)
broilers	floor management	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	1.4 kg per place and year	0.09 kg per kg N
pullets	floor management	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0.75 kg per place and year	0.09 kg per kg N
ducks	floor management	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	22 kg per place and year	0.16 kg per kg N

livestock category	housing type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	bedding material (straw) kg place d^{-1}	NH3-N EF for housing, kg NH3-N per kg TAN in excreta
geese	floor management	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100		0.57
turkeys, female	floor management	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	10.3 kg per place and year	0.22 kg per kg N
turkeys, male	floor management	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	10.3 kg per place and year	0.22 kg per kg N
horses	straw based system	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	8.0/ 5.0	0.22
	time spent on pastures (in % of year)	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21		
sheep without lambs	straw based system	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0.4	0.22
	time spent on pastures (in % of year)	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55		
lambs	straw based system	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0.16	0.22
	time spent on pastures (in % of year)	57	57	58	58	57	57	58	57	57	57	57	57	57	57	57	57	57	57	57	57	55	55	55	55	55	55	55	55		
goats	straw based system	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0.4	0.22
	time spent on pastures (in % of year)	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34	34		

*) s. Table 551: Laying hens, housing-specific partial NH_3 emission factors

Table 549: Frequency distributions of storage systems (in %); quantities of digested energy crops; and pertinent emission factors

livestock category	storage type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	NH_3-N EF for storage, kg NH_3-N per kg TAN in storage system	NH_3-N EF for storage, kg NH_3-N per kg TAN in storage system (leachate / urine)	N_2O EF for storage kg N_2O-N per kg N in storage system	N_2O EF for storage kg N_2O-N per kg N in storage system (leachate / urine)	CH_4 MCF for storage % of Bo < 10 °C	maximum CH_4 producing capacity (Bo) m³ CH4 per kg VS
cattle, untreated slurry	open tank (% of total untreated slurry)	1	1	1	1	1	1	1	1	1	1	1	2	2	2	3	3	4	4	5	5	6	6	6	6	6	6	6	6	0,150		0,000		17.0	0.23
	solid cover (% of total untreated slurry)	24	24	24	24	22	22	22	22	22	22	23	24	24	25	26	26	27	28	28	29	30	30	30	30	30	30	30	30	0,015		0,005		17.0	0.23
	natural crust (% of total untreated slurry)	33	33	33	33	40	40	40	40	40	40	39	38	36	35	34	33	31	30	29	28	26	26	26	26	26	26	26	26	0,045		0,005		10.0	0.23
	plastic film (% of total untreated slurry)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,023		0,000		17.0	0.23
	artificial crust (chaff) (% of total untreated slurry)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,030		0,000		17.0	0.23
	storage below animal confinements > 1 month (% of total untreated slurry)	43	43	43	43	36	36	36	36	36	36	36	36	37	37	37	37	37	37	38	38	38	38	38	38	38	38	38	38	0,045		0,002		17.0	0.23

livestock category	storage type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	NH_3-N EF for storage, kg NH_3-N per kg TAN in storage system	NH_3-N EF for storage, kg NH_3-N per kg TAN in storage system (leachate / urine)	N_2O EF for storage kg N_2O-N per kg N in storage system	N_2O EF for storage kg N_2O-N per kg N in storage system (leachate / urine)	CH_4 MCF for storage % of Bo < 10 °C	maximum CH_4 producing capacity (Bo) m³ CH4 per kg VS
cattle, digestion of slurry	% of total cattle slurry	0	0	0	0	0	0	0	0	0	0	1	1	1	1	2	4	6	9	11	13	17	21	22	25	25	26	26	26						
cattle, digestion of solid manure	% of total solid manure of cattle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	2	2	3	3	4	4	4	4	4	5						
cattle, storage of digestates	gas tight storage (% of slurry)	0	1	2	3	4	5	5	6	7	8	9	10	11	12	14	15	20	25	30	35	41	46	57	59	61	62	62	62	0.000 *)		0.000 *)		2.7 *)	0.23
cattle, storage of digestates	open tank (% of slurry)	100	99	98	97	96	95	95	94	93	92	91	90	89	88	86	85	80	75	70	65	59	54	43	41	39	38	38	38	0.045 *)		0.005 *)		3.1 *)	0.23
cattle, storage of digestates	gas tight storage (% of solid manure)	0	1	2	3	4	5	5	6	7	8	9	10	11	12	14	15	20	25	30	35	41	46	57	59	61	62	62	62	0.000 *)		0.000 *)		1.2 *)	0.23
cattle, storage of digestates	open tank (% of solid manure)	100	99	98	97	96	95	95	94	93	92	91	90	89	88	86	85	80	75	70	65	59	54	43	41	39	38	38	38	0.045 *)		0.005 *)		1.6 *)	0.23
dairy cows, solid manure	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0,600	0,013	0,005	0,005	2.0	0.23
male beef cattle, solid manure	heap (% of total solid manure)	46	46	46	46	39	39	39	39	38	38	30	27	25	23	22	21	21	20	20	20	19	19	19	19	19	19	19	19	0,600	0,013	0,005	0,005	2.0	0.23
	sloped floor (% of total solid manure)	54	54	54	54	61	61	61	61	62	62	70	73	75	77	78	79	79	80	80	80	81	81	81	81	81	81	81	81	0,600		0,010	0,005	17.0	0.23
heifers, solid manure	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0,600	0,013	0,005	0,005	2.0	0.23
calves, solid manure	heap (% of total solid manure)	50	50	50	50	50	50	50	50	50	50	50	50	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,600	0,013	0,005	0,005	2.0	0.23
	deep bedding (% of	50	50	50	50	50	50	50	50	50	50	50	50	50	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0,600		0,010		17.0	0.23

livestock category	storage type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	NH_3-N EF for storage, kg NH_3-N per kg TAN in storage system	NH_3-N EF for storage, kg NH_3-N per kg TAN in storage system (leachate / urine)	N_2O EF for storage kg N_2O-N per kg N in storage system	N_2O EF for storage kg N_2O-N per kg N in storage system (leachate / urine)	CH_4 MCF for storage % of Bo < 10 °C	maximum CH_4 producing capacity (Bo) m³ CH4 per kg VS
	total solid manure)																																		
suckler cows, solid manure	heap (% of total solid manure)	8	8	8	8	7	7	7	7	6	6	7	9	10	11	13	14	16	17	18	20	22	22	22	22	22	22	22	22	0,600	0,013	0,005	0,005	2.0	0.23
	deep bedding (% of total solid manure)	92	92	92	92	93	93	93	93	94	94	93	91	90	89	87	86	84	83	82	80	78	78	78	78	78	78	78	78	0,600		0,010		17.0	0.23
mature males, solid	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0,600	0,013	0,005	0,005	2.0	0.23
pigs, untreated slurry	open tank (% of total untreated slurry)	47	47	47	47	27	27	27	27	27	27	25	23	22	20	19	17	15	14	12	10	9	9	9	9	9	9	9	9	0,150		0,000		25.0	0.30
	solid cover (% of total untreated slurry)	18	18	18	18	22	22	22	22	22	22	23	23	23	24	24	24	25	25	26	26	26	26	26	26	26	26	26	26	0,015		0,005		25.0	0.30
	natural crust (% of total untreated slurry)	3	3	3	3	13	13	13	13	13	13	14	16	17	19	20	22	23	25	26	28	29	29	29	29	29	29	29	29	0,105		0,005		15.0	0.30
	plastic film (% of total untreated slurry)	0	0	0	0	6	6	6	6	6	6	6	5	4	4	3	3	2	2	1	1	0	0	0	0	0	0	0	0	0,023		0,000		25.0	0.30
	artificial crust (chaff) (% of total untreated slurry)	0	0	0	0	1	1	1	1	1	1	1	1	2	2	2	2	3	3	3	4	4	4	4	4	4	4	4	4	0,030		0,000		25.0	0.30
	storage below animal confinements > 1 month (% of	32	32	32	32	31	31	31	31	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	0,105		0,002		25.0	0.30

livestock category	storage type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	NH_3-N EF for storage, kg NH_3-N per kg TAN in storage system	NH_3-N EF for storage, kg NH_3-N per kg TAN in storage system (leachate / urine)	N_2O EF for storage kg N_2O-N per kg N in storage system	N_2O EF for storage kg N_2O-N per kg N in storage system (leachate / urine)	CH_4 MCF for storage % of Bo < 10 °C	maximum CH_4 producing capacity (Bo) m^3 CH4 per kg VS
	total untreated slurry)																																		
pigs, digested slurry	% of total pig slurry	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	3	4	5	6	8	10	12	13	15	15	16	16	16						
pigs, storage of digestates	gas tight storage (% of digestates)	0	1	2	3	4	5	5	6	7	8	9	10	11	12	14	15	20	25	30	35	41	46	57	59	61	62	62	62	0.000 *)		0.000 *)		3.5 *)	0.30
pigs, storage of digestates	open tank (% of digestates)	100	99	98	97	96	95	95	94	93	92	91	90	89	88	86	85	80	75	70	65	59	54	43	41	39	38	38	38	0.045 *)		0.005 *)		3.9 *)	0.30
fattening pigs / weaners, solid manure	heap (% of total solid manure)	75	75	75	75	70	70	70	70	69	69	69	70	70	71	71	71	72	72	73	73	74	74	74	74	74	74	74	74	0,600	0,030	0,005	0,005	3.0	0.30
	deep bedding (% of total solid manure)	25	25	25	25	30	30	30	30	31	31	31	30	30	29	29	29	28	28	27	27	26	26	26	26	26	26	26	26	0,600		0,010		25.0	0.30
sows / boars, solid manure	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0,600	0,030	0,005	0,005	3.0	0.30
laying hens	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0,140		0,001		1.5	0.39
broilers	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0,170		0,001		1.5	0.36
pullets	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0,170		0,001		1.5	0.39
ducks	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0,240		0,001		1.5	0.36
geese	heap (% of total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0,160		0,001		1.5	0.36

livestock category	storage type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	NH_3-N EF for storage, kg NH_3-N per kg TAN in storage system	NH_3-N EF for storage, kg NH_3-N per kg TAN in storage system (leachate / urine)	N_2O EF for storage kg N_2O-N per kg N in storage system	N_2O EF for storage kg N_2O-N per kg N in storage system (leachate / urine)	CH_4 MCF for storage % of Bo < 10 °C	maximum CH_4 producing capacity (Bo) m³ CH4 per kg VS
	solid manure)																																		
turkeys, female	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0,240		0,001		1.5	0.36
turkeys, male	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0,240		0,001		1.5	0.36
poultry, digested solid manure		0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	3	4	5	6	8	10	11	11	13	13	13	13	13						
poultry, storage of digestates	gas tight storage (% of digestates)	0	1	2	3	4	5	5	6	7	8	9	10	11	12	14	15	20	25	30	35	41	46	57	59	61	62	62	62	0.000 *)		0.000 *)		1.1 *)	see animal-specific
poultry, storage of digestates	open tank (% of digestates)	100	99	98	97	96	95	95	94	93	92	91	90	89	88	86	85	80	75	70	65	59	54	43	41	39	38	38	38	0.045 *)		0.005 *)		1.6 *)	values (above)
horses	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0,350		0,005		2.0	0.30
sheep	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0,280		0,005		2.0	0.19
goats	heap (% of total solid manure)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0,280		0,005		2.0	0.18

livestock category	storage type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	NH_3-N EF for storage, kg NH_3-N per kg TAN in storage system	NH_3-N EF for storage, kg NH_3-N per kg TAN in storage system (leachate / urine)	N_2O EF for storage kg N_2O-N per kg N in storage system	N_2O EF for storage kg N_2O-N per kg N in storage system (leachate / urine)	CH_4 MCF for storage % of Bo < 10 °C	maximum CH_4 producing capacity (Bo) m³ CH4 per kg VS
digestion of energy crops	amount of energy crops digested (1000 kt fresh matter)	0.01	0.02	0.03	0.04	0.05	0.12	0.20	0.25	0.56	0.64	1.0	1.5	2.1	2.5	3.2	8.7	12.2	16.7	19.5	25.0	31.4	39.2	42.9	52.0	54.3	56.5	56.2	56.9						
	gas tight storage (% of digestates)	0	1	2	3	4	5	6	7	8	8	9	10	11	13	14	16	21	26	32	37	42	48	59	62	64	64	65	65	0.000 *)		0.000 *)		1.0 *)	0.36
	open tank (% of digestates)	100	99	98	97	96	95	94	93	92	92	91	90	89	87	86	84	79	74	68	63	58	52	41	38	36	36	35	35	0.045 *)		0.005 *)		1.4 *)	0.36

*) digestion of slurry, solid manure, poultry manure and energy crops: EFs and MCFs are overall values for the system "pre-storage (if existent) + digester + storage of digestates"

Table 550: Frequency distributions of application procedures (in %), and pertinent emission factors

livestock category	application type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	NH_3-N EF for application, kg NH_3-N per kg TAN applied
cattle, untreated slurry	broadcast, without incorporation	11	11	11	11	2	2	2	2	2	2	2	2	2	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0.50
	broadcast, incorporation < 1 h	3	3	3	3	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	7	9	11	11	11	0.10
	broadcast, incorporation < 4h	0	0	0	0	2	2	2	2	2	2	3	3	4	5	6	7	7	8	9	10	11	11	18	14	11	8	8	8	0.26
	broadcast, incorporation < 6h	5	5	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.35
	broadcast, incorporation < 8h	0	0	0	0	0	0	0	0	0	0	1	1	2	2	3	3	4	4	5	5	6	6	0	0	0	0	0	0	0.40

livestock category	application type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	NH_3-N EF for application, kg NH_3-N per kg TAN applied
	broadcast, incorporation < 12h	0	0	0	0	20	20	20	20	22	22	20	18	16	14	12	11	9	7	5	3	1	1	0	0	0	0	0	0	0.43
	broadcast, incorporation < 24h	32	32	32	32	9	9	9	9	9	9	9	8	7	6	5	4	3	3	2	1	0	0	0	0	0	0	0	0	0.46
	broadcast, incorporation < 48h	4	4	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.50
	broadcast, vegetation	0	0	0	0	0	0	0	0	0	0	1	3	4	6	7	9	10	12	13	15	16	16	16	16	15	15	15	15	0.50
	broadcast, grassland	44	44	44	44	43	43	43	43	41	41	41	41	42	42	42	42	43	43	43	43	44	44	44	44	45	46	46	46	0.60
	trailing hose, without incorporation	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.46
	trailing hose, incorporation < 1 h	0	0	0	0	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	2	2	0.04
	trailing hose, incorporation < 4h	0	0	0	0	3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	3	2	2	1	1	1	0.15
	trailing hose, incorporation < 6h	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.20
	trailing hose, incorporation < 8h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0.24
	trailing hose, incorporation < 12h	0	0	0	0	9	9	9	9	9	9	8	7	7	6	5	4	3	3	2	1	0	0	0	0	0	0	0	0	0.30
	trailing hose, incorporation < 24h	1	1	1	1	2	2	2	2	2	2	2	2	2	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0.39
	trailing hose, incorporation < 48h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.46
	trailing hose, vegetation	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	2	3	3	3	4	4	4	4	4	4	4	4	4	0.35
	trailing hose, short vegetation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.46

livestock category	application type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	NH_3-N EF for application, kg NH_3-N per kg TAN applied
	trailing hose, grassland	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	0.54
	trailing shoe	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	5	6	6	6	0.36
	injection (open slot)	0	0	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0.24
	grubber and injection	0	0	0	0	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	3	3	3	3	0.04
cattle, solid manure	broadcast, without incorporation	14	14	14	14	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0.90
	broadcast, incorporation < 1 h	4	4	4	4	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	0.09
	broadcast, incorporation < 4h	0	0	0	0	9	9	9	9	8	8	10	11	13	14	15	17	18	20	21	23	24	26	27	29	30	31	31	31	0.45
	broadcast, incorporation < 12h	11	11	11	11	28	28	28	28	29	29	29	29	29	29	28	28	28	28	28	27	27	27	27	27	27	26	26	26	0.81
	broadcast, incorporation < 24h	43	43	43	43	24	24	24	24	25	25	23	22	20	19	17	15	14	12	11	9	8	6	5	3	2	0	0	0	0.90
	broadcast, incorporation < 48h	7	7	7	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.90
	broadcast, vegetation/grassland	21	21	21	21	25	25	25	25	24	24	24	24	25	25	25	25	26	26	26	26	27	27	27	27	28	28	28	28	0.90

livestock category	application type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	NH_3-N EF for application, kg NH_3-N per kg TAN applied
pigs, untreated slurry	broadcast, without incorporation	7	7	7	7	4	4	4	4	4	4	4	3	3	3	2	2	2	1	1	0	0	0	0	0	0	0	0	0	0.25
	broadcast, incorporation < 1 h	4	4	4	4	8	8	8	8	8	8	8	8	7	7	7	7	7	6	6	6	6	6	6	6	7	8	8	8	0.04
	broadcast, incorporation < 4h	0	0	0	0	1	1	1	1	1	1	2	2	3	4	5	5	6	7	8	9	9	9	15	12	9	5	5	5	0.09
	broadcast, incorporation < 6h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.11
	broadcast, incorporation < 8h	0	0	0	0	0	0	0	0	0	0	0	1	1	2	2	3	3	4	4	4	5	5	0	0	0	0	0	0	0.13
	broadcast, incorporation < 12h	0	0	0	0	29	29	29	29	28	28	25	23	20	18	16	13	11	8	6	4	1	1	0	0	0	0	0	0	0.16
	broadcast, incorporation < 24h	49	49	49	49	4	4	4	4	4	4	3	3	3	2	2	2	1	1	1	0	0	0	0	0	0	0	0	0	0.21
	broadcast, incorporation < 48h	3	3	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.25
	broadcast, vegetation	30	30	30	30	22	22	22	22	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	22	22	21	21	21	0.25
	broadcast, grassland	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	2	2	3	3	3	3	3	3	3	3	2	2	2	0.30

livestock category	application type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	NH_3-N EF for application, kg NH_3-N per kg TAN applied
	trailing hose, without incorporation	0	0	0	0	2	2	2	2	2	2	2	2	2	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0.18
	trailing hose, incorporation < 1 h	0	0	0	0	5	5	5	5	5	5	5	5	5	5	5	4	4	4	4	4	4	4	4	5	7	8	8	8	0.02
	trailing hose, incorporation < 4h	0	0	0	0	1	1	1	1	1	1	2	2	3	3	3	4	4	5	5	6	6	6	10	8	6	4	4	4	0.06
	trailing hose, incorporation < 6h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.08
	trailing hose, incorporation < 8h	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	2	2	2	2	3	3	3	0	0	0	0	0	0	0.09
	trailing hose, incorporation < 12h	0	0	0	0	10	10	10	10	10	10	9	8	7	7	6	5	4	3	2	2	1	1	0	0	0	0	0	0	0.11
	trailing hose, incorporation < 24h	4	4	4	4	2	2	2	2	2	2	2	2	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0.14
	trailing hose, incorporation < 48h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.17
	trailing hose, vegetation	0	0	0	0	0	0	0	0	0	0	3	5	8	11	13	16	19	21	24	27	29	29	29	31	33	34	34	34	0.13
	trailing hose, short vegetation	1	1	1	1	8	8	8	8	9	9	8	7	6	6	5	4	3	2	2	1	0	0	0	0	0	0	0	0	0.18
	trailing hose, grassland	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	0.21
	trailing shoe	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	2	2	2	2	2	2	4	6	7	7	7	0.12
	injection (open slot)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	2	3	3	3	3	0.06
	grubber and injection	0	0	0	0	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	0.02

livestock category	application type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	NH_3-N EF for application, kg NH_3-N per kg TAN applied
pigs, solid manure	broadcast, without incorporation	36	36	36	36	29	29	29	29	31	31	30	28	26	24	22	20	19	17	15	13	11	9	8	6	4	2	2	2	0.90
	broadcast, incorporation < 1 h	4	4	4	4	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	0.09
	broadcast, incorporation < 4h	0	0	0	0	2	2	2	2	1	1	4	6	8	10	12	14	16	18	20	23	25	27	29	31	33	35	35	35	0.45
	broadcast, incorporation < 12h	0	0	0	0	21	21	21	21	22	22	22	22	22	22	22	22	22	22	22	22	22	22	23	23	23	23	23	23	0.81
	broadcast, incorporation < 24h	53	53	53	53	33	33	33	33	30	30	28	26	24	23	21	19	17	15	13	11	9	8	6	4	2	0	0	0	0.90
	broadcast, incorporation < 48h	8	8	8	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.90
	broadcast, vegetation	0	0	0	0	0	0	0	0	0	0	2	3	5	6	8	9	11	12	14	15	17	19	20	22	23	25	25	25	0.90
cattle and pigs, leachate	broadcast, without incorporation	50	50	50	50	50	50	50	50	50	50	45	41	36	32	27	23	18	14	9	5	0	0	0	0	0	0	0	0	0.20
	broadcast, incorporation < 1 h	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	2	2	2	2	3	3	3	3	4	5	5	5	5	0.02
	broadcast, incorporation < 4h	0	0	0	0	0	0	0	0	0	0	1	1	2	3	4	4	5	6	7	7	8	8	19	15	12	9	9	9	0.07
	broadcast, incorporation < 8h	0	0	0	0	0	0	0	0	0	0	1	1	2	3	4	4	5	6	6	7	8	8	0	0	0	0	0	0	0.12
	broadcast, incorporation < 12h	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	2	2	2	2	3	3	3	0	0	0	0	0	0	0.14
	broadcast, vegetation	0	0	0	0	0	0	0	0	0	0	1	3	4	6	7	8	10	11	13	14	15	15	15	15	14	13	13	13	0.20
	broadcast, grassland	50	50	50	50	50	50	50	50	50	50	50	49	49	49	49	48	48	48	48	47	47	47	47	48	48	49	49	49	0.20

livestock category	application type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	NH_3-N EF for application, kg NH_3-N per kg TAN applied
	trailing hose, without incorporation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.18
	trailing hose, incorporation < 1 h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	2	2	2	2	0.01
	trailing hose, incorporation < 4h	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	2	2	4	3	3	2	2	2	0.05
	trailing hose, incorporation < 8h	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0.09
	trailing hose, incorporation < 12h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0.12
	trailing hose, vegetation	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	2	2	3	3	4	4	4	4	6	7	9	9	9	0.10
	trailing hose, grassland	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	2	2	2	2	3	3	3	3	3	3	3	3	3	0.14
	trailing shoe	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	2	4	5	5	5	0.08
	injection (open slot)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0.04
	grubber and injection	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	2	2	3	3	3	3	3	3	3	2	2	2	2	0.01
laying hens, solid manure	broadcast, without incorporation	8	8	8	8	5	5	5	5	8	8	9	10	11	11	12	13	13	14	15	16	16	17	18	18	19	20	20	20	0.90
	broadcast, incorporation < 1 h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
	broadcast, incorporation < 4h	0	0	0	0	0	0	0	0	0	0	4	9	13	17	22	26	31	35	39	44	48	52	57	61	65	70	70	70	0.18
	broadcast, incorporation < 12h	0	0	0	0	11	11	11	11	21	21	21	20	19	19	18	17	17	16	15	15	14	13	12	12	11	10	10	10	0.40
	broadcast, incorporation < 24h	92	92	92	92	84	84	84	84	70	70	66	61	57	53	48	44	39	35	31	26	22	18	13	9	4	0	0	0	0.45

livestock category	application type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	NH_3-N EF for application, kg NH_3-N per kg TAN applied
poultry, except laying hens, solid manure	broadcast, without incorporation	0	0	0	0	0	0	0	0	0	0	1	2	4	5	6	7	9	10	11	12	14	15	16	17	19	20	20	20	0.90
	broadcast, incorporation < 1 h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
	broadcast, incorporation < 4h	0	0	0	0	0	0	0	0	0	0	4	9	13	17	22	26	31	35	39	44	48	52	57	61	65	70	70	70	0.18
	broadcast, incorporation < 12h	0	0	0	0	0	0	0	0	0	0	1	1	2	3	3	4	5	5	6	6	7	8	8	9	10	10	10	10	0.40
	broadcast, incorporation < 24h	100	100	100	100	100	100	100	100	100	100	94	88	81	75	69	63	56	50	44	38	31	25	19	13	6	0	0	0	0.45
all other animals, solid manure (horses, sheep, goats)	broadcast, without incorporation	100	100	100	100	100	100	100	100	100	100	96	92	87	83	79	75	70	66	62	58	54	49	45	41	37	33	33	33	0.90
	broadcast, incorporation < 1 h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.09
	broadcast, incorporation < 4h	0	0	0	0	0	0	0	0	0	0	3	5	8	10	13	16	18	21	24	26	29	31	34	37	39	42	42	42	0.45
	broadcast, incorporation < 12h	0	0	0	0	0	0	0	0	0	0	2	3	5	6	8	10	11	13	14	16	18	19	21	22	24	26	26	26	0.81
	broadcast, incorporation < 24h	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.90
	broadcast, without incorporation																													

livestock category	application type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	NH_3-N EF for application, kg NH_3-N per kg TAN applied
digested manure (cattle, pigs, poultry) and digested energy crops	broadcast, without incorporation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.50
	broadcast, incorporation < 1 h	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	6	7	7	7	7	0.10
	broadcast, incorporation < 4h	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	16	12	9	5	5	5	0.26
	broadcast, incorporation < 8h	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	0	0	0	0	0	0	0.40
	broadcast, incorporation < 12h	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0.43
	broadcast, vegetation	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	12	11	10	10	10	0.50
	broadcast, grassland	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	11	10	9	9	9	0.60
	trailing hose, without incorporation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.46
	trailing hose, incorporation < 1 h	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	5	7	9	9	9	0.04
	trailing hose, incorporation < 4h	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	13	10	8	5	5	5	0.15
	trailing hose, incorporation < 8h	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	0	0	0	0	0	0	0.24
	trailing hose, incorporation < 12h	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0.30
	trailing hose, vegetation	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	17	17	17	17	17	0.35
	trailing hose, grassland	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	0.54
	trailing shoe	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6	9	12	12	12	0.36
	injection (open slot)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	7	8	8	8	0.24
	grubber and injection	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	12	13	14	14	14	0.04

Table 551: Laying hens, housing-specific partial NH_3 emission factors

<table>
<tr><th>[in kg NH3-N per excreted kg N]</th><th>≤ 2000</th><th>2001 – 2009</th><th>≥2010</th></tr>
<tr><td>cage housing;
as of 2010: small-group housing</td><td colspan="2">0,164</td><td>0,066</td></tr>
<tr><td>floor management, aviary</td><td>0,351</td><td>linear interpolation</td><td>0,090</td></tr>
<tr><td>intensive outdoor management, free-range management, organic production</td><td colspan="3">0,099</td></tr>
</table>

19.4 Other detailed methodological descriptions for the source/sink category "Land-use change and forestry" (4)

This chapter is currently not required.

19.5 Other detailed methodological descriptions for the category "Waste and wastewater" (6)

This chapter is currently not required.

20 Annex 4: CO_2 Reference Approach, and comparison with the Sectoral Approach

General information

In general, the Reference Approach briefly described in Chapter 3.2.1.1 is to be suitable for all reporting countries. Such generalization and abstraction cannot help but lead to considerable discrepancies with the Sectoral Approach.

On the whole, the Sectoral Approach supports calculations that are considerably more differentiated and precise, with results that – especially at a detailed level – differ (sharply, in some cases) from those produced by the Reference Approach.

Efforts to eliminate errors in transfer of country-specific activity data into the Reference Approach structure have gotten underway in recent years. At the level of maximum aggregation, this work, which is being continued with the present submission, has brought the results achieved with the two calculation approaches into excellent agreement (cf. Chapter 3.2.1.1). On the other hand, a number of discrepancies at the *fuel* and *fuel-group* levels still persist. While these can be explained – at least in part – as the result of country-specific circumstances, it has not yet been possible to eliminate them in a satisfactory manner.

The Reference Approach will thus continue to offer room for further improvements. Notably, the comparability of the two approaches would benefit from extensive flexibilization of data management in the CRF Reporter, as well as from review, and any necessary revision, of the input data and calculation approaches used for the area of non-energy-related consumption.

20.1 Comparing the results: The Sectoral Approach and the Reference Approach

The following section compares results obtained in calculating CO_2 emissions via the Sectoral Approach with results obtained via the Reference Approach.

CRF report table 1.A(c) compares results obtained with the Sectoral Approach with results obtained with the Reference Approach. Since the non-energy-related consumption (NEV) of the fuels considered occurs elsewhere (industrial processes and product use), the quantities that must be assigned to such consumption, pursuant to the Energy Balances, are deducted from the Reference Approach. In addition to lubricants, bitumen and naphtha, this procedure is applied to diesel fuel, light and heavy fuel oil, LPG, petroleum coke and other mineral oils, hard coal and lignite, coke and natural gas. For 2017, this approach yields an NEV of about 1,140 petajoules (cf. CRF Table 1.A(d)).

For peat, which is listed separately, identical emission factors and input quantities are used in 1.AA and 1.AB. For this reason, Table 1.A(c) shows no discrepancies in this area.

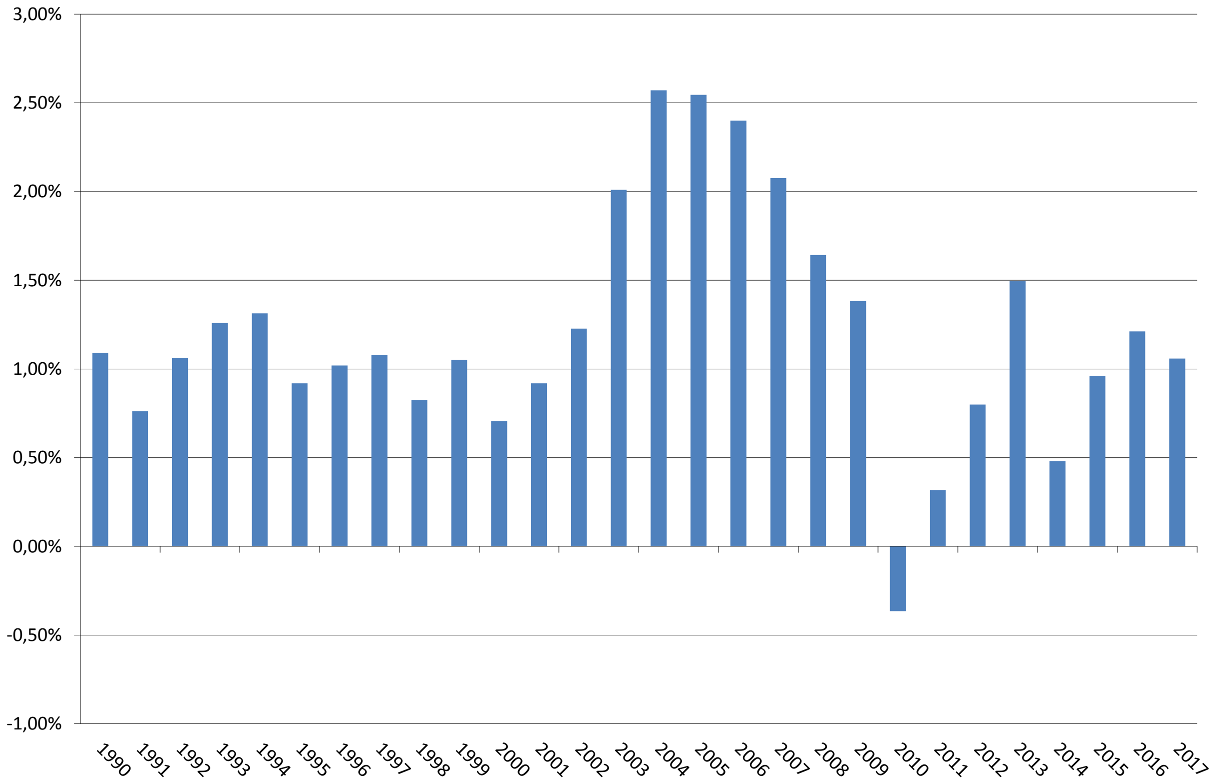
The following tables present further sample results of the comparison between the Sectoral Approach and the Reference Approach. For 2017, the Reference Approach yields fuel inputs that are 1.06 % higher and reference emissions that are 1.48 % higher (cf. Chapter 3.2.1.1).

Throughout the period as of 1990, almost all of the fuel inputs listed under the Reference Approach (less the quantities used for non-energy-related purposes) are, except fort he year 2010, higher than those listed under the Sectoral Approach.

Table 552: Comparison of the energy inputs determined via the Sectoral Approach and the Reference Approach (not including NEV), in terajoules

Year	1.AA	*1.AB (including non-energy-related consumption)*	1.AB (excluding non-energy-related consumption)	1.AB (excluding non-energy-related consumption) minus 1.AA	
1990	**11,677**	***12,961***	**11,804**	**127**	**1.09%**
1995	10,932	*12,151*	11,033	100	0.92%
2000	10,558	*11,879*	10,632	75	0.71%
2001	10,840	*12,123*	10,940	100	0.92%
2002	10,618	*11,933*	10,749	130	1.23%
2003	10,612	*12,021*	10,825	213	2.01%
2004	10,420	*11,891*	10,688	268	**2.57%**
2005	10,207	*11,739*	10,466	260	2.55%
2006	10,342	*11,821*	10,590	248	2.40%
2007	9,928	*11,298*	10,134	206	2.08%
2008	10,083	*11,386*	10,249	166	1.64%
2009	9,431	*10,607*	9,561	130	1.38%
2010	9,896	*11,015*	9,860	-36	-0.37%
2011	9,514	*10,685*	9,544	30	0.32%
2012	9,568	*10,732*	9,644	77	0.80%
2013	9,796	*11,029*	9,942	146	1.49%
2014	9,244	*10,405*	9,289	44	0.48%
2015	9,319	*10,492*	9,408	89	0.96%
2016	9,525	*10,744*	9,641	115	1.21%
2017	**9,546**	***10,787***	**9,647**	**101**	**1.06%**

Figure 90: Percentage discrepancies between annual total activity data under the Reference Approach and the corresponding total quantities under the Sectoral Approach

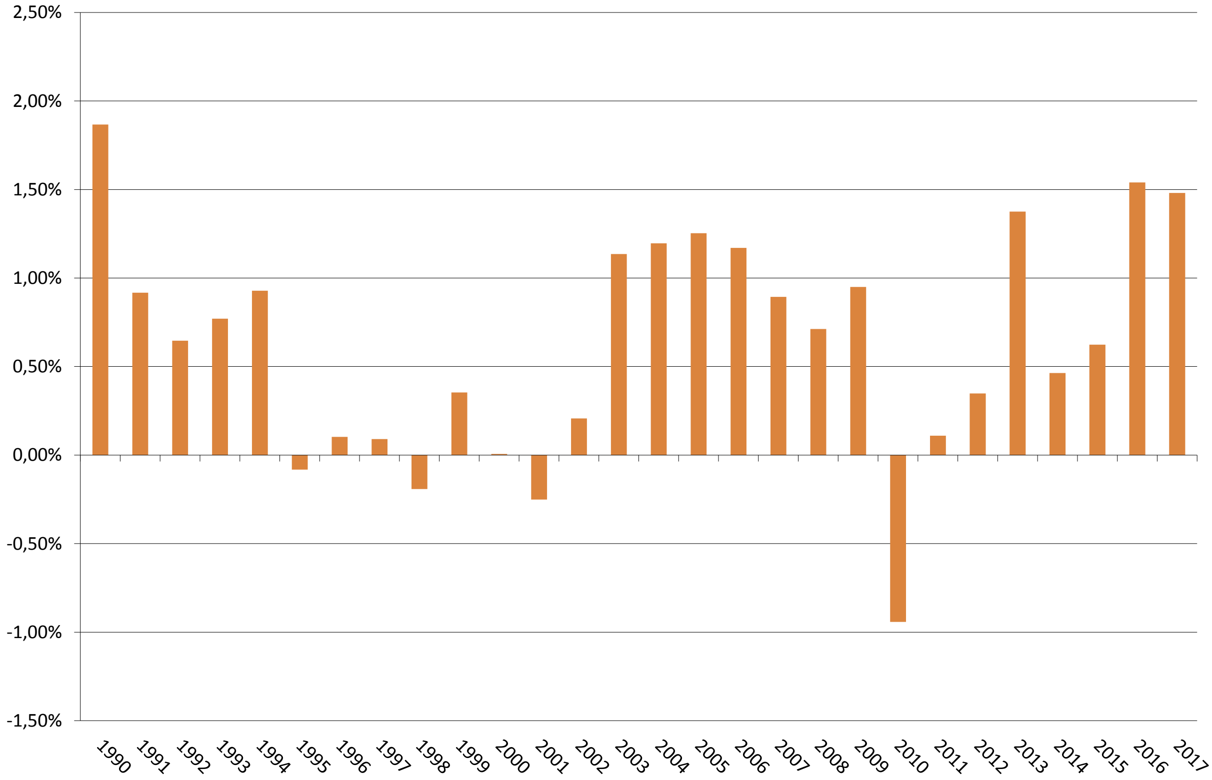


A mixed picture emerges for the carbon dioxide emissions calculated with the Reference Approach: On the one hand, they tend to be lower than those calculated with the Sectoral Approach. On the other hand, this relationship was reversed in 1990 and the more-recent years (cf. Chapter 3.2.1.1).

Table 553: Comparison of the CO_2 emissions determined via the Sectoral Approach and the Reference Approach (not including NEV), in kilotonnes

	1.AA	1.AB (excluding non-energy-related consumption)	1.AB (excluding non-energy-related consumption) minus 1.AA	
1990	**985,570**	**1,003,977**	**18,407**	**1.87%**
1995	878,100	877,384	-715	-0.08%
2000	836,564	836,622	57	0.01%
2001	859,369	857,210	-2,159	-0.25%
2002	844,619	846,364	1,745	0.21%
2003	841,335	850,885	9,550	1.14%
2004	827,285	837,180	9,895	1.20%
2005	808,620	818,753	10,132	1.25%
2006	819,454	829,047	9,593	1.17%
2007	794,171	801,268	7,097	0.89%
2008	798,929	804,623	5,694	0.71%
2009	742,566	749,618	7,052	0.95%
2010	780,959	773,601	-7,358	-0.94%
2011	757,737	758,567	830	0.11%
2012	762,965	765,622	2,657	0.35%
2013	780,510	791,249	10,738	1.38%
2014	741,852	745,288	3,436	0.46%
2015	746,545	751,199	4,653	0.62%
2016	750,803	762,366	11,563	1.54%
2017	**745,510**	**756,547**	**11,036**	**1.48%**

Figure 91: Percentage discrepancies between the annual carbon dioxide emissions as calculated with the Reference Approach and as calculated with the Sectoral Approach



21 Annex 5: Assessment of completeness, and of potentially excluded sources and sinks of greenhouse gas emissions

The following two tables show the sources for greenhouse gases that have not yet been directly reported in Germany's greenhouse-gas inventories to date. This refers to emissions for which the necessary bases for calculation are not available or which could be determined only at great effort. At the same time, the emissions need to conform to the negligibility criteria given in the definition of the notation keys "NE." The necessary estimates for such conformance are also listed.

In addition, a summary is provided of CRF Table 9(a), which lists emissions reported as "IE" at other locations in the inventory.

Additional information is presented in Chapter 1.8.

Table 554: Overview, for completeness, of sources and sinks whose emissions are not estimated (NE)

Emissions, 2017			
kt CO_2-eq.	**national total (without LULUCF)**	**906,611**	
kt CO_2-eq.	thereof 0.1 %	907	
kt CO_2-eq.	thereof 0.05 %	453	
Category code	**Category description**	**Assumption for estimated emission (in kt CO2 equiv)**	**Reference to NIR**
1.B.2.d	Geothermal Energy	< 1	see NIR Chapter 3.3.2.4
2.A.4.c	Non-metallurgical magnesium production	< 100	see NIR Chapter 4.2.4.3.2
2.B.4.a	Caprolactam	< 17.9	see NIR Chapter 4.3.4.2
2.B.6	Titanium dioxide production	< 300	see NIR chapter 4.3.6
2.D.3	Asphalt – asphalt roofing	0.2	see NIR Chapter 4.5.5.2
2.D.3	Asphalt – road paving	2.5	see NIR Chapter 4.5.5.2
3.A.4	Deer	132	see NIR Chapter 19.3.1
3.A.4	Rabbits	3.96	see NIR Chapter 19.3.1
3.A.4	Fur-bearing animals	0.16	see NIR Chapter 19.3.1
3.B(a).4	Deer	1.45	see NIR Chapter 19.3.1
3.B(a).4	Fur-bearing animals	1.08	see NIR Chapter 19.3.1
3.B(a).4	Rabbits	0.88	see NIR Chapter 19.3.1
3.B(a).4	Ostriches	1.08	see NIR Chapter 19.3.1
3.B(b).4	Fur-bearing animals	0.68	see NIR Chapter 19.3.1
3.B(b).4	Rabbits	0.82	see NIR Chapter 19.3.1
3.B(b).4	Ostriches	0.06	see NIR Chapter 19.3.1
3.B(b).5	Indirect emissions	1.01	see NIR Chapter 19.3.1
3.D	Other animals	29.48	The entries for other animals are not shown in CRF Reporter under 3 D., see NIR Chapter 19.3.1
5.A	Flaring	0.0006	see NIR Chapter 7.2.1.2.8
5.E	accidental fires (buildings, cars ...)	< 100	see NIR Chapter 7.6
Sum		**695**	

Table 555: Overview, for completeness, of sources and sinks that are reported elsewhere (included elswhere, IE)

Source/sink category	**GHG**	**Explanation**
1.A.2.a Iron and Steel/Biomass	CO_2	Emissions are part of the carbon balance and were reported under blast furnace gas incineration (solid fuels).
1.A.2.a Iron and Steel/Other Fossil Fuels	CO_2	The use of reducing agents is part of the carbon balance. Emissions were reported under blast furnace gas incineration (solid fuels).
1.A.2.b Non-Ferrous Metals	CH4, CO2, N2O	Reported in source category 1.A.2.g

Source/sink category	GHG	Explanation
1.A.2.c Chemicals/Gaseous Fuels	CH4, CO2, N2O	Reported in source category 1.A.2.g
1.A.2.c Chemicals/Liquid Fuels	CH4, CO2, N2O	Reported in source category 1.A.2.g
1.A.2.c Chemicals/Other Fossil Fuels	CH4, N2O	Reported in source category 1.A.2.g
1.A.2.c Chemicals/Solid Fuels	CH4, CO2, N2O	Reported in source category 1.A.2.g
1.A.2.c Chemicals	CO_2	Reported in source category 1.A.2.g
1.A.2.d Pulp, Paper and Print/Gaseous Fuels	CH4, CO2, N2O	Reported in source category 1.A.2.g
1.A.2.d Pulp, Paper and Print/Liquid Fuels	CH4, CO2, N2O	Reported in source category 1.A.2.g
1.A.2.d Pulp, Paper and Print/Solid Fuels	CH_4	Reported in source category 1.A.2.g
1.A.2.d Pulp, Paper and Print	CO2, N2O	Reported in source category 1.A.2.g
1.A.2.e Food Processing, Beverages and Tobacco/Gaseous Fuels	CH4, CO2, N2O	Reported in source category 1.A.2.g
1.B.1.a.2.ii Post-Mining Activities	CH_4	already included under mining activity (1.B.1.a.2..i)
1.B.2.b.1 Exploration	CH4, CO2	included in 1.B.2.a.i
1.B.2.c.1.i Oil	CH4, CO2	included in 1.B.2.a
1.B.2.c.1.ii Gas	CH4, CO2	included in 1.B.2.b
1.B.2.c.1.iii Combined	CH4, CO2	see 1.B.2.c.2.i and 1.B.2.c.2.ii
1.B.2.c.2.iii Combined	CH4, CO2, N2O	included in 1.B.2.a+b
2.A.4.d Other	CO_2	see documentation box
2.B.10 Other	N2O	Due to confidentiality allocated to 2.G.3.
2.B.4.a Caprolactam	N2O	For both national producers the emissions considered insignificant according to new definition of NE. But the emissions of one producer are still allocated to 2.B.2.
2.B.8.a Methanol	CH4, CO2	emissions and production quantities are aggregated together with other products of 2.B.8 exclusive of Carbon black and allocated to 2.B.8.g Petrochemicals.
2.B.8.b Ethylene	CH4, CO2	emissions and production quantities are aggregated together with other products of 2.B.8 exclusive of Carbon black and allocated to 2.B.8.g Petrochemicals.
2.B.8.c Ethylene Dichloride and Vinyl Chloride Monomer	CH4, CO2	emissions and production quantities are aggregated together with other products of 2.B.8 exclusive of Carbon black and allocated to 2.B.8.g Petrochemicals.
2.B.8.d Ethylene Oxide	CH4, CO2	emissions and production quantities are aggregated together with other products of 2.B.8 exclusive of Carbon black and allocated to 2.B.8.g Petrochemicals.
2.B.8.e Acrylonitrile	CH4, CO2	emissions and production quantities are aggregated together with other products of 2.B.8 exclusive of Carbon black and allocated to 2.B.8.g Petrochemicals.
2.B.9.a.1 Production of HCFC-22/HFC-23	HFC-23	The emissions are reported because of confidentiality reasons together with the other emissions from 2B9 as unspecified mix at 2.B.9 By product emissions as unspecified mix.
2.B.9.b.1 Production of HFC-134a	HFC-134a	The emissions are reported because of confidentiality reasons together with the other emissions from 2B9 as unspecified mix at 2.B.9 By product emissions as unspecified mix.
2.B.9.b.3 Other	CF4	The emissions are reported because of confidentiality reasons together with the other emissions from 2B9 as unspecified mix at 2.B.9 By product emissions as unspecified mix.
2.B.9.b.3 Other	HFC-227ea	The emissions are reported because of confidentiality reasons together with the other emissions from 2B9 as unspecified mix at 2.B.9 By product emissions as unspecified mix.

Source/sink category	GHG	Explanation
2.C.1.b Pig Iron	CH4, CO2	Recalculations in CRF 1.A.2
2.C.1.c Direct Reduced Iron	CH4, CO2	Recalculations in CRF 1.A.2
2.C.1 Iron and Steel Production	CH4, CO2	considered in 2.C.1
2.C.7.i Copper Production	CH4, CO2, N2O	is considered in CRF 1.A.2.b
2.E.1 Integrated Circuit or Semiconductor	c-C4F8, CF4, HFC-23, C2F6, C3F8, HFC-32, NF3	Because of confidentiality the emissions are reported at 2.H.3 confidential F-gas data.
2.F.2.a Closed Cells	HFC-134a, HFC-227ea, HFC-245fa, HFC-365mfc	The emissions are reported because of confidentiality at 2.F.2 open cell foams - from stocks.
2.F.2.b Open Cells	HFC-134a, HFC-152a, HFC-227ea, HFC-245fa, HFC-365mfc	The emissions are reported because of confidentiality at 2.F.2 open cell foams - from stocks.
2.F.4.a Metered Dose Inhalers	HFC-134a	The emissions from manufacturing are reported because of confidentiality together with the emissions from stocks.
2.F.5 Solvents	C6F14, HFC-245fa, HFC-365mfc, HFC-43-10mee	The emissions are confidential and are reported at 2.H.3 Other/Confidential Emissions of F-Gases
2.G.2.d Adiabatic Properties: Shoes and Tyres	C3F8, SF6	The emissions are confidential and are reported at 2.H.3 Other/Confidential Emissions of F-Gases
2.G.2.e Other/Medical and cosmetical applications	C10F18	The emissions are confidential and are reported at 2.H.3 Other/Confidential Emissions of F-Gases
2.G.2.e Other/Optical glass fibres	SF6	The emissions are confidential and are reported at 2.H.3 Other/Confidential Emissions of F-Gases
2.G.2.e Other/Welding	SF6	The emissions are confidential and are reported at 2.H.3 Other/Confidential Emissions of F-Gases
2.G.3.b Other/Explosives	N2O	The emissions are confidential and are reported at 2.G.3.a Medical Applications
2.G.3.b Other/Semiconductor production	N2O	The emissions are confidential and are reported at 2.G.3.a Medical Applications
2.G.3.b Other/Propellant for pressure and aerosol products	N2O	The emissions are confidential and are reported at 2.G.3.a Medical Applications
2.G.4 Other/ORC	HFC-245fa, HFC-365mfc	The emissions are confidential and are reported at 2.H.3. Other Confidential Emissions from F-Gases
2.G.4 Other/use of charcoal for BBQ	CO2	included in biomass
3.A.4 Other livestock/Buffalo	CH4	Buffalo: before 1996: NO, since 1996: IE; Buffalo are no longer treated as a separated category (included elsewhere, IE) in the inventory from 2015 onwards. See chapter 5.1.3.2.2
3.A.4 Other livestock/Mules and Asses	CH4	In the 2010 agricultural census and in the 2013 census, number of horses was raised instead of horse numbers. Their number includes donkeys and mules in an inseparable manner (included elsewhere, ie). See NIR chapter 5.1.3.2.2
3.B.1.4 Other livestock/Buffalo	CH4	Buffalo: before 1996: NO, since 1996: IE; Buffalo are no longer treated as a separated category (included elsewhere, IE) in the inventory from 2015 onwards. See chapter 5.1.3.2.2
3.B.1.4 Other livestock/Mules and Asses	CH4	In the 2010 agricultural census and in the 2013 census, number of horses was raised instead of horse numbers. Their number includes donkeys and mules in an inseparable manner (included elsewhere, ie). See NIR chapter 5.1.3.2.2

Source/sink category	GHG	Explanation
3.B.2.4 Other livestock/Buffalo	N2O	Buffalo: before 1996: NO, since 1996: IE; Buffalo are no longer treated as a separated category (included elsewhere, IE) in the inventory from 2015 onwards. See chapter 5.1.3.2.2
3.B.2.4 Other livestock/Mules and Asses	N2O	In the 2010 agricultural census and in the 2013 census, number of horses was raised instead of horse numbers. Their number includes donkeys and mules in an inseparable manner (included elsewhere, ie). See NIR chapter 5.1.3.2.2
4(IV) Indirect N2O Emissions from Managed Soils/Atmospheric Deposition	N2O	is included under 3.B.2.5 Indirect N2O Emissions (Agriculture).
4.A Forest Land/4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils/Total Organic Soils/Drained Organic Soils	CO2	See explanation in NIR chapter 6.4.2.7.2
4.A.1 Forest Land Remaining Forest Land/4(V) Biomass Burning/Wildfires	CO2	4.A Biomass, wildfires, CO2 emissions: IE: included in carbon stock change.
4.A.2 Land Converted to Forest Land/4(V) Biomass Burning/Wildfires	CH4, CO2, N2O	IE: included in forest land reamining forest land (see NIR chapter 6.4.2.7.5).
4.B Cropland/4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils/Total Organic Soils/Drained Organic Soils	CO2	The carbon emissions from organic soils are included in CRF Tables 4.A to 4.F See explanation NIR chapter 6.1.2.6.
4.C Grassland/4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils/Total Organic Soils/Drained Organic Soils	CO2	The carbon emissions from organic soils are included in CRF Tables 4.A to 4.F. See explanation NIR chapter 6.1.2.6.
4.D Wetlands/4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils/Other Wetlands/Other/Total Organic Soils/Drained Organic Soils	CH4, CO2, N2O	4.D Emissions/Removal: IE: under [Other Wetlands][Total Organic Soils][Other], See explanation NIR chapter 6.1.2.6.
4.D Wetlands/4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils/Other Wetlands/Other/Total Organic Soils/Other/Other	CH4, CO2, N2O	The carbon emissions from organic soils are included in CRF Tables 4.A to 4.F. See explanation NIR chapter 6.1.2.6.
4.D Wetlands/4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils/Other Wetlands/Other/Total Organic Soils/Rewetted Organic Soils	N2O	4.D Emissions/Removal: IE: under [Other Wetlands][Total Organic Soils][Other]. See explanation NIR chapter 6.1.2.6.
4.D Wetlands/4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils/Peat Extraction Lands/Total Organic Soils/Drained Organic Soils	CH4, CO2, N2O	4.D Emissions/Removal: IE: under [Peat Extraction Lands][Total Organic Soils][Other] . See explanation NIR chapter 6.1.2.6.
4.D Wetlands/4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils/Peat Extraction Lands/Total Organic Soils/Other (please specify)/Other	CO2	The carbon emissions from organic soils are included in CRF Tables 4.A to 4.F. See explanation NIR chapter 6.1.2.6.
4.D Wetlands/4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils/Peat Extraction Lands/Total Organic Soils/Rewetted Organic Soils	CH4, CO2, N2O	4.D Emissions/Removal: IE: under [Peat Extraction Lands][Total Organic Soils][Other] . See explanation NIR chapter 6.1.2.6.
4.H Other/Settlements/4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils/Total Organic Soils	CH4, CO2	CO2 emissions IE: under 4 E, Carbon stock change; CH4 emissions: IE under 4 E.
5.D.2 Industrial Wastewater	CH4	Out of statistical reasons CH4-recovery from domestic and industrial treatment cannot be devided. Data are reported under 5.D.1
Indirect emissions	N2O	Indirect emissions of N2O are covered in the sectoral tables for agriculture.
Indirect emissions	N2O	Indirect N2O emissions are reported under CRF Table 4(IV), leaching and runoff.

22 Annex 6: Additional information to be considered as part of the NIR submission (where relevant) or other useful reference information

22.1 Additional information relative to inventory preparation and to the National System

22.1.1 Definitions in the "National System" principles paper on emissions reporting

In the "National System" principles paper on emissions reporting, state secretaries of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB); Federal Ministry of the Interior (BMI); Federal Ministry of Defence (BMVg); Federal Ministry of Finance (BMF); Federal Ministry for Economic Affairs and Energy (BMWi); Federal Ministry of Transport, Building and Urban Affairs (BMVBS) and Federal Ministry of Food and Agriculture (BMEL) defined responsibilities pertaining to the various relevant source and sink categories and to the necessary financing for 2008. The agreement reads as follows:

BMUB, BMI, BMVg, BMF, BMWi, BMVBS, BMEL Berlin, 5 June 2007

"National System" principles paper on emissions reporting

The state secretaries of the ministries concerned have determined as follows, by common consent, with regard to the issue of the "National System" for emissions reporting pursuant to Art. 5(1) Kyoto Protocol:

1. *The Federal Environmental Agency, Section I 4.6[220] "Emissions Situation", is the responsible "Single national entity" (national co-ordinating agency) for reporting pursuant to the UN Framework Convention on Climate Change and the Kyoto Protocol. A country's Single National Entity is responsible for preparing the country's national inventory, working for continual improvement of the inventory, supporting those persons involved in the national system and preparing decisions of the Co-ordinating Committee.*

2. *A Co-ordinating Committee, representing all affected departments, has been established to deal with all questions arising in the framework of the National System, and to be responsible for official discussion and approval of the inventories and the reports required pursuant to Articles 5, 7 and 8 of the Kyoto Protocol. The Committee shall support all pertinent processes in this framework and, in particular, it shall clarify any pertinent uncertainties – for example, in connection with definition of individual emission factors.*

   In particular, the Committee shall define key source and sink categories, and the minimum requirements pertaining to quality control and quality assurance for data collection and processing and to the annual quality control and quality assurance plan.

   As necessary, the Committee may specify the methods to be used for calculating emissions in the various categories and for calculating storage in sink categories. The Committee is chaired by the BMUB. The Committee shall meet whenever at least one department sees a need for such a meeting. Subordinate authorities and other institutions involved in inventory preparation may be included in meetings as necessary.

3. *For preparation of the national inventory, such data shall be used, for calculations of emissions and reductions, as are required pursuant to the provisions of Art. 3 (1) of decision 280/2004/EC and of Art. 2 (1) of the Ground rules for calculating emissions in source categories and storage in sink categories. Inventories shall be prepared on an annual basis. In addition, quality assurance in keeping with the*

[220] Author's remark: currently, I 2.6.

requirements of Art. 12 of the rules shall be carried out. Furthermore, reliable documentation and archiving shall be required.

Existing data-transfer arrangements, such as those made on the basis of voluntary agreements or legal provisions, should not be fundamentally changed; they should only be completed and improved as necessary in order to provide a reliable database. For this reason, the aforementioned responsibilities do not necessarily include data collection and forwarding. With regard to division of responsibilities between BMUB/UBA, BMVBS and BMWI, attention is called especially to Annex 1.

The responsibilities for ensuring proper data delivery to the Single National Entity, and for quality control, documentation and data archiving, shall be distributed as follows among the various relevant departments:

a) For category 1 (Energy) – with the exception of categories 1.A.3 (Transport) und 1.A.5a (Energy: other), where emissions sources of the German Federal Armed Forces (Bundeswehr) are concerned – the Federal Ministry for Economic Affairs and Energy (BMWi) has responsibility.

b) For categories 2 (Production processes) and 3 (Use of solvents and other products), the Federal Ministry for Economic Affairs and Energy (BMWi) has responsibility.

c) For category 1.A.3 (Transport), the Federal Ministry of Transport, Building and Urban Affairs (BMVBS) has responsibility.

d) For category 1.A.5a (Energy: other), where emissions sources of the German Federal Armed Forces (Bundeswehr) are concerned – the Federal Ministry of Defence (BMVg) has responsibility. Where data are subject to secrecy provisions, the Federal Environment Agency shall take the relevant secrecy requirements into account.

e) For source and sink categories 4 (Agriculture) and 5 (Land use, land-use changes and forestry), the Federal Ministry of Food and Agriculture (BMEL) has responsibility.

f) For category 6 (Waste) and category 7, and well as for issues related to greenhouse-gas emissions from biomass combustion, the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) has responsibility.

g) The Federal Ministry of Food and Agriculture (BMEL) is also responsible for preparing tables in the standardised reporting format pursuant to Art. 2 (2) letter a of Decision 2005/166/EC (implementation rules) in source and sink categories 4 and 5.

In addition, the relevant authorities, as determined by the pertinent statistics regulations, are responsible for tasks relative to official statistics, including data delivery, quality assurance and data documentation and archiving. Co-operation between a) the statistical offices of the Federal Government and the Länder and b) the agencies concerned with reporting is co-ordinated via the Federal Statistical Office. In the process, secrecy requirements pertaining to statistics are to be observed.

4. The responsible departments shall clarify, in the short term, how proper data provision is to be permanently assured, to the extent such clarification has not already been completed. In particular, this requirement shall apply to agreements, ordinances or laws needed for institutionalisation of the National System. In general, for purposes of emissions reporting, voluntary agreements with associations and/or individual companies shall have the same status as pertinent legal provisions. In addition, as agreed in the co-ordination discussion on 12 September 2006, the Federal Environment Agency and the Federal Statistical Office shall determine what data can be provided, for reporting purposes, from the official statistical system, as well as what additional data should be collected via the official statistical system. The various relevant departments, the Federal Environment Agency and the Federal Statistical Office shall send their pertinent proposals to the BMUB by 15 July 2007.

5. *By 31 July 2007, the BMUB shall invite participating departments to co-ordinate pertinent proposals and to establish a schedule for implementing the required instruments. The responsible departments, and the Federal Government, shall arrange for the establishment of the required instruments as quickly as possible.*

6. *Where additional funding is required for execution of the responsibilities mentioned under 3., such funding shall be provided from proceeds from sale of AAUs, via an expansion of the state secretaries' agreement of 22 December 2006 relative to Article 3.4 of the Kyoto Protocol.*

   To this end, a budget item for relevant income shall be established within Individual Plan 16 (Einzelplan 16) as of the 2008 fiscal year. Following review by the Federal Ministry of Finance (BMF), the additional requirements requiring financing shall be listed as expenditures within the departments' individual budgets. The departments' additional requirements in this regard must be submitted to the BMF by 6 June 2007.

   Should additional budget funding be required in coming years, in addition to the additional requirements determined in connection with the 2008 budget, then suitable relevant amounts of additional AAUs shall be sold in subsequent years.

[...]

Annex: Division of responsibilities between BMUB/UBA, BMVBS and BMWI

The BMUB, BMVBS and BMWi have agreed that the existing emissions-reporting structures are to be retained and that the Federal Environment Agency (UBA) shall continue to perform its existing tasks with regard to the categories 1, 1.A.3, 2 and 3. The BMVBS and the BMWi shall ensure that any gaps in the data for those categories for which they are responsible are closed.

Specifically:

BMWi:

With regard to category 1: The inventories in this area shall be prepared by the Federal Environment Agency, on a basis that shall include energy data provided by the agency contracted by the BMWi for preparation of energy balances, as well as on the basis of additional relevant statistics and association information.

With regard to category 2: The inventories in this area shall be produced by the Federal Environment Agency on the basis of data that shall include data from statistics of the manufacturing sector (Produzierendes Gewerbe – ProdGewStatG) and from communications of relevant associations / individual companies.

With regard to category 3: The inventories in this area shall be produced by the Federal Environment Agency on the basis of data that shall include data from statistics of the manufacturing sector (Produzierendes Gewerbe – ProdGewStatG), from foreign trade statistics and from communications of relevant associations / individual companies.

Existing requirements for further optimisation shall be clarified, in the short term, by BMWi, BMUB and UBA, working in co-ordination. Where data optimisation is required via changes in existing surveys based on the Environmental Statistics Act (UStatG) or on the 13th Ordinance on the Execution of the Federal Immission Control Act (13. BimSchV), the BMUB shall be responsible. The Federal Environment Agency shall assume responsibility for recording and archiving data received by the Federal Environment Agency.

BMVBS:

Emissions relative to category 1.A.3 (Transport) shall be calculated by the Federal Environment Agency, using the TREMOD model. The BMVBS shall provide data/calculations as needed to close data gaps and determine emissions relative to international air transports or shall ensure that such data/calculations are provided by third parties. At present, emissions from ship transports may be calculated from Energy Balance data, using *default emission factors. The Federal Environment Agency shall assume responsibility for recording and archiving data received by the Federal Environment Agency.*

22.1.2 Additional information about the Quality System of Emissions Inventories

22.1.2.1 Minimum requirements pertaining to a system for quality control and assurance

As described above in the main section, the requirements pertaining to the system for quality control and quality assurance (QC/QA system) and to measures for quality control and quality assurance are defined primarily by Chapter 8 of the *IPCC Good Practice Guidance*.

From those provisions, the Federal Environment Agency has derived its own "General minimum requirements pertaining to quality control and quality assurance in connection with greenhouse-gas-emissions reporting" ("Allgemeine Mindestanforderungen an die Qualitätskontrolle und Qualitätssicherung bei der Treibhausgasemissionsberichterstattung"; last revision: November 2007). These are described below.

22.1.2.1.1 Introduction

Representatives of the departments participating in the co-ordinating committee for the National System of Emissions Inventories define the general minimum requirements, which are described in the present document, for quality control and quality assurance (QC/QA) in reporting on greenhouse-gas emissions. Such minimum requirements serve as the basis for collection, processing and forwarding of, and reporting on, all data that support the process of reporting on greenhouse-gas emissions.

These minimum QC/QA requirements must be adhered to on all levels of inventory preparation. In many cases, relevant efforts can draw on existing processes and systems, such as the quality standards for public statistics. Annex 1 of the present document describes, by way of example, implementation of the minimum QC/QA requirements and the QC/QA system within the Federal Environment Agency. All participating institutions are required to submit suitable descriptions of their implementation of these minimum requirements; such descriptions are to be published with the inventory report in the framework of reporting in 2009. On request, the Federal Environment Agency supports participating ministries in preparing QC/QA systems in their relevant areas of responsibility.

22.1.2.1.2 System for quality control and quality assurance

The *rules (Commission Decision 2005/166/EC) implementing Decision 280/2004/EC* require national greenhouse-gas inventories to conform to the QC/QA requirements of the *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC Good Practice Guidance) and the *IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry* (IPCC Good Practice Guidance for LULUCF).

The *IPCC Good Practice Guidance* specifies that QC/QA systems must be introduced, with the aim of enhancing transparency, consistency, comparability, completeness and precision of national emissions inventories and, especially, that such inventories must fulfill requirements pertaining to "good inventory practice". A QC/QA system comprises the following:

- An agency responsible for co-ordinating QC/QA activities
- Development and implementation of a QC/QA plan
- General QC procedures
- Category-specific QC procedures
- QA procedures and
- Reporting procedures
- Documentation and archiving procedures

QC/QA measures can conflict with requirements for punctuality and cost-effectiveness. Available time, and available staffing and financial resources, should thus be taken into account in any QC/QA-system development. In good practice, more stringent data-quality requirements are applied to key categories. For other categories, not all category-specific QC procedures have to be implemented. In addition, not all measures have to be carried out on an annual basis; for example, data-collection methods have to be reviewed only once in detail. Thereafter, it suffices to carry out periodic controls to determine whether the prerequisites for application of relevant methods are still being fulfilled. Data uncertainty is another factor that enters into requirements pertaining to QC/QA measures. In order to reduce an inventory's overall uncertainty, those categories that have high levels of uncertainty should be reviewed in detail.

22.1.2.1.3 Agency responsible for co-ordinating QC/QA activities

As the Single National Entity (national co-ordinating agency), the Federal Environment Agency is responsible for the QC/QA system for the national greenhouse-gas inventory. In this function, it has established the position of co-ordinator for the Quality System for Emissions Inventories (QSE). In good practice, each company and organisation involved in inventory preparation appoints a QC/QA co-ordinator and notifies the QSE co-ordinator of such appointment.

A QC/QA co-ordinator has responsibility for ensuring that a relevant QC/QA system is developed and implemented. Such implementation should be suitably institutionalised – for example, by means of an in-house directive or association agreement.

In order to ensure that the Single National Entity can efficiently carry out its supporting tasks, the persons responsible for the following additional functions should be announced (by name) to the QSE co-ordinator:

Responsible expert (Fachverantwortlicher) – Person responsible for data collection, data entry and pertinent calculation, in keeping with the prescribed methods, as well as for carrying out QC measures and preparing a relevant textual contribution for the National Inventory Report.

Quality control manager (Qualitätskontrollverantwortlicher) – Person responsible for checking and approving data and report sections (the QC/QA co-ordinator may also perform this function).

22.1.2.1.4 QC/QA plan

The purpose of the QC/QA plan is to ensure that QC/QA measures are properly organised and executed. It includes a description of all required QC/QA measures and a schedule for implementation of such measures. The QC/QA plan also defines the primary emphases of such measures. The criteria for selection of categories for detailed review include the following:

- The category's relevance (key category yes/no, uncertainties high/low)
- The time of the last detailed QC/QA measure for the source category, and the results of such measure
- Changes in methods or the pertinent database
- Results of annual inventory review in keeping with the UN Framework Convention on Climate Change and the Kyoto Protocol
- Available resources for execution of QC/QA measures

Good practice calls for establishing a QC/QA plan and then reviewing and updating it each year after the latest inventory has been prepared.

On the basis of the results of annual inventory review, and of the results of QC/QA measures of which it is aware, the Single National Entity prepares an improvement plan for the entire inventory. On this basis, in turn, it derives proposals for a binding inventory plan for the next report year. Such proposals are then submitted to the co-ordinating committee for approval. The

QC/QA co-ordinator, working in co-operation with the QSE co-ordinator in the Single National Entity, defines the procedures, scheduling and scope for inclusion of his institution's QC/QA measures in the inventory plan for the overall inventory.

22.1.2.1.5 General quality control

Pursuant to the definition used by the IPCC (Chapter 8.1 *Good Practice Guidance*), quality control (QC) comprises a system of routine specialised measures for measuring and checking the quality of inventories in preparation.

Consequently, a QC system should achieve the following:

- Facilitate routine, standardised checks in the interest of data integrity, correctness and completeness;
- Identify and eliminate errors and omissions;
- List and archive inventory material and record all QC activities.

Table 8.1 of the *IPCC Good Practice Guidance* includes a complete list of general QC measures. Requirements pertaining to general, Tier-1 QC procedures can be derived from the requirements mentioned in Chapter 8.6 of the *IPCC Good Practice Guidance*. Typical general quality control measures in activity-rate determination include checking data for transfer errors, checking data for completeness, checking formulae for combining data and carrying out plausibility checks with the help of external data sources and earlier calculations. Suppliers of emissions calculations have to carry out additional QC measures – for example, checking formulae for emissions calculation.

Required quality controls should be recorded in checklists. Such lists should include at least the checking measures carried out, the results of checking, any pertinent corrections made and the name of the person(s) responsible for the measures. Annex 2 of the present document includes a sample checklist of the Federal Environment Agency.

Not all quality controls have to be carried out on an annual basis; some may be implemented at longer regular intervals. This applies especially to aspects of data collection that do not change from year to year. Requirements pertaining to the frequency and completeness of QC measures are more stringent for key categories than for other categories. It should be ensured that all categories undergo detailed quality control at least periodically.

22.1.2.1.6 Category-specific quality control

Available resources permitting, particularly relevant categories (such as key categories), in addition to undergoing Tier 1 procedures, should undergo Tier 2 quality control with regard to determination of activity rates, emissions and uncertainties (cf. Chapter 8.7 *Good Practice Guidance*). The chapters of the IPCC Good Practice Guidance that pertain to the various individual categories (Chapter 5) include additional information relative to category-specific QC measures. Such guidelines must be observed in preparation of any QC/QA plan. :

Where combined **activity data** from secondary sources are used, good practice calls for evaluating pertinent QC measures in connection with preparation of such secondary sources. If the level of such measures is adequate, it suffices to call attention to this fact in the documentation. Where secondary sources do not fulfill minimum requirements pertaining to quality control, suitable QC/QA checks should be carried out by the institution that uses the data. Results of subsequent QC/QA checks should enter into determination of uncertainties for activity rates. In addition, wherever possible, a range of different sources should be compared for purposes of determining data quality.

In use of facility-specific activity data, it is good practice to review the methods and QC/QA standards applied to data collection. Where such methods and standards do not meet minimum requirements, the advisability of using the data should be reconsidered and the uncertainties should be adjusted as necessary.

With regard to **emissions data**, it is good practice to review the emission factors that have been used. Such efforts include using national emission factors for key categories and reviewing the validity of IPCC standard factors under the applicable national circumstances. Where emissions data are obtained via direct measurements, it is good practice to review the relevant measurement methods and the quality standards applied. Emissions data and emission factors should be reviewed in light of data from previous years, and from independent sources, and any resulting discrepancies should be explained.

Quality control for uncertainties includes checking to determine whether calculations are free of errors and whether documentation for reproduction of results is adequate. In use of experts' assessments, the pertinent experts' qualifications and estimation methods should be reviewed and documented.

22.1.2.1.7 Quality assurance procedures

While the primary aim of quality control is to ensure that methods are correctly applied, the primary purpose of quality assurance is to examine methods as such and improve them as necessary.

Pursuant to the relevant IPCC definition (Chapter 8.1 Good Practice Guidance), measures for **quality assurance** (QA) are based *"on a planned system of reviews by persons who are not directly involved in preparing the inventory. Such reviews – which are best carried out by independent third parties – should be applied to completed inventories, after QC procedures have been carried out. Such measures accomplish the following:*

- Verify that data-quality criteria are fulfilled,
- Ensure that the inventory takes account of the best available estimates of emissions and sinks, in keeping with the latest scientific findings and available data, and
- Promote the efficiency of the QC system".

The required instrument for quality assurance is the peer review. While use of audits is encouraged, audits are not required.

22.1.2.1.8 Reporting procedures

The Single National Entity is responsible for initiating and co-ordinating reporting and carrying out relevant overall organisation. Provision of data and reports by third parties must conform to applicable requirements pertaining to the scope, form and scheduling of/for such provision.

22.1.2.1.9 Documentation and archiving

As a general requirement, all data and information used for inventory calculation must be documented (i.e. recorded) and archived, for each report year. The purpose of such documentation (i.e. recording) is to make it possible to completely reconstruct all emissions calculations after the fact. The general requirements pertaining to documentation and archiving for the entire process of preparation of greenhouse-gas inventories are described in Chapter 8.10.1 of the *IPCC Good Practice Guidance*.

Consequently, data providers have the obligation to keep records of the following information relative to data they supply to the Federal Environment Agency, for purposes of inventory calculations:

Data providers:

- Publication / source of activity data, with detailed referencing of the relevant Table numbers and names, and of the relevant pages in the original sources;
- Survey contents (definitions of the surveyed characteristics, delimitations used, survey units used) and survey methods;
- The legal foundations and ordinances on which surveys are based;
- Chronological and spatial comparability with previous-year data, and any changes with regard to definitions, scopes of validity, cut-off points, sources of activity rates or data-collection methods;
- Any revision of previously published data;
- The accuracy or quantitative error of activity data, methods used to estimate errors and the names of experts who have carried out error estimation.
- Secrecy and data protection: suitable notification with regard to any individual data items that are considered secret.

Such materials should be provided to the Federal Environment Agency on an annual basis, together with pertinent data, and they are centrally archived by the Federal Environment Agency.

Quality control (QC)

The records kept in the framework of quality control should include the names of the persons responsible for managing and carrying out relevant actions, the types of quality control carried out, the dates on which quality control measures were carried out, the pertinent results, and the corrections and modifications triggered by quality control measures. In each case, record-keeping and archiving for quality control measures are carried out internally, by the institution supplying the pertinent data. A general description of regularly executed quality control measures is provided to the Federal Environment Agency for purposes of the national inventory report and inventory review.

Providers of emissions calculations

For providers of emissions calculations, the minimum requirements pertaining to record-keeping also include the following:

- Description of the pertinent calculation methods and reasons why the methods were selected;
- Assumptions and criteria pertaining to selection of activity data and emission factors;
- Documentation pertaining to emission factors and their sources, with detailed references to the relevant numbers and pages in original sources;
- Calculation models;
- Calculation files, calculation software.

Points 1-4 are recorded and archieved along with descriptions provided for the national inventory report. Separate documentation pertaining to calculation models must be provided, in keeping with general scientific practice, and along with internal documentation in the form of manuals or guides. Data suppliers archive calculation files and calculation software, and keep pertinent records, on an internal basis. Such materials should be provided to the Federal Environment Agency as necessary in the framework of inventory review.

Quality assurance

In addition to carrying out quality control measures, providers of emissions calculations are obligated to carry out quality assurance. The records kept in the framework of quality assurance should include the names of the persons responsible for managing and carrying out relevant actions, the types of quality assurance carried out, the dates on which quality assurance measures were carried out, the pertinent results, and the corrections and modifications triggered by quality assurance measures. In addition, records should be kept of category-specific quality controls.

In each case, record-keeping and archiving relative to pertinent quality assurance are carried out internally, by the relevant data-supplying institution. In addition, pertinent quality assurance measures are summarised in the national inventory report.

Confidential data / secrecy

In general, confidential data must be designated as such when they are provided, to ensure that the proper precautions are taken when they are used.

In inventory review, general obligations apply whereby confidential data must be disclosed in cases in which inventory reviewers consider such disclosure to be necessary to ensure that emissions calculations are transparent and clear. The extent to which such disclosure actually must involve disclosure of individual data items should be clarified on a case-by-case basis with the institution providing the data.

22.1.2.1.10 Annex 1: Minimum requirements pertaining to quality control and quality assurance in emissions reporting in the Federal Environment Agency

22.1.2.1.10.1 Introduction

The general minimum requirements, as approved by the co-ordinating committee for the National System of Emissions Inventories, pertaining to quality control and quality assurance (QC/QA) in reporting on greenhouse-gas emissions apply to all participants. These requirements are the basis for collecting, processing, forwarding and reporting of/on all data that support reporting on greenhouse-gas emissions. They are thus binding for all working groups involved, in the Federal Environment Agency, in fulfillment of this reporting task.

22.1.2.1.10.2 System for quality control and quality assurance

In addition to the general minimum requirements, approved by the co-ordinating committee for the National System of Emissions Inventories, pertaining to quality control and quality assurance (QC/QA) in reporting on greenhouse-gas emissions, the specific provisions of in-house directive (Hausanordnung) No. 11/2005 also apply at the Federal Environment Agency. Pursuant to that directive, the pertinent procedure defined in the QSE manual is binding for all Federal Environment Agency personnel involved in emissions reporting (Rules of procedure of the Federal Environment Agency (Geschäftsordnung des Umweltbundesamtes), Volume II, Numeral XV).

The in-house directive fully implements the requirements of Chapter 8 of the *IPCC Good Practice Guidance*. Suitable UBA-specific instruments have been established to ensure effective identification and execution of measures for continual inventory improvement (improvement plan and inventory plan; cf. 22.1.2.1.10.3). That work has led to the development of the Quality System for Emissions Inventories (QSE), via which the points mentioned in Chapter 22.1.2.1.2 have been implemented.

22.1.2.1.10.2.1 Agency responsible for co-ordinating QC/QA activities in the Federal Environment Agency

Pursuant to in-house directive No. 11/2005, section FG V 1.6, "Emissions Situation", is the "Single National Entity" (SNE) within the Federal Environment Agency. In the Federal Environment Agency's organisational diagramme, the so-defined SNE is thus included in the Federal Environment Agency’s group of "focal points" and liaison offices for international organisations. In addition, this assignment of responsibility was confirmed by the relevant ministries via a state secretaries' resolution of 5 June 2007.

The roles and responsibilities of the Single National Entity, and of the specialised departments participating in emissions reporting, are described in Chapter 3.2, "Roles and responsibilities", of the QSE manual. The Single National Entity is responsible for updating and managing the QSE manual and its appendices and annexes. In carrying out this responsibility, the SNE is assisted by the contact persons named to it by the relevant specialised departments. The version of the QSE manual and its co-applicable documents published on the Single National Entity's intranet is the binding version of these materials.

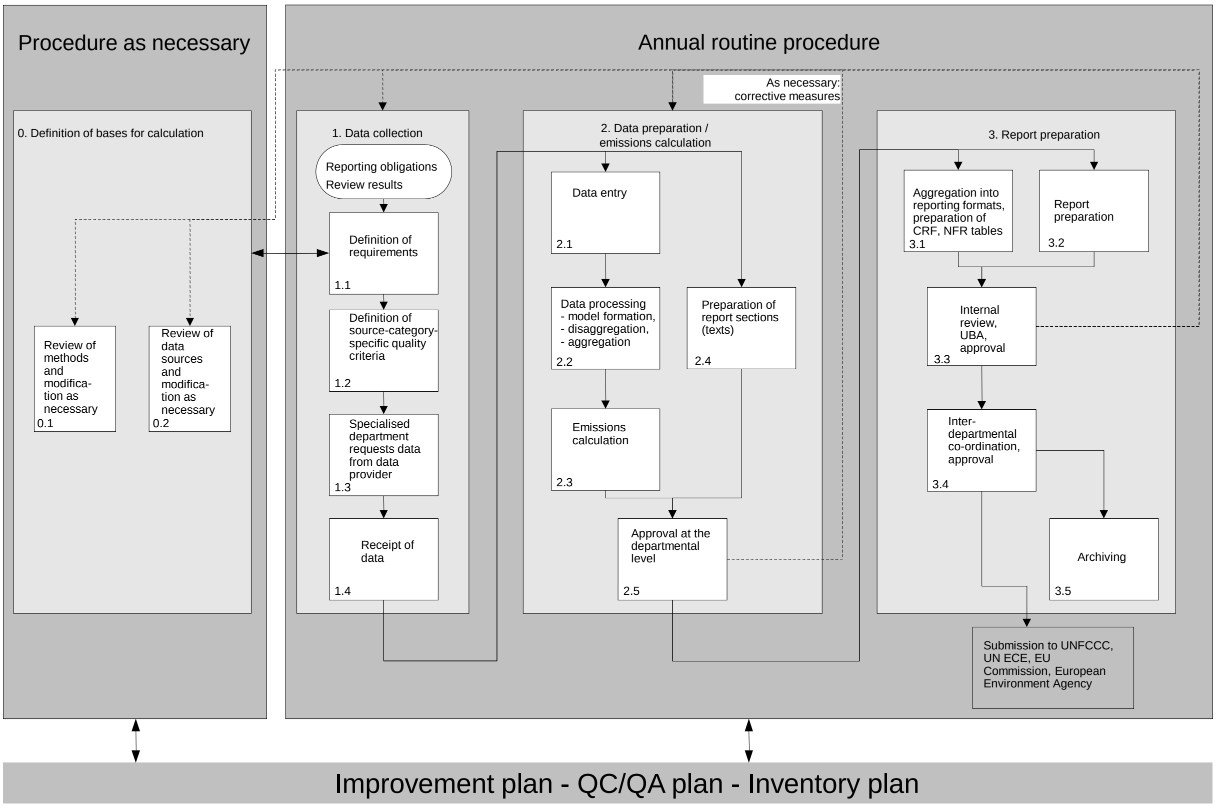
22.1.2.1.10.2.2 Reporting procedures

In many cases, complex activities comprise numerous different, but related and cumulative, activities (processes) that lead to the production of a single product. To manage such processes effectively, one must strive to understand the manner in which the processes function (or should function), to describe such functioning in logical, realistic ways (activities, dependencies, responsibilities, and many more) and to interrelate the processes in a useful way.

In practice, workflows of complex processes cannot always be fit smoothly into the hierarchical, traditional structures of companies and institutions. The required processes are often diametrally opposed to such structures, since they have to cut across different organisational units. To organise interrelated work processes in a manner oriented to production of the desired product, one must look outside of rigid hierarchies and redefine the processes with a view to improvement.

For this reason, emissions reporting was first described as a process that, via a number of interrelated activities, leads to a product (NIR and inventories) (cf. Figure 92). Additional relevant information is provided in the QSE manual, Chapter 4.3.

Figure 92: Overview of the overall emissions-reporting process



Via a role concept, suitable responsibilities have been assigned to cover the activities within the main processes and sub-processes shown. Each responsibility thus involves execution of pertinent processes. To understand this approach, it is useful to consider the situation in which many different people carry out the same basic activities even though they work in different work units and on different categories. In the present case, this situation was approached by defining a certain group of persons (persons with a specific role – for example, responsible experts). That group was then seen to be subordinate to another group of persons (with a different role – for example, specialised contact persons) that ensures that the first group observes and fulfills the requirements pertaining to its work. In addition, a QSE co-ordinator was appointed, in keeping with relevant requirements of the IPCC (cf. Chapter 22.1.2.1.2), to ensure that the system is refined and improved as necessary.

Overall, a comprehensive role concept was developed that addresses the many different requirements applying to the Federal Environment Agency in its task as Single National Entity. The roles involved include the following:

1. Responsible expert at the operational level (FV)

- Main responsibilities: data collection, data entry, calculations with prescribed methods, execution of QC measures, preparation of the NIR text

2nd Quality control manager (QKV)

- Is the superior for the FV
- Main responsibilities: checking and approving data and report sections

3rd Specialised contact person (FAP)

- Member of the Single National Entity's staff
- Main responsibilities: providing category-specific support for involved experts (inventory work and report preparation) and quality control / quality assurance relative to pertinent categories in the NIR and CSE.

4th Co-ordinator for the national inventory report (NIRK)

- Member of the Single National Entity's staff
- Main responsibilities: co-ordination of supporting textual work, preparation of the NIR from the various relevant contributions, overarching QC and QA for the NIR

5th CSE co-ordinator (ZSEK)

- Member of the Single National Entity's staff
- Main responsibilities: maintenance of databases, emissions calculation and aggregation, overarching QC and QA in connection with data entries and calculations for the inventory

6. QSE co-ordinator (QSEK)

- Member of the Single National Entity's staff
- Main responsibilities: maintenance and refinement of the QSE (system, checklists, improvement plan, inventory plan, QC/QA plan and QSE manual)

7. NaSE co-ordinator (NaSEK)

- Member of the Single National Entity's staff
- Main responsibilities: schedule-conformal, requirements-conformal reporting, providing for involvement of national institutions, establishing/recording legal agreements

As a rule, each of the above-described roles will have tasks in several different main and sub-processes of emissions reporting.

22.1.2.1.10.3 QC plan, QA plan and inventory plan

To ensure that all potential improvements identified during the course of inventory work are systematically implemented, identified improvements must be listed in a co-ordinated way. In the process, identified potential improvements should be listed together with all relevant information (origin of the potential improvement, category, pertinent responsibility, priority, etc.) needed for efficient further processing. Planning and arrangements for implementing identified potential improvements (required actions / corrective measures, deadlines, etc.) should then be made on the basis of such information.

In the interest of proper control and record-keeping in the framework of the NaSE and the QSE (cf. Figure 93), procedures have been defined for processing identified potential improvements for their systematic management and further use. The overall aim is to answer the central question of WHO should do WHAT, HOW, WHEN and WHY:

WHO: This provides the reference to the role concept: A certain person xy is responsible – for example, in the role of responsible expert (FV)

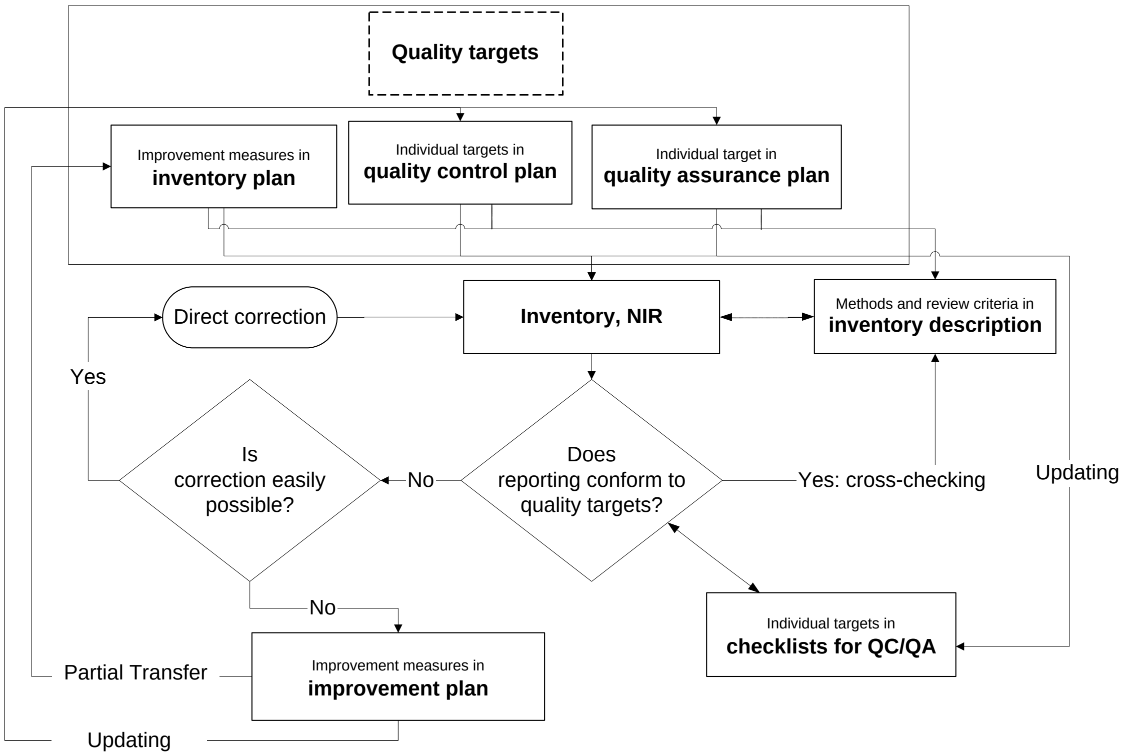
WHAT: This provides the reference to the object that is to be improved – for example, the CO_2 calculation in category xy needs to be improved

HOW: This provides the reference to the aim that is to be achieved – for example, a certain improvement, pursuant to an inventory plan or checklist.

WHEN: This provides the reference to the time by which the improvement must be completed, pursuant to the inventory plan

WHY: This provides the reference to the origin of the necessary action – for example, the improvement must be carried out as a result of a recommendation via the UNFCCC review process

Figure 93: Control and documentation in the framework of the NaSE and the QSE



The **quality targets** have been derived from the general quality aims of the IPCC Good Practice Guidance (transparency, consistency, accuracy, comparability, completeness). In addition, operational individual objectives, relative to quality control and quality assurance, for the various categories, have to be derived from comparison of the requirements from the *IPCC Good Practice Guidance*, the results of independent inventory review (UNFCCC and EU) and assessment of inventory realities.

In an **improvement plan**, all potential improvements and criticisms resulting from independent inventory review are collected and assigned potential corrective measures. The Single National Entity categorises the corrective measures, prioritises them and then, via consultations with the relevant responsible experts, integrates them as necessary within the **inventory plan**. There, they are linked with deadlines and responsibilities. As an annex to the NIR, the inventory plan undergoes a co-ordination and release process in the Federal Environment Agency and in the co-ordinating committee. It is thus a binding set of specifications for improvements to be carried out in future.

In the interest of transparent, effective control and execution of inventory-improvement measures, such measures, in keeping with the *IPCC Good Practice Guidance* (Chapter 8.5) are defined role-specifically, as well as category-specifically as necessary, in the **quality control plan / quality assurance plan (QC/QA plan)**. The QC plan is oriented solely to quality control aims for the inventory. In the QA plan, quality assurance objectives may be focused on the inventory, the reporting process or the QSE itself. Furthermore, the quality assurance plan includes scheduling of quality assurance measures to be performed by external third parties.

The **checklists for quality control and quality assurance** list all individual objectives in the emissions-reporting process, in keeping with the pertinent quality control and quality assurance plans. The checklists, which are designed to facilitate review of achievement of individual objectives, are made available to all persons responsible for quality control and quality assurance. The checklists are used to record execution of measures for quality control and quality assurance. Where individual objectives are not achieved and direct correction is not possible, a pertinent entry must be made in the improvement plan (see above).

22.1.2.1.10.4 Procedures for general and category-specific quality control

From the requirements set forth in the IPCC Good Practice Guidance, the Federal Environment Agency has developed a checklist concept via which quality requirements are formulated as specific targets. Every effort should be made to achieve such targets. When a target is achieved, such achievement is noted and described in the checklists. The possible entries for such records include "yes" (the target was achieved), "not relevant" (the target as formulated does not correspond to the special situation for the category in question; this answer is seldom a viable option) and "no" (it was not possible to achieve the target).

Each checklist includes a general section that reflects all Tier 1 QC requirements from IPCC Good Practice Guidance and that is used in connection with every instance of reporting. In addition, each checklist contains a category-specific section (Tier 2) that provides concrete objectives for the relevant key category area.

Checklists are provided only for the first five roles within the role concept. Where different roles are responsible for different main and sub- processes of emissions reporting (cf. Chapter 22.1.2.1.10.2.2), pertinent checklists will also be oriented to several different main and sub-processes of emissions reporting. They thus represent a cross-section of emissions reporting. The checklists of the FV and the FAP include a basic common set of goals. The FAP are responsible for checking the work of the FV, and such checking is most effective when both roles are oriented to the same goals.

22.1.2.1.10.5 Quality assurance procedures

In the role concept, procedures are designed to ensure that quality assurance is always supported by a "four-eyes" principle. The specialised contact persons (FAP) have the task of ensuring that the emissions calculations and textual work of the responsible experts (FV) are of the proper quality.

In its section on "Expert Peer Review", the IPCC notes that the (above-described) formal procedure selected by the Federal Environment Agency can complement, but not replace, expert peer review (Good Practice Guidance; Chapter 8.8). In one solution found for addressing the justified call for inclusion of external experts, within the framework of available resources, detailed review of specific issues is carried out by external third parties via research projects and studies. In general, the two sides involved (i.e. FV and FAP) jointly manage the process of commissioning third parties. In another means found for addressing the need for third-party inclusion, workshops on the National System are held at irregular intervals. For such workshops, national experts are invited to come to the Federal Environment Agency for discussion with Federal Environment Agency experts (FV) on current inventory issues relative to selected categories.

No audits have been carried out in the Federal Environment Agency to date, and none are planned at present. According to the Good Practice Guidance, audits are not absolutely required.

22.1.2.1.10.6 Documentation and archiving

Standardised record-keeping and archiving procedures are to be used in preparation of German greenhouse-gas inventories. At the same time, it is important to differentiate between the central record-keeping and archiving carried out by the Single National Entity and the non-central record-keeping and archiving carried out by the specialised departments of the Federal Environment Agency and of other institutions.

Record-keeping procedures for data and context information vary in accordance with specific requirements. In their information storage, they overlap to some degree, with such overlapping consisting partly of redundancies and partly of storage of similar items at differing levels of detail. On a regular basis, consistency must be ensured for both types of overlapping.

To ensure that all of the Federal Environment Agency's working units use basically consistent procedures, the specifications applying to the instruments used in such procedures – including both general specifications and specifications developed especially for emissions reporting – must be complied with. For purposes of "documentation" (i.e. record-keeping), the Federal Environment Agency has access to the instruments described in Table 556. The specifications pertaining to each type of document / record must be observed. Where no special specifications apply, the provisions from the "General minimum requirements for quality control and quality assurance in reporting on greenhouse-gas emissions" ("Allgemeine Mindestanforderungen an die Qualitätskontrolle und Qualitätssicherung bei der Treibhausgasemissionsberichterstattung") apply.

Table 556: Documentation / record-keeping instruments at the Federal Environment Agency

Instrument	Specifications
Publicly available	
National inventory (CRF tables, CRF-Reporter)	Annex 2, QSE manual: instructions for carrying out recalculations in the CRF tables
National Inventory Report	Annex 3, QSE manual: specifications for preparing report sections in the context of the National System
Publication	Rules of procedure of the Federal Environment Agency: Point 6.2 Publications
Published manuals, guides	For IT descriptions: procedural model of the Federal Environment Agency; otherwise: no special specifications
Centralised, and internally available, at the Single National Entity	
CSE database	Annex 5, QSE manual: specifications for data recording within the CSE
Inventory description	Annex 4, QSE manual: requirements pertaining to documentation (record-keeping) and archiving
De-centralised, and internally available	
Files of the central registry	Rules of procedure of the Federal Environment Agency: Point 4.2.10 Handling of files
Reference files	no special specifications
Internal manuals, guides	For IT descriptions: procedural model of the Federal Environment Agency; otherwise: no special specifications

An integrated documentation / record-keeping concept defines what key content should be stored in the aforementioned documentation instruments. It also defines how a suitable referencing system is to be used to ensure consistency and transparency throughout all such instruments (cf. Annex 4, QSE manual).

22.1.2.1.11 Annex 2: Example of a general checklist for the responsible-expert role

The example presented below (last revision: CHKL 2010) includes only the relevant requirements. Detailed information has been removed in the interest of clarity.

Table 557: General checklist for responsible experts

Process No.	Sub-process name	Individual goal	Optional goal
Main process: 0. Definition of bases for calculation			
0.1	Review of methods, and modification as necessary	The calculation method is in conformance with current key-category analysis.	
0.1	Review of methods, and modification as necessary	The calculation method has been selected in accordance with, or accords with, the pertinent decision tree of the IPCC Good Practice Guidance.	Departures from the decision tree of the IPCC Good Practice Guidance have been properly explained, in keeping with logical and pertinent specialised criteria, and have been duly documented.
0.1	Review of methods, and modification as necessary	The calculation method has been selected in keeping with requirements from the inventory plan.	Departures from the inventory plan have been properly explained, in keeping with logical and pertinent specialised criteria, and have been duly documented.
0.1	Review of methods, and modification as necessary	The selected calculation method can be applied to the entire time series as of 1990, or is already being consistently applied.	In cases of changes of methods in the time series, recalculation pursuant to the QSE manual (Annex 2), and proper pertinent documentation, are assured.

0.1	Review of methods, and modification as necessary	Departures from the objectives required via 0.1.01-0.1.04 have been properly explained, in keeping with logical and pertinent specialised criteria, and have been duly documented.	
0.2	Review of data sources, and modification as necessary	Have new data sources been used?	
0.2	Review of data sources, and modification as necessary	The data source(s) is / are / will be available throughout the long term (for example, on the basis of legal provisions, long-term agreements [> 3 years], etc.).	
0.2	Review of data sources, and modification as necessary	One / several complete time series as of 1990 are available in the data source(s).	Gaps in the data available for time series as of 1990 have been properly and logically explained, and have been duly documented.
0.2	Review of data sources, and modification as necessary	One / several complete time series as of 1990 are available in the data source(s).	A suitable procedure (interpolation/ extrapolation) has been chosen for dealing with data gaps, in conformance with IPCC Good Practice Guidance (Chap. 7.3.2.2), and the procedure has been logically documented. Note: Continued use of the same value is not extrapolation !
0.2	Review of data sources, and modification as necessary	One / several complete time series as of 1990 are available in the data source(s).	Following closure of data gaps, time-series recalculation has been carried out as necessary, pursuant to QSE manual (Annex 2), and such recalculation has been documented and substantiated in the NIR and CRF.

Process No.	Sub-process name	Individual goal	Optional goal
0.2	Review of data sources, and modification as necessary	The data source(s) completely cover the category.	The incomplete coverage has been addressed in an extrapolation and has been taken into account in the uncertainties calculation. All steps have been documented and justified clearly and logically.
0.2	Review of data sources, and modification as necessary	Uncertainties information (amount and distribution) is available for the data source(s).	
0.2	Review of data sources, and modification as necessary	The EF and the AD agree in terms of the manner in which they are tailored to the category.	In the case of discrepancies between the EF and AD, other data sources can establish agreement between the two values. Alternatively, the lack of agreement has been taken into account in an extrapolation, and in the uncertainties calculation, and the entire process has been properly and logically documented.
0.2	Review of data sources, and modification as necessary	The procedures for calculating outset data are clearly described.	
0.2	Review of data sources, and modification as necessary	The data source(s) have been selected in keeping with requirements from the inventory plan.	Any discrepancies have been clearly and logically justified and documented.
0.2	Review of data sources, and modification as necessary	The assumptions and criteria upon which the relevant data source(s) have been selected have been clearly and logically documented.	
0.2	Review of data sources, and modification as necessary	The data provider has carried out routine quality controls of the data source(s). For one-time projects, one-time quality controls have been carried out. Execution of the controls has been duly documented.	

0.2	Review of data sources, and modification as necessary	In use of one/more new data sources, a recalculation pursuant to the QSE manual (Annex 2) was carried out on the basis of this/these other data source(s).	
0.2	Review of data sources, and modification as necessary	In use of IPCC default EF, the manner in which the EF were generated has been reviewed in light of national circumstances, and the EF may be used for Germany. The result of such review has been duly documented.	For IPCC default values that do not fit with national circumstances, the discrepances have been taken into account in the uncertainties and documented.
0.2	Review of data sources, and modification as necessary	In use of EF other than the IPCC default EF, use of such EF has been clearly and logically justified and substantiated. Note: Use of other EF is permissible only when such EF permit more precise calculation of country-specific emissions.	
0.2	Review of data sources, and modification as necessary	The AD used have been compared with other data sources (for example, EU-ETS, IEA, EPER, etc.), and the result has been duly documented.	
Main process: 1. Data collection			
1.1	Definition of requirements	The requirements pertaining to data reflect the information and indications from the inventory plan and the inventory reviews (for example, S&A Report, Centralized Review).	

Process No.	Sub-process name	Individual goal	Optional goal
1.3	The relevant specialised department requests the data from the pertinent data provider(s)	The requirements pertaining to QC and data formats have been forwarded to the data suppliers and/or contracting entities, and such forwarding has been duly documented. Note: Where data suppliers are involved via NaSE agreements, this objective has been achieved.	The data supplier (for example, an association) carries out its own routine quality controls, and the results have been duly documented.
1.4	Receipt of data	The data provider or contracting entity has carried out the required quality controls and made proper records of such action.	The data supplier (for example, an association) carries out its own routine quality controls, and the results have been duly documented.
1.4	Receipt of data	The received data are complete, without any gaps.	All data gaps in the time series as of 1990 have been closed, in accordance with the IPCC Good Practice Guidance, via extrapolation/interpolation (Chapter 7.3.2.2) and duly documented and justified. Note: Continued use of the same value is not extrapolation
1.4	Receipt of data	The data received are consistent with the previous year's data, and they have been properly described.	Any marked discrepancies with the previous year's data have been duly documented and justified.
1.4	Receipt of data	The order of magnitude of the received data is in line with that of comparable data from other sources (such as ETS data, IEA, EPER, etc.). The result of the review has been duly documented.	The reasons for any discrepancies have been clearly and logically explained and duly documented.
1.4	Receipt of data	The methods/assumptions on which the uncertainties determinations are based have been clearly and logically documented.	Where it was not possible to derive assumptions, expert assessment was carried out, and the relevant expert's quantification was clearly and logically documented.
1.4	Receipt of data	The uncertainties determinations are complete and plausible.	
Main process: 2. Data preparation / emissions calculation			

Process No.	Sub-process name	Individual goal	Optional goal
2.1	Data entry (preferably into the CSE)	All of the EF have been entered into the CSE.	
2.1	Data entry (preferably into the CSE)	The documentation for the EF data source(s) is complete and conforms to the requirements of the QSE manual (Annexes 3, 4 and 5).	
2.1	Data entry (preferably into the CSE)	Development of the EF within the time series has been plausibly explained and, in the case of unusual effects (such as changes in order of magnitude), has been clearly and logically explained and documented.	Implausible EF have been corrected.
2.1	Data entry (preferably into the CSE)	All of the AD have been entered into the CSE.	
2.1	Data entry (preferably into the CSE)	The documentation for the AD data source(s) is complete and conforms to the requirements of the QSE manual (Annexes 3, 4 and 5).	
2.1	Data entry (preferably into the CSE)	Development of the AD within the time series has been plausibly explained and, in the case of unusual effects (such as changes in order of magnitude), has been clearly and logically explained and documented.	Implausible discrepancies have been corrected.
2.1	Data entry (preferably into the CSE)	Following entry of all data into the CSE, all entered figures, units and conversion factors have been checked for correctness and confirmed.	
2.1	Data entry (preferably into the CSE)	All of the uncertainties have been entered into the CSE and have been documented in keeping with the requirements of the QSE manual (Annexes 3, 4 and 5).	
2.2	Data preparation (model formation, disaggregation, aggregation)	The inventory description includes an adequate description of pertinent models, with regard to organisation, structure, calculation procedures, assumptions, etc..	
2.3	Emissions calculation	The current inventory calculations have been checked against calculations from previous reports.	Where any significant changes or obvious deviations from an expected trend have occurred, the pertinent calculation, and the data used in calculation, have been reviewed, and any persisting discrepancies have been properly, clearly and logically explained and duly documented.
2.3	Emissions calculation	The results of emissions calculation for current / previous reports have been checked against other data sources for Germany, especially ETS data, and found to be comparable. The result has been duly documented.	Where comparability has not been found, or no comparison was carried out, the pertinent reasons have been properly, clearly and logically explained.
2.3	Emissions calculation	The national Implied EF (cf. S&A Report I) from the previous report is comparable with the Implied EF of other countries (same order of magnitude).	Extreme Implied EF have been properly, clearly and logically explained, and duly documented, in the NIR, or reference to an existing explanation has been made.
2.4	Preparation of report sections (texts)	The category has been completely and logically described, for the NIR, in terms of the required six sub-chapters for the NIR ("Category description", "Methodological issues", etc.).	
2.5	Approval by the relevant experts	The values of AD, EF and ED, of their uncertainties, are up to date in the NIR and congruent with the pertinent values in the CSE.	

2.5	Approval by the relevant experts	Documentation of the origins for AD, EF and ED data, and for their uncertainties, are up to date in the NIR and congruent with the pertinent values in the CSE.	Lacking or incomplete documentation of data origin has been properly, clearly and logically explained and duly documented.

22.1.3 The database system for emissions – Central System of Emissions

Since 1998, the Federal Environment Agency has maintained and managed an IT tool for inventory preparation: the *Central System of Emissions (CSE)*, an integrated national database. The CSE implements the diverse requirements pertaining to emissions calculation and reporting, and it automates key steps in such work. It supports the processes of inventory planning and reporting (for example, by carrying out emissions calculations and recalculations, and relevant error analysis); inventory management (for example, by carrying out archiving and annual data evaluation); and quality management at the data level (cf. UBA 2003a, Projekthandbuch Decor (Decor project handbook)). The CSE makes it possible to fulfill the key requirements of transparency, consistency, completeness, comparability and accuracy at the data level.

Data documentation plays a central role in the CSE. The CSE stores such information as who is responsible for handling specific tasks; data sources and calculation procedures; and uncertainties in time-series values. The times at which changes are made, and the persons by whom they are made, are also recorded. The system has a history-management function that archives deleted items and can restore them as necessary. This makes it possible to trace back and reconstruct data, and it enables third parties to carry out independent reviews. The system also provides mechanisms that support quality assurance at the data level (e.g. components for detecting uncertainties and checking plausibility). Above all, transparency is accommodated by ensuring that data are recorded within the same structure in which they are provided, and that all processing and transformations into a reporting format take place first in the CSE itself, and thus remain open to examination. In addition, the CSE manages detailed technology-specific activity data and emission factors that can be processed, via calculation rules (calculation methods), into aggregated, category-specific values for the various reporting formats. Aggregation of individual CSE time series for the CRF report lines, for example, is described in Annex 3 and Chapter 3ff – in each case, with regard to individual categories. In addition to aggregation and model formation for calculations, the CSE also supports scenario and forecast calculations and use of the reference approach.

Data exchange within the framework of the National System – i.e. within the Federal Environment Agency and with third parties – is also organised via the Central System of Emissions. Such processes involve both direct data entry and imports of aggregated values, from existing databases and via a standard interface (for example, TREMOD, for transport data; and GAS-EM, for agricultural data). Ideally, inventory data should be entered into the CSE directly by the relevant responsible experts or should be imported, by the CSE administrator, via the import interface. This applies to in-house UBA employees as well as to external parties involved in the National System. To this end, a range of measures have been implemented:

- Provision of a *standardised import format for the CSE* in 2002 has facilitated the direct import of data from other emissions-relevant databases.
- In September 2002, participating technical experts from the Federal Environment Agency were given direct access to the CSE via the Federal Environment Agency intranet.
- Since November 2002, training courses on CSE procedures have been held on an annual basis for involved Federal Environment Agency staff.
- Since 2005, qualitative and quantitative information about data uncertainties has also been included in the CSE.

- Since 2006, reporting obligations under the Geneva Convention on Long-Range Transboundary Air Pollution and EU legislation (such as the NEC directive) have been fulfilled via the CSE.
- Since 2008, data providers and experts outside of the Federal Environment Agency, and project partners, can work interactively with the CSE via remote access.

22.2 Supplementary information as required pursuant to Article 7 (1) of the Kyoto Protocol

22.2.1 KP-LULUCF

The CRF tables are reported separately.

22.2.2 Standard Electronic Format (SEF) Tables

22.2.2.1 Standard Electronic Format for the reported year 2016 (Commitment Period 2)

Report Type	RREG1
Registry	DE
Reported Year	2017
Submission Year	2018
CP	2
Version	1
Status	FINAL
Validity	VALID

Party	Germany
Submission Year	2018
Reported Year	2017
Commitment Period	2

Table 1. Total quantities of Kyoto Protocol units by account type at beginning of reported year

	Account type	Unit type					
		AAUs	ERUs	RMUs	CERs	tCERs	lCERs
1	Party holding accounts	NO	NO	NO	NO	NO	NO
2	Entity holding accounts	NO	NO	NO	542.954	NO	NO
3	Retirement account	NO	NO	NO	NO	NO	NO
4	Previous period surplus reserve account	NO					
5	Article 3.3/3.4 net source cancellation accounts	NO	NO	NO	NO		
6	Non-compliance cancellation account	NO	NO	NO	NO		
7	Voluntary cancellation account	NO	NO	NO	836.573	NO	NO
8	Cancellation account for remaining units after carry-over	NO	NO	NO	NO	NO	NO
9	Article 3.1 ter and quater ambition increase cancellation account	NO					
10	Article 3.7 ter cancellation account	NO					
11	tCER cancellation account for expiry					NO	
12	lCER cancellation account for expiry						NO
13	lCER cancellation account for reversal of storage						NO
14	lCER cancellation account for non-submission of certification report						NO
15	tCER replacement account for expiry	NO	NO	NO	NO	NO	
16	lCER replacement account for expiry	NO	NO	NO	NO		
17	lCER replacement account for reversal of storage	NO	NO	NO	NO		NO
18	lCER replacement account for non-submission of certification report	NO	NO	NO	NO		NO
19	Total	NO	NO	NO	1.379.527	NO	NO

Party	Germany
Submission Year	2018
Reported Year	2017
Commitment Period	2

Table 2a. Annual internal transactions

	Transaction type	Additions						Subtractions					
		AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
	Art6 issuance and conversion												
1	**Party verified projects**		NO					NO		NO			
2	**Independently verified projects**		NO					NO		NO			
	Art3.3 and 3.4 issuance or cancellation												
3	**3.3 Afforestation reforestation**			NO				NO	NO	NO	NO		
4	**3.3 Deforestation**			NO				NO	NO	NO	NO		
5	**3.4 Forest management**			NO				NO	NO	NO	NO		
6	**3.4 Cropland management**			NO				NO	NO	NO	NO		
7	**3.4 Grazing land management**			NO				NO	NO	NO	NO		
8	**3.4 Revegetation**			NO				NO	NO	NO	NO		
9	**3.4 Wetland drainage and rewetting**			NO				NO	NO	NO	NO		
	Art 12 afforestation and reforestation												
10	**Replacement of expired tCERs**							NO	NO	NO	NO	NO	
11	**Replacement of expired lCERs**							NO	NO	NO	NO		
12	**Replacement for reversal of storage**							NO	NO	NO	NO		NO
13	**Cancellation for reversal of storage**												NO
14	**Replacement for non-submission of certification report**							NO	NO	NO	NO		NO
15	**Cancellation for non submission of certification report**												NO
	Other cancelation												
16	**Voluntary cancellation**							NO	NO	NO	831.662	NO	NO
17	**Article 3.1 ter and quater ambition increase cancellation**							NO					
18	**Subtotal**		NO	NO				NO	NO	NO	831.662	NO	NO

	Transaction type	Retirement					
		AAUs	ERUs	RMUs	CERs	tCERs	lCERs
1	**Retirement**	NO	NO	NO	NO	NO	NO
2	**Retirement from PPSR**	NO					
3	**Total**	NO	NO	NO	NO	NO	NO

Party	Germany
Submission Year	2018
Reported Year	2017
Commitment Period	2

Table 2b. Annual external transactions

		Additions						Subtractions					
	Total transfers and acquisitions	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**
1	**NO**	NO	28.999	NO	835.316	NO	NO	NO	NO	NO	NO	NO	NO
2	**CH**	NO	NO	NO	105.258	NO	NO	NO	NO	NO	441.643	NO	NO
3	**CDM**	NO	NO	NO	1.927.292	NO	NO	NO	NO	NO	NO	NO	NO
4	**NL**	NO	NO	NO	277.000	NO	NO	NO	NO	NO	246.154	NO	NO
5	**EU**	NO	NO	NO	554.336	NO	NO	NO	NO	NO	953.892	NO	NO
6	**GB**	NO	NO	NO	NO	NO	NO	NO	NO	NO	94.018	NO	NO
7	**IT**	NO	NO	NO	64.529	NO	NO	NO	NO	NO	NO	NO	NO
8	**LI**	NO	NO	NO	NO	NO	NO	NO	NO	NO	37.000	NO	NO
9	**ES**	NO	NO	NO	NO	NO	NO	NO	NO	NO	132.841	NO	NO
10	**Subtotal**	NO	28.999	NO	3.763.731	NO	NO	NO	NO	NO	1.905.548	NO	NO

Table 2c. Annual transactions between PPSR accounts

		AAUs	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**
1	**Subtotal**	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Table 2d. Share of proceeds transactions under decision 1/CMP.8, paragraph 21 - Adaptation Fund

		AAUs	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**
1	**First international transfers of AAUs**	NO						NO					
2	**Issuance of ERU from Party-verified projects**		NO						NO				
3	**Issuance of independently verified ERUs**		NO						NO				

Table 2e. Total annual transactions

		AAUs	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**
1	**Total (Sum of sub-totals in table 2a and table 2b)**	NO	28.999	NO	3.763.731	NO	NO	NO	NO	NO	2.737.210	NO	NO

Party	Germany

Submission Year	2018
Reported Year	2017
Commitment Period	2

Table 3. Expiry, cancellation and replacement

	Transaction or event type	**Requirement to replace or cancel**			**Replacement**						**Cancellation**					
	Transaction or event type	**tCERs**	**lCERs**	**CERs**	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**
	Temporary CERs															
1	**Expired in retirement and replacement accounts**	NO			NO	NO	NO	NO	NO							
2	**Expired in holding accounts**	NO													NO	
	Long-term CERs															
3	**Expired in retirement and replacement accounts**		NO		NO	NO	NO	NO								
4	**Expired in holding accounts**		NO													NO
5	**Subject to reversal of Storage**		NO		NO	NO	NO	NO		NO						NO
6	**Subject to non submission of certification Report**		NO		NO	NO	NO	NO		NO						NO
	Carbon Capture and Storage CERs															
7	**Subject to net reversal of storage**			NO							NO	NO	NO	NO		
8	**Subject to non submission of certification report**			NO							NO	NO	NO	NO		
9	**Total**	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Party	Germany
Submission Year	2018
Reported Year	2017
Commitment Period	2

Table 4. Total quantities of Kyoto Protocol units by account type at end of reported year

	Account type	**Unit type**					
		AAUs	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**
1	**Party holding accounts**	NO	NO	NO	NO	NO	NO
2	**Entity holding accounts**	NO	28.999	NO	1.569.475	NO	NO
3	**Retirement account**	NO	NO	NO	NO	NO	NO
4	**Previous period surplus reserve account**	NO					
5	**Article 3.3/3.4 net source cancellation accounts**	NO	NO	NO	NO		
6	**Non-compliance cancellation account**	NO	NO	NO	NO		
7	**Voluntary cancellation account**	NO	NO	NO	1.668.235	NO	NO
8	**Cancellation account for remaining units after carry-over**	NO	NO	NO	NO	NO	NO
9	**Article 3.1 ter and quater ambition increase cancellation account**	NO					
10	**Article 3.7 ter cancellation account**	NO					
11	**tCER cancellation account for expiry**					NO	
12	**lCER cancellation account for expiry**						NO
13	**lCER cancellation account for reversal of storage**						NO
14	**lCER cancellation account for non-submission of certification report**						NO
15	**tCER replacement account for expiry**	NO	NO	NO	NO	NO	
16	**lCER replacement account for expiry**	NO	NO	NO	NO		
17	**lCER replacement account for reversal of storage**	NO	NO	NO	NO		NO
18	**lCER replacement account for non-submission of certification report**	NO	NO	NO	NO		NO
19	**Total**	NO	28.999	NO	3.237.710	NO	NO

Party	Germany
Submission Year	2018
Reported Year	2017
Commitment Period	2

Table 5a. Summary information on additions and subtractions

		Additions						Subtractions					
		AAUs	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**
1	**Assigned amount units issued**	NO											
2	**Article 3 Paragraph 7 ter cancellations**							NO					
3	**Cancellation following increase in ambition**							NO					
4	**Cancellation of remaining units after carry over**							NO	NO	NO	NO	NO	NO
5	**Non-compliance cancellation**							NO	NO	NO	NO		
6	**Carry-over**		NO		NO				NO		NO		
7	**Carry-over to PPSR**	NO						NO					
8	**Total**	NO	NO		NO			NO	NO	NO	NO	NO	NO

Table 5b. Summary information on annual transactions

		Additions						Subtractions					
		AAUs	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**	**AAUs**	**ERUs**	**RMUs**	**CERs**	**tCERs**	**lCERs**
1	**Year 1 (2013)**	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2	**Year 2 (2014)**	NO	NO	NO	1.761.325	NO	NO	NO	NO	NO	151.074	NO	NO
3	**Year 3 (2015)**	NO	NO	NO	4.556.137	NO	NO	NO	NO	NO	5.639.465	NO	NO
4	**Year 4 (2016)**	NO	NO	NO	2.367.730	NO	NO	NO	NO	NO	2.351.699	NO	NO
5	**Year 5 (2017)**	NO	28.999	NO	3.763.731	NO	NO	NO	NO	NO	2.737.210	NO	NO
6	**Year 6 (2018)**	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
7	**Year 7 (2019)**	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
8	**Year 8 (2020)**	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
9	**Year 2021**	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
10	**Year 2022**	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
11	**Year 2023**	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
12	**Total**	NO	28.999	NO	12.448.923	NO	NO	NO	NO	NO	10.879.448	NO	NO

Table 5c. Summary information on annual transactions between PPSR accounts

		Additions						Subtractions					
		AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
1	Year 1 (2013)	NO						NO					
2	Year 2 (2014)	NO						NO					
3	Year 3 (2015)	NO						NO					
4	Year 4 (2016)	NO						NO					
5	Year 5 (2017)	NO						NO					
6	Year 6 (2018)	NO						NO					
7	Year 7 (2019)	NO						NO					
8	Year 8 (2020)	NO						NO					
9	Year 2021	NO						NO					
10	Year 2022	NO						NO					
11	Year 2023	NO						NO					
12	Total	NO						NO					

Table 5d. Summary information on expiry, cancellation and replacement

		Requirement to replace or cancel			Replacement						Cancellation					
		tCERs	lCERs	CERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
1	Year 1 (2013)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2	Year 2 (2014)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
3	Year 3 (2015)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4	Year 4 (2016)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
5	Year 5 (2017)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
6	Year 6 (2018)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
7	Year 7 (2019)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
8	Year 8 (2020)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
9	Year 2021	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
10	Year 2022	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
11	Year 2023	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
12	Total	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

	Table 5e. Summary information on retirement	AAUs	ERUs	RMUs	CERs	tCERs	lCERs
1	Year 1 (2013)	NO	NO	NO	NO	NO	NO
2	Year 2 (2014)	NO	NO	NO	NO	NO	NO
3	Year 3 (2015)	NO	NO	NO	NO	NO	NO
4	Year 4 (2016)	NO	NO	NO	NO	NO	NO
5	Year 5 (2017)	NO	NO	NO	NO	NO	NO
6	Year 6 (2018)	NO	NO	NO	NO	NO	NO
7	Year 7 (2019)	NO	NO	NO	NO	NO	NO
8	Year 8 (2020)	NO	NO	NO	NO	NO	NO
9	Year 2021	NO	NO	NO	NO	NO	NO
10	Year 2022	NO	NO	NO	NO	NO	NO
11	Year 2023	NO	NO	NO	NO	NO	NO
12	Total	NO	NO	NO	NO	NO	NO

Party	Germany
Submission Year	2018
Reported Year	2017
Commitment Period	2

Table 6a. Memo item: corrective transactions relating to additions and subtractions

Additions						Subtractions					
AAUs	ERUs	RMUs	CERs	tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs

Table 6b. Memo item: corrective transactions relating to replacement

Expiry, cancellation and requirement to replace		Replacement					
tCERs	lCERs	AAUs	ERUs	RMUs	CERs	tCERs	lCERs

Table 6c. Memo item: corrective transactions relating to retirement

Retirement					
AAUs	ERUs	RMUs	CERs	tCERs	lCERs

22.2.2.2 Discrepant transactions

No discrepant transactions occurred in 2016.

22.2.3 Detailed information about the National System, and about changes within the National System

All of this information has been provided in the preceding chapters.

22.2.4 Further detailed information about the National Registries and about accounting of Kyoto units

The required documents are confidential and accessible for assessors only.

22.3 Additional information about greenhouse-gas trends

Here, we provide the detailed tables relative to the trend discussion presented in Chapters 0.2 and 0.

Table 558: Emissions trends in Germany, by greenhouse gas and category

GHG emissions / sinks, in CO_2 equivalents (kt)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
CO_2 emissions (without LULUCF)	**1,052,520**	**1,014,440**	**966,177**	**956,517**	**939,908**	**939,543**	**959,606**	**931,750**	**923,824**	**896,313**	**900,376**	**916,913**	**900,387**	**901,409**	**887,458**
Net CO_2 emissions/removals	1,019,502	983,937	935,079	925,539	905,669	904,802	924,786	895,907	887,611	859,032	860,743	876,679	894,504	893,515	876,471
CH_4 (with LULUCF)	**120,944**	**114,827**	**111,335**	**112,002**	**108,059**	**105,665**	**103,335**	**98,886**	**93,803**	**92,926**	**88,789**	**85,240**	**81,149**	**77,733**	**72,646**
CH_4 (without LULUCF)	121,820	115,700	112,225	112,877	108,933	106,537	104,210	99,757	94,673	93,796	89,660	86,108	82,017	78,606	73,513
N_2O (with LULUCF)	**64,134**	**61,825**	**62,984**	**60,253**	**61,381**	**60,747**	**62,069**	**59,094**	**46,313**	**42,734**	**42,745**	**44,110**	**43,245**	**42,879**	**45,027**
N_2O (without LULUCF)	64,964	62,651	63,819	61,076	62,199	61,561	62,883	59,903	47,119	43,538	43,546	44,899	44,023	43,651	45,786
HFCs	**5,898**	**5,422**	**5,645**	**7,843**	**8,307**	**8,513**	**7,857**	**8,491**	**9,100**	**9,267**	**8,230**	**9,370**	**10,088**	**9,487**	**9,737**
PFC	**3,069**	**2,664**	**2,418**	**2,268**	**1,931**	**2,099**	**2,055**	**1,670**	**1,800**	**1,504**	**975**	**887**	**964**	**1,032**	**993**
SF_6	**4,428**	**4,746**	**5,238**	**5,974**	**6,249**	**6,467**	**6,162**	**6,109**	**5,889**	**4,290**	**4,072**	**3,752**	**3,087**	**3,034**	**3,262**
NF_3	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**
Total emissions, apart from LULUCF	**1,250,993**	**1,203,924**	**1,153,796**	**1,144,857**	**1,125,835**	**1,123,035**	**1,141,085**	**1,106,001**	**1,080,729**	**1,047,034**	**1,045,187**	**1,060,271**	**1,038,920**	**1,035,574**	**1,019,124**
Total emissions / removals, with LULUCF	**1,219,681**	**1,175,120**	**1,124,424**	**1,115,576**	**1,093,289**	**1,089,980**	**1,107,953**	**1,071,838**	**1,046,193**	**1,011,427**	**1,007,227**	**1,021,695**	**1,034,683**	**1,029,325**	**1,009,762**

GHG emissions / sinks, in CO_2 equivalents (kt)	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
CO_2 emissions (without LULUCF)	**866,640**	**878,076**	**851,418**	**853,771**	**788,924**	**832,388**	**809,749**	**814,138**	**831,570**	**792,793**	**795,940**	**801,655**	**797,966**
Net CO_2 emissions/removals	852,967	864,005	837,916	833,357	769,229	814,342	792,327	797,960	815,575	776,190	779,843	786,020	781,052
CH_4 (with LULUCF)	**69,455**	**65,665**	**63,460**	**62,404**	**60,099**	**59,353**	**58,230**	**58,826**	**58,376**	**57,215**	**57,079**	**55,924**	**55,247**
CH_4 (without LULUCF)	70,321	66,532	64,326	63,272	60,968	60,221	59,097	59,693	59,242	58,080	57,946	56,789	56,111
N_2O (with LULUCF)	**43,016**	**42,755**	**44,706**	**45,147**	**44,302**	**36,362**	**37,707**	**36,899**	**37,447**	**38,106**	**38,698**	**37,858**	**37,666**
N_2O (without LULUCF)	43,765	43,515	45,476	45,928	45,098	37,171	38,529	37,734	38,288	38,953	39,553	38,718	38,531
HFC	**10,059**	**10,215**	**10,484**	**10,664**	**11,274**	**10,840**	**11,029**	**11,230**	**11,237**	**11,352**	**11,574**	**11,479**	**11,258**
PFC	**852**	**683**	**601**	**578**	**417**	**356**	**285**	**248**	**262**	**238**	**247**	**252**	**234**
SF_6	**3,321**	**3,242**	**3,268**	**3,060**	**3,014**	**3,191**	**3,254**	**3,246**	**3,352**	**3,487**	**3,652**	**3,881**	**4,241**
NF_3	**C**	**2**	**4**	**21**	**24**	**54**	**52**	**25**	**6**	**6**	**C**	**C**	**C**
Total emissions, without LULUCF	**993,344**	**1,000,638**	**973,942**	**975,646**	**908,054**	**942,542**	**920,306**	**924,611**	**942,250**	**903,196**	**907,190**	**911,049**	**906,611**
Total emissions / removals, with LULUCF	**981,284**	**988,194**	**962,075**	**956,881**	**890,025**	**926,173**	**904,573**	**910,136**	**927,963**	**888,305**	**892,815**	**897,140**	**891,426**

GHG emissions / sinks, by source and sink categories, in CO_2 equivalents (kt)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1. Energy	1,036,608	999,632	950,918	941,841	919,472	918,079	939,052	907,660	897,983	873,480	870,346	890,809	874,440	869,640	852,798
2. Industrial processes	96,838	93,114	93,335	94,520	100,302	98,547	96,666	96,957	83,140	75,105	78,018	74,623	73,286	77,220	79,174
3. Agriculture	79,195	71,443	69,234	68,366	66,727	68,058	68,456	67,429	67,756	68,236	68,187	67,868	65,618	64,653	64,530
4. Land use, land-use change & forestry	-31,312	-28,804	-29,373	-29,281	-32,547	-33,055	-33,131	-34,162	-34,536	-35,607	-37,960	-38,576	-4,237	-6,249	-9,362
CO_2	*-33,018*	*-30,503*	*-31,098*	*-30,979*	*-34,239*	*-34,741*	*-34,821*	*-35,843*	*-36,212*	*-37,281*	*-39,633*	*-40,234*	*-5,883*	*-7,895*	*-10,987*
N_2O & CH_4	*1,706*	*1,699*	*1,725*	*1,698*	*1,692*	*1,686*	*1,689*	*1,680*	*1,676*	*1,674*	*1,673*	*1,657*	*1,646*	*1,645*	*1,626*
5. Waste	38,352	39,736	40,310	40,130	39,333	38,350	36,910	33,955	31,849	30,212	28,637	26,972	25,577	24,060	22,621

GHG emissions / sinks, by source and sink categories, in CO_2 equivalents (kt)	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	
1. Energy	832,197	841,703	815,440	820,023	761,949	801,237	778,192	784,567	801,833	761,976	767,091	770,912	765,661
2. Industrial processes	75,921	76,118	77,445	73,619	66,113	63,092	63,019	62,104	61,957	62,056	60,938	62,903	64,496
3. Agriculture	64,068	63,318	62,881	65,062	64,273	63,621	65,268	64,901	66,127	67,490	67,996	66,536	66,273
4. Land use, land-use change & forestry	-12,060	-12,444	-11,867	-18,765	-18,029	-16,369	-15,733	-14,476	-14,288	-14,891	-14,375	-13,909	-15,185
CO_2	*-13,674*	*-14,071*	*-13,502*	*-20,414*	*-19,694*	*-18,045*	*-17,421*	*-16,178*	*-15,995*	*-16,603*	*-16,097*	*-15,634*	*-16,914*
N_2O & CH_4	*1,614*	*1,627*	*1,636*	*1,649*	*1,665*	*1,677*	*1,688*	*1,703*	*1,707*	*1,712*	*1,721*	*1,725*	*1,729*
5. Waste	21,158	19,499	18,177	16,942	15,720	14,591	13,828	13,039	12,333	11,674	11,165	10,697	10,182

Table 559: Contributions to emissions trends in Germany, by greenhouse gas and category

GHG emissions / sinks; shares for greenhouse gases* (%)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
CO_2 emissions*	84.13	84.26	83.74	83.55	83.49	83.66	84.10	84.25	85.48	85.60	86.14	86.48	86.67	87.04	87.08	87.24	87.75	87.42	87.51	86.88	88.31	87.99	88.05	88.25	87.78	87.74	87.99	88.02
CH_4*	9.67	9.54	9.65	9.78	9.60	9.41	9.06	8.94	8.68	8.88	8.50	8.04	7.81	7.51	7.13	6.99	6.56	6.52	6.40	6.62	6.30	6.33	6.36	6.20	6.33	6.29	6.14	6.09
N_2O*	5.13	5.14	5.46	5.26	5.45	5.41	5.44	5.34	4.29	4.08	4.09	4.16	4.16	4.14	4.42	4.33	4.27	4.59	4.63	4.88	3.86	4.10	3.99	3.97	4.22	4.27	4.16	4.15
HFCs	0.47	0.45	0.49	0.69	0.74	0.76	0.69	0.77	0.84	0.89	0.79	0.88	0.97	0.92	0.96	1.01	1.02	1.08	1.09	1.24	1.15	1.20	1.21	1.19	1.26	1.28	1.26	1.24
PFC	0.25	0.22	0.21	0.20	0.17	0.19	0.18	0.15	0.17	0.14	0.09	0.08	0.09	0.10	0.10	0.09	0.07	0.06	0.06	0.05	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03
SF_6	0.35	0.39	0.45	0.52	0.56	0.58	0.54	0.55	0.54	0.41	0.39	0.35	0.30	0.29	0.32	0.33	0.32	0.34	0.31	0.33	0.34	0.35	0.35	0.36	0.39	0.40	0.43	0.47
NF_3	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	0.002	0.003	0.006	0.006	0.003	0.001	0.001	C	C	C
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

GHG emissions / sinks; shares for categories* (%)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1. Energy	82.86	83.03	82.42	82.27	81.67	81.75	82.29	82.07	83.09	83.42	83.27	84.02	84.17	83.98	83.68	83.78	84.12	83.73	84.05	83.91	85.01	84.56	84.85	85.10	84.36	84.56	84.62	84.45
2. Industrial processes	7.74	7.73	8.09	8.26	8.91	8.78	8.47	8.77	7.69	7.17	7.46	7.04	7.05	7.46	7.77	7.64	7.61	7.95	7.55	7.28	6.69	6.85	6.72	6.58	6.87	6.72	6.90	7.11
4. Agriculture	6.33	5.93	6.00	5.97	5.93	6.06	6.00	6.10	6.27	6.52	6.52	6.40	6.32	6.24	6.33	6.45	6.33	6.46	6.67	7.08	6.75	7.09	7.02	7.02	7.47	7.50	7.30	7.31
5. Waste	3.07	3.30	3.49	3.51	3.49	3.41	3.23	3.07	2.95	2.89	2.74	2.54	2.46	2.32	2.22	2.13	1.95	1.87	1.74	1.73	1.55	1.50	1.41	1.31	1.29	1.23	1.17	1.12
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

* Not including emissions from Land Use, Land Use Change and Forestry (LULUCF).

Table 560: Emissions of direct and indirect greenhouse gases and SO_2 in Germany since 1990

Emissions development (kt)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
CO_2 emissions (without LULUCF)	**1,052,520**	**1,014,440**	**966,177**	**956,517**	**939,908**	**939,543**	**959,606**	**931,750**	**923,824**	**896,313**	**900,376**	**916,913**	**900,387**	**901,409**	**887,458**
Net CO_2 emissions / removals	1,019,502	983,937	935,079	925,539	905,669	904,802	924,786	895,907	887,611	859,032	860,743	876,679	894,504	893,515	876,471
CH_4 (without LULUCF)	**4,838**	**4,593**	**4,453**	**4,480**	**4,322**	**4,227**	**4,133**	**3,955**	**3,752**	**3,717**	**3,552**	**3,410**	**3,246**	**3,109**	**2,906**
CH_4 (with LULUCF)	4,873	4,628	4,489	4,515	4,357	4,261	4,168	3,990	3,787	3,752	3,586	3,444	3,281	3,144	2,941
N_2O (without LULUCF)	**215**	**207**	**211**	**202**	**206**	**204**	**208**	**198**	**155**	**143**	**143**	**148**	**145**	**144**	**151**
N_2O (with LULUCF)	218	210	214	205	209	207	211	201	158	146	146	151	148	146	154
HFC (CO_2-eq.)	**5,898**	**5,422**	**5,645**	**7,843**	**8,307**	**8,513**	**7,857**	**8,491**	**9,100**	**9,267**	**8,230**	**9,370**	**10,088**	**9,487**	**9,737**
PFC (CO_2-eq.)	**3,069**	**2,664**	**2,418**	**2,268**	**1,931**	**2,099**	**2,055**	**1,670**	**1,800**	**1,504**	**975**	**887**	**964**	**1,032**	**993**
SF_6 (CO_2-eq.)	**4,428**	**4,746**	**5,238**	**5,974**	**6,249**	**6,467**	**6,162**	**6,109**	**5,889**	**4,290**	**4,072**	**3,752**	**3,087**	**3,034**	**3,262**
NF_3 (CO_2-eq.)	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**
NO_x	**2,892**	**2,649**	**2,502**	**2,395**	**2,207**	**2,184**	**2,112**	**2,048**	**2,024**	**1,998**	**1,947**	**1,869**	**1,794**	**1,737**	**1,658**
SO_2	**5,486**	**3,970**	**3,242**	**2,906**	**2,419**	**1,747**	**1,479**	**1,228**	**982**	**801**	**646**	**625**	**561**	**534**	**492**
NMVOC	**3,439**	**2,954**	**2,720**	**2,570**	**2,160**	**2,066**	**1,995**	**1,971**	**1,931**	**1,786**	**1,638**	**1,533**	**1,466**	**1,395**	**1,402**
CO	**12,544**	**10,318**	**8,932**	**8,135**	**6,779**	**6,482**	**6,028**	**5,891**	**5,449**	**5,108**	**4,831**	**4,655**	**4,380**	**4,200**	**3,961**

Emissions development (kt)	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
CO_2 emissions (without LULUCF)	**866,640**	**878,076**	**851,418**	**853,771**	**788,924**	**832,388**	**809,749**	**814,138**	**831,570**	**792,793**	**795,940**	**801,655**	**797,966**
Net CO_2 emissions / removals	852,967	864,005	837,916	833,357	769,229	814,342	792,327	797,960	815,575	776,190	779,843	786,020	781,052
CH_4 (without LULUCF)	**2,778**	**2,627**	**2,538**	**2,496**	**2,404**	**2,374**	**2,329**	**2,353**	**2,335**	**2,289**	**2,283**	**2,237**	**2,210**
CH_4 (with LULUCF)	2,813	2,661	2,573	2,531	2,439	2,409	2,364	2,388	2,370	2,323	2,318	2,272	2,244
N_2O (without LULUCF)	**144**	**143**	**150**	**151**	**149**	**122**	**127**	**124**	**126**	**128**	**130**	**127**	**126**
N_2O (with LULUCF)	147	146	153	154	151	125	129	127	128	131	133	130	129
HFC (CO_2-eq.)	**10,059**	**10,215**	**10,484**	**10,664**	**11,274**	**10,840**	**11,029**	**11,230**	**11,237**	**11,352**	**11,574**	**11,479**	**11,258**
PFC (CO_2-eq.)	**852**	**683**	**601**	**578**	**417**	**356**	**285**	**248**	**262**	**238**	**247**	**252**	**234**
SF_6 (CO_2-eq.)	**3,321**	**3,242**	**3,268**	**3,060**	**3,014**	**3,191**	**3,254**	**3,246**	**3,352**	**3,487**	**3,652**	**3,881**	**4,241**
NF_3 (CO_2-eq.)	**C**	**2**	**4**	**21**	**24**	**54**	**52**	**25**	**6**	**6**	**C**	**C**	**C**
NO_x	**1,584**	**1,573**	**1,504**	**1,429**	**1,331**	**1,355**	**1,338**	**1,305**	**1,307**	**1,271**	**1,247**	**1,221**	**1,184**
SO_2	**472**	**472**	**455**	**451**	**395**	**409**	**395**	**375**	**366**	**346**	**343**	**319**	**315**
NMVOC	**1,349**	**1,369**	**1,301**	**1,242**	**1,136**	**1,257**	**1,147**	**1,146**	**1,102**	**1,068**	**1,042**	**1,043**	**1,068**
CO	**3,753**	**3,657**	**3,540**	**3,431**	**2,981**	**3,347**	**3,259**	**2,887**	**2,859**	**2,757**	**2,864**	**2,802**	**2,828**

Table 561: Changes in emissions of direct and indirect greenhouse gases and SO_2 in Germany, since 1990

Emissions trend Trend with respect to 1990 / 1995 (%)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
CO_2 emissions (without LULUCF)		-3.6	-8.2	-9.1	-10.7	-10.7	-8.8	-11.5	-12.2	-14.8	-14.5	-12.9	-14.5	-14.4	-15.7
Net CO_2 emissions / removals		-3.5	-8.3	-9.2	-11.2	-11.3	-9.3	-12.1	-12.9	-15.7	-15.6	-14.0	-12.3	-12.4	-14.0
CH_4 (without LULUCF)		-5.1	-7.9	-7.4	-10.7	-12.6	-14.6	-18.2	-22.4	-23.2	-26.6	-29.5	-32.9	-35.7	-39.9
N_2O (without LULUCF)		-3.6	-1.8	-6.1	-4.3	-5.3	-3.2	-7.9	-27.8	-33.4	-33.4	-31.2	-32.6	-33.1	-29.8
HFCs							-7.7	-0.3	+6.9	+8.8	-3.3	+10.1	+18.5	+11.4	+14.4
PFC							-2.1	-20.4	-14.3	-28.3	-53.5	-57.7	-54.1	-50.8	-52.7
SF_6							-4.7	-5.5	-8.9	-33.7	-37.0	-42.0	-52.3	-53.1	-49.6
NF_3															
Total emissions, without LULUCF		-3.8	-7.8	-8.5	-10.0	-10.2	-8.8	-11.6	-13.6	-16.3	-16.5	-15.2	-17.0	-17.2	-18.5
Total emissions / removals, with LULUCF		-3.7	-7.8	-8.5	-10.4	-10.6	-9.2	-12.1	-14.2	-17.1	-17.4	-16.2	-15.2	-15.6	-17.2
Total emissions, without LULUCF, with respect to base year*		*-4.0*	*-8.0*	*-8.8*	*-10.3*	*-10.5*	*-9.1*	*-11.8*	*-13.9*	*-16.5*	*-16.7*	*-15.5*	*-17.2*	*-17.5*	*-18.8*
NO_x		-8.4	-13.5	-17.2	-23.7	-24.5	-27.0	-29.2	-30.0	-30.9	-32.7	-35.4	-38.0	-39.9	-42.6
SO_2		-27.6	-40.9	-47.0	-55.9	-68.2	-73.0	-77.6	-82.1	-85.4	-88.2	-88.6	-89.8	-90.3	-91.0
NMVOC		-14.1	-20.9	-25.3	-37.2	-39.9	-42.0	-42.7	-43.8	-48.1	-52.4	-55.4	-57.4	-59.4	-59.2
CO		-17.7	-28.8	-35.1	-46.0	-48.3	-51.9	-53.0	-56.6	-59.3	-61.5	-62.9	-65.1	-66.5	-68.4

Emissions trend Trend with respect to 1990 / 1995 (%)	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
CO_2 emissions (without LULUCF)	-17.7	-16.6	-19.1	-18.9	-25.0	-20.9	-23.1	-22.6	-21.0	-24.7	-24.4	-23.8	-24.2
Net CO_2 emissions / removals	-16.3	-15.3	-17.8	-18.3	-24.5	-20.1	-22.3	-21.7	-20.0	-23.9	-23.5	-22.9	-23.4
CH_4 (without LULUCF)	-42.6	-45.7	-47.5	-48.4	-50.3	-50.9	-51.9	-51.4	-51.7	-52.7	-52.8	-53.8	-54.3
N_2O (without LULUCF)	-32.9	-33.3	-30.3	-29.6	-30.9	-43.3	-41.2	-42.5	-41.6	-40.6	-39.7	-41.0	-41.3
HFC	+18.2	+20.0	+23.1	+25.3	+32.4	+27.3	+29.6	+31.9	+32.0	+33.3	+36.0	+34.8	+32.2
PFC	-59.4	-67.5	-71.4	-72.4	-80.1	-83.0	-86.4	-88.2	-87.5	-88.7	-88.2	-88.0	-88.9
SF_6	-48.7	-49.9	-49.5	-52.7	-53.4	-50.7	-49.7	-49.8	-48.2	-46.1	-43.5	-40.0	-34.4
NF_3													
Total emissions, without LULUCF	-20.6	-20.0	-22.1	-22.0	-27.4	-24.7	-26.4	-26.1	-24.7	-27.8	-27.5	-27.2	-27.5
Total emissions / removals, with LULUCF	-19.5	-19.0	-21.1	-21.5	-27.0	-24.1	-25.8	-25.4	-23.9	-27.2	-26.8	-26.4	-26.9
Total emissions, without LULUCF, with respect to base year*	*-20.8*	*-20.2*	*-22.4*	*-22.2*	*-27.6*	*-24.9*	*-26.7*	*-26.3*	*-24.9*	*-28.0*	*-27.7*	*-27.4*	*-27.7*
NO_x	-45.2	-45.6	-48.0	-50.6	-54.0	-53.1	-53.7	-54.9	-54.8	-56.1	-56.9	-57.8	-59.0
SO_2	-91.4	-91.4	-91.7	-91.8	-92.8	-92.5	-92.8	-93.2	-93.3	-93.7	-93.7	-94.2	-94.3
NMVOC	-60.8	-60.2	-62.2	-63.9	-67.0	-63.4	-66.6	-66.7	-68.0	-68.9	-69.7	-69.7	-68.9
CO	-70.1	-70.8	-71.8	-72.6	-76.2	-73.3	-74.0	-77.0	-77.2	-78.0	-77.2	-77.7	-77.5

* The base year for CO_2, CH_4 & N_2O is 1990; the base year for HFC, PFC, SF_6 & NF_3 is 1995.

Table 562: Changes in emissions of direct and indirect greenhouse gases and SO_2 in Germany, since the relevant previous year

Emissions trend Emissions trend with respect to the previous year in each case (%)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
CO_2 emissions (without LULUCF)		-3.6	-4.8	-1.0	-1.7	-0.0	+2.1	-2.9	-0.9	-3.0	+0.5	+1.8	-1.8	+0.1	-1.5
Net CO_2 emissions / removals		-3.5	-5.0	-1.0	-2.1	-0.1	+2.2	-3.1	-0.9	-3.2	+0.2	+1.9	+2.0	-0.1	-1.9
CH_4 (without LULUCF)		-5.1	-3.0	+0.6	-3.5	-2.2	-2.2	-4.3	-5.1	-0.9	-4.5	-4.0	-4.8	-4.2	-6.5
N_2O (without LULUCF)		-3.6	+1.9	-4.3	+1.9	-1.0	+2.2	-4.8	-21.6	-7.7	+0.0	+3.2	-2.0	-0.8	+5.0
HFC							-7.7	+8.1	+7.2	+1.8	-11.2	+13.9	+7.7	-6.0	+2.6
PFC							-2.1	-18.7	+7.7	-16.4	-35.2	-9.0	+8.6	+7.2	-3.8
SF_6							-4.7	-0.9	-3.6	-27.2	-5.1	-7.9	-17.7	-1.7	+7.5
NF_3															
Total emissions, without LULUCF		-3.8	-4.2	-0.8	-1.7	-0.2	+1.6	-3.1	-2.3	-3.1	-0.2	+1.4	-2.0	-0.3	-1.6
Total emissions / removals, with LULUCF		-3.7	-4.3	-0.8	-2.0	-0.3	+1.6	-3.3	-2.4	-3.3	-0.4	+1.4	+1.3	-0.5	-1.9
NO_X		-8.4	-5.5	-4.3	-7.8	-1.1	-3.3	-3.0	-1.2	-1.3	-2.6	-4.0	-4.1	-3.2	-4.5
SO_2		-27.6	-18.3	-10.4	-16.7	-27.8	-15.3	-16.9	-20.1	-18.4	-19.4	-3.3	-10.2	-4.8	-7.8
NMVOC		-14.1	-7.9	-5.5	-16.0	-4.3	-3.4	-1.2	-2.0	-7.5	-8.3	-6.4	-4.4	-4.9	+0.5
CO		-17.7	-13.4	-8.9	-16.7	-4.4	-7.0	-2.3	-7.5	-6.3	-5.4	-3.6	-5.9	-4.1	-5.7

Emissions trend Emissions trend with respect to the previous year in each case (%)	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
CO_2 emissions (without LULUCF)	-2.3	+1.3	-3.0	+0.3	-7.6	+5.5	-2.7	+0.5	+2.1	-4.7	+0.4	+0.7	-0.5
Net CO_2 emissions / removals	-2.7	+1.3	-3.0	-0.5	-7.7	+5.9	-2.7	+0.7	+2.2	-4.8	+0.5	+0.8	-0.6
CH_4 (without LULUCF)	-4.4	-5.5	-3.4	-1.7	-3.7	-1.2	-1.9	+1.0	-0.8	-2.0	-0.2	-2.0	-1.2
N_2O (without LULUCF)	-4.5	-0.6	+4.6	+1.0	-1.9	-17.9	+3.7	-2.1	+1.5	+1.8	+1.6	-2.2	-0.5
HFC	+3.3	+1.5	+2.6	+1.7	+5.7	-3.9	+1.8	+1.8	+0.1	+1.0	+2.0	-0.8	-1.9
PFC	-14.3	-19.9	-12.0	-3.7	-27.8	-14.7	-19.9	-13.1	+5.6	-9.0	+3.7	+2.1	-7.4
SF_6	+1.8	-2.4	+0.8	-6.4	-1.5	+5.9	+2.0	-0.2	+3.3	+4.0	+4.7	+6.2	+9.3
NF_3													
Total emissions, without LULUCF	-2.5	+0.7	-2.7	+0.2	-6.9	+3.8	-2.4	+0.5	+1.9	-4.1	+0.4	+0.4	-0.5
Total emissions / removals, with LULUCF	-2.8	+0.7	-2.6	-0.5	-7.0	+4.1	-2.3	+0.6	+2.0	-4.3	+0.5	+0.5	-0.6
NO_X	-4.5	-0.7	-4.4	-5.0	-6.9	+1.9	-1.2	-2.5	+0.1	-2.8	-1.9	-2.1	-3.0
SO_2	-4.2	+0.0	-3.5	-1.0	-12.5	+3.7	-3.4	-5.1	-2.6	-5.5	-0.7	-6.9	-1.3
NMVOC	-3.8	+1.5	-4.9	-4.6	-8.5	+10.7	-8.7	-0.1	-3.8	-3.1	-2.5	+0.1	+2.5
CO	-5.3	-2.6	-3.2	-3.1	-13.1	+12.3	-2.6	-11.4	-1.0	-3.5	+3.9	-2.2	+0.9

Table 563: Changes in emissions in Germany, by categories, since 1990 / since the relevant previous year

Emissions change with respect to 1990 (%)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1. Energy		-3.6%	-8.3%	-9.1%	-11.3%	-11.4%	-9.4%	-12.4%	-13.4%	-15.7%	-16.0%	-14.1%	-15.6%	-16.1%	-17.7%	-19.7%	-18.8%	-21.3%	-20.9%	-26.5%	-22.7%	-24.9%	-24.3%	-22.6%	-26.5%	-26.0%	-25.6%	-26.1%
2. Industrial processes		-3.8%	-3.6%	-2.4%	3.6%	1.8%	-0.2%	0.1%	-14.1%	-22.4%	-19.4%	-22.9%	-24.3%	-20.3%	-18.2%	-21.6%	-21.4%	-20.0%	-24.0%	-31.7%	-34.8%	-34.9%	-35.9%	-36.0%	-35.9%	-37.1%	-35.0%	-33.4%
3. Agriculture		-9.8%	-12.6%	-13.7%	-15.7%	-14.1%	-13.6%	-14.9%	-14.4%	-13.8%	-13.9%	-14.3%	-17.1%	-18.4%	-18.5%	-19.1%	-20.0%	-20.6%	-17.8%	-18.8%	-19.7%	-17.6%	-18.0%	-16.5%	-14.8%	-14.1%	-16.0%	-16.3%
4. Land use, land-use change & forestry (CO_2, N_2O & CH_4)		-8.0%	-6.2%	-6.5%	3.9%	5.6%	5.8%	9.1%	10.3%	13.7%	21.2%	23.2%	-86.5%	-80.0%	-70.1%	-61.5%	-60.3%	-62.1%	-40.1%	-42.4%	-47.7%	-49.8%	-53.8%	-54.4%	-52.4%	-54.1%	-55.6%	-51.5%
5. Waste		3.6%	5.1%	4.6%	2.6%	0.0%	-3.8%	-11.5%	-17.0%	-21.2%	-25.3%	-29.7%	-33.3%	-37.3%	-41.0%	-44.8%	-49.2%	-52.6%	-55.8%	-59.0%	-62.0%	-63.9%	-66.0%	-67.8%	-69.6%	-70.9%	-72.1%	-73.5%
Emissions change, in each case with respect to the previous year; change in %	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
1. Energy		-3.6%	-4.9%	-1.0%	-2.4%	-0.2%	2.3%	-3.3%	-1.1%	-2.7%	-0.4%	2.4%	-1.8%	-0.5%	-1.9%	-2.4%	1.1%	-3.1%	0.6%	-7.1%	5.2%	-2.9%	0.8%	2.2%	-5.0%	0.7%	0.5%	-0.7%
2. Industrial processes		-3.8%	0.2%	1.3%	6.1%	-1.8%	-1.9%	0.3%	-14.3%	-9.7%	3.9%	-4.4%	-1.8%	5.4%	2.5%	-4.1%	0.3%	1.7%	-4.9%	-10.2%	-4.6%	-0.1%	-1.5%	-0.2%	0.2%	-1.8%	3.2%	2.5%
3. Agriculture		-9.8%	-3.1%	-1.3%	-2.4%	2.0%	0.6%	-1.5%	0.5%	0.7%	-0.1%	-0.5%	-3.3%	-1.5%	-0.2%	-0.7%	-1.2%	-0.7%	3.5%	-1.2%	-1.0%	2.6%	-0.6%	1.9%	2.1%	0.7%	-2.1%	-0.4%
4. Land use, land-use change & forestry (CO_2, N_2O & CH_4)		-8.0%	2.0%	-0.3%	11.2%	1.6%	0.2%	3.1%	1.1%	3.1%	6.6%	1.6%	-89.0%	47.5%	49.8%	28.8%	3.2%	-4.6%	58.1%	-3.9%	-9.2%	-3.9%	-8.0%	-1.3%	4.2%	-3.5%	-3.2%	9.2%
5. Waste		3.6%	1.4%	-0.4%	-2.0%	-2.5%	-3.8%	-8.0%	-6.2%	-5.1%	-5.2%	-5.8%	-5.2%	-5.9%	-6.0%	-6.5%	-7.8%	-6.8%	-6.8%	-7.2%	-7.2%	-5.2%	-5.7%	-5.4%	-5.3%	-4.4%	-4.2%	-4.8%

22.4 Recalculations: detailed consideration on the basis of CRF Table 8

The following tables provide a numerical overview of the revised emissions figures for the years 1990 and 2016, pursuant to CRF tables 8s1 through 8s4 of the current CRF submission. For remarks regarding the recalculations shown, please refer to Chapter 10.1 of the present report and to the relevant category-specific chapters.

22.4.1 Overview for report year 1990

Table 564: Revised carbon dioxide emissions, 1990

Carbon dioxide - CO_2	Submission 2018	Submission 2019	Change		Impacts on total national emissions *Without LULUCF*	*With LULUCF*
		[kt]			[%]	
National total emissions and removals	**1,019,979.69**	**1,019,502.32**	**-477.37**	**-0.0468**	**-0.0375**	**-0.0385**
1. Energy	**989,771.64**	**989,636.72**	**-134.92**	**-0.0136**	**-0.0106**	**-0.0109**
A. Combustion of fuels	985,704.89	985,569.97	-134.92	-0.0137	-0.0106	-0.0109
1. Energy generation	423,905.78	423,905.78	0.00	0.0000	0.0000	0.0000
2. Manufacturing	185,107.47	185,107.56	0.09	0.0000	0.00001	0.00001
3. Transport	161,882.41	161,747.40	-135.01	-0.0834	-0.0106	-0.0109
2. Industrial processes & product use	**60,042.25**	**59,699.80**	**-342.44**	**-0.5703**	**-0.0269**	**-0.0276**
D. Non-energy-related fuel use and solvent use	3,330.94	2,988.50	-342.44	-10.2807	-0.0269	-0.0276
3. Agriculture	**3,183.61**	**3,183.61**	**0.00**	**0.0000**	**0.0000**	**0.0000**
4. Land use, land-use changes, forestry	**-33,017.81**	**-33,017.81**	**0.00**	**0.0000**		**0.0000**
5. Waste & wastewater	**NO,NE,NA**	**NO,NE,NA**				
6. Other	**NA**	**NA**				
Reported as memo items:						
International transports	**18,364.98**	**18,499.99**	**135.01**	**0.735**	**0.0106**	**0.0109**
International air transports	11,959.63	12,094.64	135.01	1.129	0.0106	0.0109
International sea transports	6,405.35	6,405.35	0.00	0.000	0.0000	0.0000
Multilateral operations	**NE**	**NE**				
CO_2 from biomass	**22,101.38**	**22,101.38**	**0.00**	**0.000**	**0.0000**	**0.0000**
collected CO_2	**NO**	**NO**				
Long-term C storage in landfills	**NA**	**NA**				
Indirect CO_2	**NO,NA**	**NE**				

Table 565: Revised methane emissions, 1990

Methane - CH_4	Submission 2018	Submission 2019	Change		Impacts on total national emissions *Without LULUCF*	*With LULUCF*
		[kt CO_2-eq.]			[%]	
National total emissions and removals	**121,102.34**	**121,819.72**	**717.38**	**0.592**	**0.0564**	**0.0578**
1. Energy	**40,223.56**	**40,224.88**	**1.32**	**0.003**	**0.0001**	**0.0001**
A. Combustion of fuels	6,324.24	6,325.56	1.32	0.021	0.0001	0.0001
1. Energy generation	*280.21*	*280.21*	*0.00*	*0.000*	*0.0000*	*0.0000*
2. Manufacturing	*249.93*	*251.56*	*1.62*	*0.649*	*0.0001*	*0.0001*
3. Transport	*1,329.19*	*1,328.88*	*-0.31*	*-0.023*	*-0.00002*	*-0.00002*
2. Industrial processes & product use	**351.46**	**351.46**	**0.00**	**0.000**	**0.0000**	**0.0000**
3. Agriculture	**42,737.38**	**43,453.44**	**716.06**	**1.675**	**0.0563**	**0.0577**
A. Enteric fermentation	34,664.20	35,352.94	688.74	1.987	0.0542	0.0555
B. Manure management	8,072.91	8,100.23	27.32	0.338	0.0022	0.0022
J. Other	0.27	0.27	0.00	0.000	0.0000	0.0000
4. Land use, land-use changes, forestry	**875.64**	**875.64**	**0.00**	**0.000**		**0.0000**
5. Waste & wastewater	**36,914.30**	**36,914.30**	**0.002**	**0.000**	**0.0000**	**0.0000**

Methane - CH_4	Submission 2018	Submission 2019	Change		Impacts on total national emissions *Without LULUCF*	*With LULUCF*
	[kt CO_2-eq.]				[%]	
6. Other	**NA**	**NA**				
Reported only as memo items:						
International transports	**2.70**	**2.53**	**-0.16**	**-6.013**	**-0.00001**	**-0.00001**
International air transports	1.13	0.97	-0.16	-14.322	-0.00001	-0.00001
International sea transports	1.56	1.56	0.00	0.000	0.00000	0.00000
Multilateral operations	**NE**	**NE**				

Table 566: Revised nitrous oxide emissions, 1990

Nitrous oxide - N_2O	Submission 2018	Submission 2019	Change		Impacts on total national emissions *Without LULUCF*	*With LULUCF*
	[kt CO_2-eq.]				[%]	
National total emissions and removals	**65,854.93**	**64,964.16**	**-890.77**	**-1.353**	**-0.0700**	**-0.0718**
1. Energy	6,740.57	6,746.08	5.51	0.082	0.0004	0.0004
A. Combustion of fuels	6,739.51	6,745.02	5.51	0.082	0.0004	0.0004
1. Energy generation	3,167.08	3,167.08	0.00	0.000	0.0000	0.0000
2. Manufacturing	1,342.69	1,349.65	6.97	0.519	0.0006	0.0006
3. Transport	1,192.61	1,191.15	-1.46	-0.122	-0.0001	-0.0001
2. Industrial processes & product use	**23,367.47**	**23,391.77**	**24.30**	**0.104**	**0.0019**	**0.0020**
C. Metal production	2.24	26.54	24.30	1084	0.0019	0.0020
3. Agriculture	**33,477.02**	**32,558.45**	**-918.58**	**-2.744**	**-0.0722**	**-0.0741**
B. Manure management	5,084.43	3,903.33	-1,181.10	-23.230	-0.0929	-0.0952
D. Agricultural soils	28,392.47	28,654.99	262.52	0.925	0.0206	0.0212
4. Land use, land-use changes, forestry	**830.43**	**830.43**	**0.00**	**0.000**		**0.0000**
5. Waste & wastewater	**1,439.43**	**1,437.43**	**-2.00**	**-0.14**	**-0.0002**	**-0.0002**
D. Wastewater treatment	1,423.47	1,421.47	-2.00	-0.14	-0.0002	-0.0002
6. Other	**NA**	**NA**				
Reported as memo items:						
International transports	**196.10**	**197.53**	**1.43**	**0.73**	**0.0001**	**0.0001**
International air transports	112.09	113.52	1.43	1.27	0.0001	0.0001
International sea transports	84.01	84.01	0.00	0.00	0.0000	0.0000
Multilateral operations	**NE**	**NE**				
Indirect N_2O	**NO,IE**	**NO,IE**				

Table 567: Revised HFC emissions, 1990

Hydrofluorocarbons – HFCs	Submission 2018	Submission 2019	Change		Impacts on total national emissions *Without LULUCF*	*With LULUCF*
	[kt CO_2-eq.]				[%]	
Total national emissions	**50.32**	**NO,IE,NA**	**-50.32**	**-100**	**-0.0040**	**-0.0041**
2.E.1. Electronics industry	50.32	IE	-50.32	-100	-0.0040	-0.0041

Table 568: Revised PFC emissions, 1990

Poly– and perfluorocarbons – PFCs	Submission 2018	Submission 2019	Change		Impacts on total national emissions *Without LULUCF*	*With LULUCF*
	[kt CO_2-eq.]				[%]	
Total national emissions	**3060.42**	**25211.32**	**22150.90**	**724**	**1.7417**	**1.7856**
2.C.3. Aluminium production	2888.66	25202.76	22314.11	772	1.7545	1.7988
2.E.1. Electronics industry	171.58	IE	-171.58	-100	-0.0135	-0.0133
2.E.4. Heat transfer fluids	0.18	8.56	8.37	4544	0.0007	0.0007

Table 569: Revised SF_6 emissions, 1990

Sulphur hexafluoride - SF_6	Submission 2018	Submission 2019	Change		Impacts on total national emissions *Without LULUCF*	*With LULUCF*
	[kt CO_2-eq.]				[%]	
Total national emissions	**4,428.00**	**2,946.00**	**-1,482.00**	**-33.469**	**-0.1165**	**-0.1195**
2.G.2. SF_6 and PFC from other product use	3,181.68	1,699.68	-1,482.00	-46.579	-0.1165	-0.1195

Table 570: Revised *unspecified-mix* emissions, 1990

Unspecified mix of HFCs and PFCs	Submission 2018	Submission 2019	Change		Impacts on total national emissions *Without LULUCF*	*With LULUCF*
	[kt CO_2-eq.]				[%]	
Total national emissions	**5840.87**	**6077.83**	**236.96**	**4.0570**	**0.0186**	**0.0191**
2.H. Other	273.78	510.75	236.96	86.5510	0.0186	0.0191

Table 571: Revised NF_3 emissions, 1990

Nitrogen trifluoride - NF_3	Submission 2018	Submission 2019	Change		Impacts on total national emissions *Without LULUCF*	*With LULUCF*
	[kt CO_2-eq.]				[%]	
Total national emissions	**6.88**	**NO,IE**	**-6.88**	**-100**	**-0.0005**	**-0.0006**
2.E.1. Electronics industry	6.88	IE	-6.88	-100	-0.0005	-0.0006

22.4.2 Overview for report year 2016

Table 572: Revised carbon dioxide emissions, 2016

Carbon dioxide – CO_2	Submission 2018	Submission 2019	Change		Impacts on total national emissions *Without LULUCF*	*With LULUCF*
	[kt]				[%]	
National total emissions and removals	**785,548.91**	**786,020.43**	**471.52**	**0.0600**	**0.0518**	**0.0526**
1. Energy	**754,110.44**	**753,218.17**	**-892.27**	**-0.1183**	-0.0979	-0.0995
A. Combustion of fuels	751,700.22	750,803.04	-897.18	-0.1194	-0.0985	-0.1000
1. Energy generation	326,539.30	327,298.78	759.48	0.2326	0.0834	0.0847
2. Manufacturing	125,308.33	129,186.36	3,878.03	3.0948	0.4257	0.4323
3. Transport	165,045.79	164,213.19	-832.60	-0.5045	-0.0914	-0.0928
4. Other sectors	133,790.70	129,088.22	-4,702.47	-3.5148	-0.5162	-0.5242
5. Other	1,016.10	1,016.49	0.39	0.0383	0.0000	0.0000
B. Fugitive emissions from fuels	2,410.22	2,415.12	4.91	0.2035	0.0005	0.0005
1. Solid fuels	706.59	706.59	0.00	0.0000	0.0000	0.0000
2. Oil and natural gas	1,703.62	1,708.53	4.91	0.2879	0.0005	0.0005
2. Industrial processes & product use	**44,869.68**	**45,663.77**	**794.10**	**1.7698**	**0.0872**	**0.0885**
A. Mineral industry	19,609.12	19,526.26	-82.86	-0.4225	-0.0091	-0.0092
B. Chemical industry	5,617.25	5,628.58	11.33	0.2017	0.0012	0.0013
C. Metal production	17,094.45	18,419.72	1,325.27	7.7526	0.1455	0.1477
D. Non-energy-related fuel use and solvent use	2,548.86	2,089.21	-459.64	-18.0333	-0.0505	-0.0512
3. Agriculture	**2,772.89**	**2,772.89**	**0.00**	**0.0000**	**0.0000**	**0.0000**
4. Land use, land-use changes, forestry	**-16,204.10**	**-15,634.40**	**569.69**	**-3.5157**		**0.0635**
G. Harvested wood products	-2,328.38	-1,758.68	569.70	-24.4675		0.0635
5. Waste & wastewater	**NO,NE,NA**	**NO,NE,NA**				
6. Other	**NA**	**NA**				

Carbon dioxide – CO_2	Submission 2018	Submission 2019	Change		Impacts on total national emissions Without LULUCF	With LULUCF
		[kt]			[%]	
Reported only as memo items:						
International transports	**34,370.45**	**34,563.29**	**192.85**	**0.5611**	**0.0212**	**0.0215**
International air transports	26,170.07	26,374.97	204.90	0.7829	0.0225	0.0228
International sea transports	8,200.38	8,188.32	-12.05	-0.1469	-0.0013	-0.0013
Multilateral operations	**NE**	**NE**				
CO_2 from biomass	**108,067.09**	**108,378.96**	311.86	0.2886	0.0342	0.0348
collected CO_2	**NO**	**NO**				
Long-term C storage in landfills	**NA**	**NA**				
Indirect CO_2	**NO,NA**	**NE**				

Table 573: Revised methane emissions, 2016

Methane – CH_4	Submission 2018	Submission 2019	Change		Impacts on total national emissions Without LULUCF	With LULUCF
		[kt CO_2-eq.]			[%]	
Total national emissions	**55,267.37**	**56,788.81**	**1,521.45**	**2.753**	**0.1670**	**0.1696**
1. Energy	**12,265.05**	**12,107.82**	**-157.24**	**-1.282**	-0.0173	-0.0175
A. Combustion of fuels	4,718.01	4,617.33	-100.69	-2.134	-0.0111	-0.0112
1. Energy generation	3,041.37	2,968.41	-72.96	-2.399	-0.0080	-0.0081
2. Manufacturing	277.28	288.09	10.81	3.899	0.0012	0.0012
3. Transport	145.34	144.45	-0.89	-0.612	-0.0001	-0.0001
4. Other sectors	1,252.47	1,214.82	-37.65	-3.006	-0.0041	-0.0042
5. Other	1.56	1.56	0.00	-0.050	0.0000	0.0000
B. Fugitive emissions from fuels	7,547.04	7,490.49	-56.55	-0.749	-0.0062	-0.0063
1. Solid fuels	2,480.85	2,480.85	0.00	0.000	0.0000	0.0000
2. Oil and natural gas	5,066.19	5,009.64	-56.55	-1.116	-0.0062	-0.0063
2. Industrial processes & product use	**534.40**	**534.43**	**0.028**	**0.005**	**0.000003**	**0.000003**
C. Metal production	6.93	6.93	-0.0004	-0.006	0.000000	0.000000
G. Other product use	31.97	32.00	0.028	0.088	0.000003	0.000003
3. Agriculture	**31,958.54**	**33,420.80**	**1,462.26**	**4.576**	**0.1605**	**0.1630**
A. Enteric fermentation	24,455.99	25,771.76	1,315.78	5.380	0.1444	0.1467
B. Manure management	6,142.81	6,308.52	165.7115	2.698	0.0182	0.0185
J. Other	1,359.74	1,340.52	-19.22	-1.414	-0.0021	-0.0021
4. LULUCF	**864.75**	**864.75**	**0.0000**	**0.000**		**0.0000**
5. Waste & wastewater	**9,644.62**	**9,861.01**	**216.3913**	**2.244**	**0.0238**	**0.0241**
A. Landfilling of solid waste	8,375.00	8,575.00	200.00	2.388	0.0220	0.0223
B. Biological treatment of solid waste	690.31	708.56	18.2536	2.644	0.0020	0.0020
D. Wastewater treatment	575.12	573.41	-1.7087	-0.297	-0.0002	-0.0002
E. Other	4.19	4.04	-0.1535	-3.663	-0.00002	-0.00002
6. Other	**NA**	**NA**				
Reported as memo items:						
International transports	**4.60**	**4.29**	**-0.3062**	**-6.659**	-0.00003	-0.00003
International air transports	2.61	2.29	**-0.3204**	**-12.282**	-0.00004	-0.00004
International sea transports	1.99	2.00	**0.0142**	**0.716**	0.00000	0.00000
Multilateral operations	**NA**	**NE**				

Table 574: Revised nitrous oxide emissions, 2016

Nitrous oxide – N_2O	Submission 2018	Submission 2019	Change		Impacts on total national emissions Without LULUCF	With LULUCF
	[kt CO_2-eq.]				[%]	
Total national emissions	**38,808.35**	**38,718.16**	**-90.19**	**-0.232**	**-0.0099**	**-0.0101**
1. Energy	**5,525.07**	**5,586.27**	**61.19**	**1.108**	0.0067	0.0062
A. Combustion of fuels	5,524.93	5,586.13	61.19	1.108	0.0067	0.0068
1. Energy generation	2,577.01	2,615.41	38.40	1.490	0.0042	0.0043
2. Manufacturing	820.34	881.87	61.54	7.502	0.0068	0.0069
3. Transport	1,623.41	1,616.36	-7.06	-0.435	-0.0008	-0.0008
4. Other sectors	499.75	468.06	-31.69	-6.340	-0.0035	-0.0035
5. Other	4.42	4.42	0.00	0.027	0.0000	0.0000
2. Industrial processes & product use	**1,092.43**	**1,093.02**	**0.59**	**0.054**	**0.0001**	**0.0001**
B. Chemical industry	669.65	670.82	1.17	0.174	0.0001	0.0003
C. Metal production	15.39	14.81	-0.58	-3.752	-0.0001	-0.0001
D. Non-energy-related fuel use and solvent use	1.408	1.409	0.001	0.042	0.0000	0.0000
3. Agriculture	**30,496.96**	**30,342.38**	**-154.58**	**-0.507**	**-0.0170**	**-0.0172**
B. Manure management	3,793.91	3,273.38	-520.54	-13.720	-0.0571	-0.0580
D. Agricultural soils	26,435.56	26,805.93	370.37	1.401	0.0407	0.0413
J. Other	267.49	263.08	-4.41	-1.649	-0.0005	-0.0005
4. Land use, land-use changes, forestry	**860.16**	**860.16**	**0.00**	**0.000**		**0.0000**
5. Waste & wastewater	**833.73**	**836.33**	**2.60**	**0.312**	**0.0003**	**0.0003**
B. Biological treatment of solid waste	303.72	310.42	6.70	2.206	0.0007	0.0008
D. Wastewater treatment	457.96	456.50	-1.46	-0.318	-0.0002	-0.0002
E. Other	72.05	69.41	-2.64	-3.663	-0.0003	-0.0003
6. Other	**NA**	**NO**				
Reported as memo items:						
International transports	**348.29**	**351.16**	**2.87**	**0.825**	**0.0003**	**0.0003**
International air transports	245.16	247.39	2.24	0.912	0.0003	0.0003
International sea transports	103.13	103.77	0.64	0.618	0.0001	0.0001
Multilateral operations	**NE**	**NE**				
Indirect N_2O	**NO,IE**	**NE,IE**				

Table 575: Revised HFC emissions, 2016

Hydrofluorocarbons – HFCs	Submission 2018	Submission 2019	Change		Impacts on total national emissions Without LULUCF	With LULUCF
	[kt CO_2-eq.]				[%]	
Total national emissions	**10963.59**	**11258.48**	**294.89**	**2.690**	**0.0324**	**0.0329**
2.C.4. Magnesium production	61.05	30.53	-30.53	-50.000	-0.0034	-0.0034
2.E.1. Electronics industry	15.43	IE	-15.43	-100	-0.0017	-0.0017
2.F.1. Air-conditioning and refrigeration systems	9593.77	9645.60	51.84	0.540	0.0057	0.0058
2.F.2. Foam production	631.41	899.30	267.89	42.428	0.0294	0.0299
2.F.3. Fire extinguishers	49.75	50.10	0.35	0.713	0.0000	0.0000
2.F.4. Aerosols	602.36	632.74	30.39	5.045	0.0033	0.0034
2.G.4. Other	9.83	0.20	-9.63	-97.963	-0.0011	-0.0011

Table 576: Revised PFC emissions, 2016

Poly– and perfluorocarbons – PFCs	Submission 2018	Submission 2019	Change		Impacts on total national emissions *Without LULUCF*	*With LULUCF*
	[kt CO_2-eq.]			[%]		
Total national emissions	**260.64**	**103.15**	**-157.50**	**-60.426**	**-0.0173**	**-0.0176**
2.C.3. Aluminium production	95.44	95.38	-0.07	-0.069	-0.00001	-0.00001
2.E.1. Electronics industry	157.62	IE	-157.62	-100	-0.0173	-0.0176
2.F.1. Air-conditioning and refrigeration systems	7.58	7.77	0.19	2.472	0.00002	0.00002

Table 577: Revised SF_6 emissions, 2016

Sulphur hexafluoride - SF_6	Submission 2018	Submission 2019	Change		Impacts on total national emissions *Without LULUCF*	*With LULUCF*
	[kt CO_2-eq.]			[%]		
Total national emissions	**3880.69**	**3543.52**	**-337.17**	**-8.688**	**-0.0370**	**-0.0376**
2.C.3. Aluminium production	13.50	13.45	-0.05	-0.341	-0.00001	-0.00001
2.G.2. SF_6 and PFC from other product use	3411.61	3074.49	-337.12	-9.882	-0.0370	-0.0376

Table 578: Revised *unspecified-mix* emissions, 2016

Unspecified mix of HFCs and PFCs	Submission 2018	Submission 2019	Change		Impacts on total national emissions *Without LULUCF*	*With LULUCF*
	[kt CO_2-eq.]			[%]		
Total national emissions	**184.63**	**706.86**	**522.24**	**283**	**0.0573**	**0.0582**
2.H. Other	122.81	645.05	522.24	425	0.0573	0.0582

Table 579: Revised NF_3 emissions, 2016

Nitrogen trifluoride - NF_3	Submission 2018	Submission 2019	Change		Impacts on total national emissions *Without LULUCF*	*With LULUCF*
	[kt CO_2-eq.]			[%]		
Total national emissions	**11.15**	**NO,IE**	**-11.15**	**-100**	**-0.0012**	**-0.0012**
2.E.1. Electronics industry	11.15	IE	-11.15	-100	-0.0012	-0.0012

23 Annex 7: Uncertainties by categories

The uncertainties for the German greenhouse-gas inventories have been determined completely, for all categories, for the base year in each case, for 2017 and for the trend in each case. In Germany, uncertainties are calculated, each year, pursuant to both the Tier 1 and Tier 2 methods.

The results of this year's uncertainties analysis are shown, in keeping with the specifications given in Tables 3.4 and 3.5 of the 2006 IPCC Guidelines (IPCC, 2006), in Table 580 and Table 581.

Table 580: Uncertainties by sectors (Tier 1; error propagation pursuant to Table 3.4 of the 2006 IPCC Guidelines)

A	B	C	D	E	F	G	H	I	J	K	L	M
IPCC category	Gas	Base year emissions or removals	Year *x* emissions or removals	Activity data uncertainty	Emission factor / estimation parameter uncertainty	Combined uncertainty	Contribution to Variance by Category in Year x	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		Input data	Input data	Input data Note A	Input data Note A	$\sqrt{E^2+F^2}$	$\frac{(G \cdot D)^2}{(\sum D)^2}$	Note B	$\left\|\frac{D}{\sum C}\right\|$	$I * F$ Note C	$J * E * \sqrt{2}$ Note D	$\sqrt{K^2+L^2}$
		t CO_2 equivalent	t CO_2 equivalent	%	%	%		%	%	%	%	%
1 A 1 a, Public Electricity and Heat Production	CO2	338451.16	277858.61	3.85	1.54	4.14	1.29	0.02	0.22	1.20	0.48	1.66
1 A 1 a, Public Electricity and Heat Production	CH4	172.17	2845.58	9.30	69.88	70.49	0.04	0.00	0.00	0.03	0.22	0.05
1 A 1 a, Public Electricity and Heat Production	N2O	2407.46	2309.28	3.42	20.31	20.60	0.00	0.00	0.00	0.01	0.05	0.00
1 A 1 b, Petroleum Refining	CO2	20165.56	20301.34	3.13	4.76	5.70	0.01	0.00	0.02	0.07	0.11	0.02
1 A 1 b, Petroleum Refining	CH4	16.06	15.06	2.32	17.55	17.70	0.00	0.00	0.00	0.00	0.00	0.00
1 A 1 b, Petroleum Refining	N2O	100.39	64.59	2.81	33.33	33.45	0.00	0.00	0.00	0.00	0.00	0.00
1 A 1 c, Manufacture of Solid Fuels and Other Energy	CO2	65289.06	9719.00	4.52	3.36	5.63	0.00	0.02	0.01	0.05	0.04	0.00
1 A 1 c, Manufacture of Solid Fuels and Other Energy	CH4	91.98	180.61	27.78	139.09	141.84	0.00	0.00	0.00	0.01	0.03	0.00
1 A 1 c, Manufacture of Solid Fuels and Other Energy	N2O	659.23	152.93	5.12	21.88	22.47	0.00	0.00	0.00	0.00	0.00	0.00
1 A 2 a, Iron and steel	CO2	35269.33	38437.65	5.11	3.68	6.29	0.06	0.01	0.03	0.22	0.16	0.07
1 A 2 a, Iron and steel	CH4	62.45	60.12	8.44	25.42	26.78	0.00	0.00	0.00	0.00	0.00	0.00
1 A 2 a, Iron and steel	N2O	155.10	111.58	4.61	33.85	34.16	0.00	0.00	0.00	0.00	0.00	0.00
1 A 2 b, Non-ferrous metals	CO2	1629.22	1818.52	9.88	0.99	9.93	0.00	0.00	0.00	0.02	0.00	0.00
1 A 2 b, Non-ferrous metals	CH4	1.39	2.05	9.84	61.85	62.63	0.00	0.00	0.00	0.00	0.00	0.00
1 A 2 b, Non-ferrous metals	N2O	17.14	10.60	8.28	54.31	54.94	0.00	0.00	0.00	0.00	0.00	0.00
1 A 2 d, Pulp, Paper and Print	CO2	3.65	3.88	5.22	2.24	5.68	0.00	0.00	0.00	0.00	0.00	0.00
1 A 2 d, Pulp, Paper and Print	CH4	0.65	2.64	4.27	45.78	45.98	0.00	0.00	0.00	0.00	0.00	0.00
1 A 2 d, Pulp, Paper and Print	N2O	2.81	11.33	4.27	54.93	55.10	0.00	0.00	0.00	0.00	0.00	0.00

A	B	C	D	E	F	G	H	I	J	K	L	M
1 A 2 e, Food Processing, Beverages and Tobacco	CO2	2015.91	241.97	4.45	1.49	4.69	0.00	0.00	0.00	0.00	0.00	0.00
1 A 2 e, Food Processing, Beverages and Tobacco	CH4	4.48	0.19	4.63	34.56	34.87	0.00	0.00	0.00	0.00	0.00	0.00
1 A 2 e, Food Processing, Beverages and Tobacco	N2O	24.65	2.31	4.47	50.69	50.89	0.00	0.00	0.00	0.00	0.00	0.00
1 A 2 f, Non-Metallic Minerals	CO2	18507.38	15233.50	3.30	1.22	3.52	0.00	0.00	0.01	0.06	0.02	0.00
1 A 2 f, Non-Metallic Minerals	CH4	50.28	17.31	3.06	20.72	20.95	0.00	0.00	0.00	0.00	0.00	0.00
1 A 2 f, Non-Metallic Minerals	N2O	205.26	142.49	2.66	27.88	28.01	0.00	0.00	0.00	0.00	0.00	0.00
1 A 2 g, Other	CO2	127682.07	78617.30	3.43	0.88	3.54	0.08	0.01	0.06	0.30	0.08	0.10
1 A 2 g, Other	CH4	132.30	213.15	3.07	29.22	29.38	0.00	0.00	0.00	0.00	0.01	0.00
1 A 2 g, Other	N2O	944.69	635.40	2.84	13.82	14.11	0.00	0.00	0.00	0.00	0.01	0.00
1 A 3 a, Domestic Aviation	CO2	2238.52	2056.18	7.55	3.78	8.44	0.00	0.00	0.00	0.02	0.01	0.00
1 A 3 a, Domestic Aviation	CH4	2.30	1.74	9.53	95.38	95.85	0.00	0.00	0.00	0.00	0.00	0.00
1 A 3 a, Domestic Aviation	N2O	22.33	20.45	7.38	110.71	110.95	0.00	0.00	0.00	0.00	0.00	0.00
1 A 3 b, Road Transport	CO2	151880.55	160082.89	9.23	0.79	9.26	2.14	0.02	0.13	1.65	0.14	2.76
1 A 3 b, Road Transport	CH4	1316.84	134.93	21.94	36.47	42.56	0.00	0.00	0.00	0.00	0.01	0.00
1 A 3 b, Road Transport	N2O	1113.49	1601.20	9.66	25.95	27.69	0.00	0.00	0.00	0.02	0.05	0.00
1 A 3 c, Railways	CO2	2900.52	1045.25	9.71	2.91	10.14	0.00	0.00	0.00	0.01	0.00	0.00
1 A 3 c, Railways	CH4	2.60	0.36	9.11	30.90	32.21	0.00	0.00	0.00	0.00	0.00	0.00
1 A 3 c, Railways	N2O	6.68	2.56	9.02	67.22	67.83	0.00	0.00	0.00	0.00	0.00	0.00
1 A 3 d, Domestic Navigation	CO2	3644.53	1721.28	16.54	2.22	16.69	0.00	0.00	0.00	0.03	0.00	0.00
1 A 3 d, Domestic Navigation	CH4	1.83	0.61	19.52	31.45	37.01	0.00	0.00	0.00	0.00	0.00	0.00
1 A 3 d, Domestic Navigation	N2O	34.17	17.89	7.59	119.62	119.86	0.00	0.00	0.00	0.00	0.00	0.00
1 A 3 e, Other Transportation	CO2	1083.27	1249.47	2.76	0.92	2.91	0.00	0.00	0.00	0.00	0.00	0.00
1 A 3 e, Other Transportation	CH4	5.31	6.11	2.76	69.04	69.09	0.00	0.00	0.00	0.00	0.00	0.00
1 A 3 e, Other Transportation	N2O	14.49	10.84	2.88	47.99	48.08	0.00	0.00	0.00	0.00	0.00	0.00
1 A 4 a, Commercial/Institutional	CO2	64105.89	38110.99	7.99	1.07	8.06	0.09	0.00	0.03	0.34	0.05	0.12
1 A 4 a, Commercial/Institutional	CH4	1461.53	24.16	23.61	162.19	163.90	0.00	0.00	0.00	0.00	0.00	0.00
1 A 4 a, Commercial/Institutional	N2O	145.05	85.15	6.90	94.30	94.55	0.00	0.00	0.00	0.00	0.01	0.00
1 A 4 b, Residential	CO2	128635.75	91807.53	8.44	1.26	8.54	0.60	0.01	0.07	0.87	0.13	0.77
1 A 4 b, Residential	CH4	2483.93	777.25	14.63	137.38	138.15	0.01	0.00	0.00	0.01	0.12	0.01
1 A 4 b, Residential	N2O	768.86	308.26	8.43	80.61	81.05	0.00	0.00	0.00	0.00	0.03	0.00
1 A 4 c, Agriculture/Forestry/Fishing	CO2	10270.09	6356.45	13.03	1.98	13.18	0.01	0.00	0.01	0.09	0.01	0.01
1 A 4 c, Agriculture/Forestry/Fishing	CH4	240.02	394.84	10.78	69.71	70.54	0.00	0.00	0.00	0.00	0.03	0.00
1 A 4 c, Agriculture/Forestry/Fishing	N2O	61.89	83.45	11.79	88.66	89.44	0.00	0.00	0.00	0.00	0.01	0.00
1 A 5, Other: Military	CO2	11797.50	848.42	5.69	1.50	5.89	0.00	0.00	0.00	0.01	0.00	0.00
1 A 5, Other: Military	CH4	279.43	1.51	3.70	38.50	38.68	0.00	0.00	0.00	0.00	0.00	0.00
1 A 5, Other: Military	N2O	61.33	3.10	3.09	62.94	63.01	0.00	0.00	0.00	0.00	0.00	0.00
1 B 1, Solid Fuels	CO2	1832.80	693.40	0.00	35.78	35.78	0.00	0.00	0.00	0.00	0.03	0.00
1 B 1, Solid Fuels	CH4	25553.44	2484.45	0.00	37.31	37.31	0.01	0.01	0.00	0.00	0.10	0.01
1 B 2 a, Öl	CO2	282.70	309.78	0.00	29.29	29.29	0.00	0.00	0.00	0.00	0.01	0.00
1 B 2 a, Öl	CH4	404.31	217.40	0.00	28.85	28.85	0.00	0.00	0.00	0.00	0.01	0.00

A	B	C	D	E	F	G	H	I	J	K	L	M
1 B 2 b, Gas	CO2	1407.72	1020.10	0.00	22.32	22.32	0.00	0.00	0.00	0.00	0.03	0.00
1 B 2 b, Gas	CH4	7939.92	4790.60	0.00	16.19	16.19	0.01	0.00	0.00	0.00	0.09	0.01
1 B 2 c, Venting and Flaring	CO2	543.52	380.68	0.00	127.05	127.05	0.00	0.00	0.00	0.00	0.05	0.00
1 B 2 c, Venting and Flaring	CH4	1.65	2.74	0.00	37.23	37.23	0.00	0.00	0.00	0.00	0.00	0.00
1 B 2 c, Venting and Flaring	N2O	1.06	0.13	0.00	15.30	15.30	0.00	0.00	0.00	0.00	0.00	0.00
2 A 1, Cement Production	CO2	15297.27	13408.15	2.50	2.00	3.20	0.00	0.00	0.01	0.04	0.03	0.00
2 A 2, Lime Production	CO2	5986.62	4777.29	2.39	10.60	10.87	0.00	0.00	0.00	0.01	0.06	0.00
2 A 3, Glass Production	CO2	780.48	926.84	3.10	11.06	11.48	0.00	0.00	0.00	0.00	0.01	0.00
2 A 4, Other Process Uses of Carbonates	CO2	1457.67	1088.32	6.18	13.85	15.17	0.00	0.00	0.00	0.01	0.02	0.00
2 B 1, Ammonia Production	CO2	6025.00	4228.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
2 B 2, Nitric Acid Production	N2O	3258.45	492.82	1.00	5.00	5.10	0.00	0.00	0.00	0.00	0.00	0.00
2 B 3, Adipic Acid Production	N2O	18076.68	200.86	2.00	6.00	6.32	0.00	0.01	0.00	0.00	0.00	0.00
2 B 5, Carbide Production	CO2	443.16	4.31	10.00	10.00	14.14	0.00	0.00	0.00	0.00	0.00	0.00
2 B 7, Soda Ash Production	CO2	C	C	0.00	2.50	2.50	0.00	0.00	0.00	0.00	0.00	0.00
2 B 8, Petrochemical and Carbon Black Production	CO2	973.97	885.47	11.26	13.89	17.88	0.00	0.00	0.00	0.01	0.01	0.00
2 B 8, Petrochemical and Carbon Black Production	CH4	333.69	501.68	15.85	13.68	20.94	0.00	0.00	0.00	0.01	0.01	0.00
2 B 9 a, By-product Emissions	HFC-23	C	C	0.00	3.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00
2 B 9 b, Fugitive Emissions	SF6	159.60	78.75	0.00	3.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00
2 B 9 b, Fugitive Emissions	HFC-134a	C	C	0.00	3.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00
2 B 9 b, Fugitive Emissions	HFC-227ea	C	C	0.00	3.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00
2 B 9 b, Fugitive Emissions	CF4	C	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 B 10, Other	N2O	C	C	300.00	75.00	309.23	0.00	0.00	0.00	0.02	0.01	0.00
2 C 1, Iron and Steel Production	CO2	22810.29	18060.12	0.00	8.19	8.19	0.02	0.00	0.01	0.00	0.17	0.03
2 C 1, Iron and Steel Production	CH4	4.67	5.29	0.00	67.26	67.26	0.00	0.00	0.00	0.00	0.00	0.00
2 C 1, Iron and Steel Production	N2O	26.54	15.55	7.61	63.37	63.82	0.00	0.00	0.00	0.00	0.00	0.00
2 C 2, Ferroalloys Production	CO2	429.00	6.07	50.00	7.00	50.49	0.00	0.00	0.00	0.00	0.00	0.00
2 C 2, Ferroalloys Production	CH4	8.58	1.65	50.00	50.00	70.71	0.00	0.00	0.00	0.00	0.00	0.00
2 C 3, Aluminium Production	CO2	1011.92	751.84	1.00	50.00	50.01	0.00	0.00	0.00	0.00	0.04	0.00
2 C 3, Aluminium Production	SF6	11.40	10.74	0.00	50.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00
2 C 3, Aluminium Production	CF4	1544.51	70.15	0.00	15.00	15.00	0.00	0.00	0.00	0.00	0.00	0.00
2 C 3, Aluminium Production	C2F6	256.20	14.02	0.00	15.03	15.03	0.00	0.00	0.00	0.00	0.00	0.00
2 C 4, Magnesium Production	SF6	176.63	86.00	0.00	30.04	30.04	0.00	0.00	0.00	0.00	0.00	0.00
2 C 4, Magnesium Production	HFC-134a	0.00	25.76	0.00	35.00	35.00	0.00	0.00	0.00	0.00	0.00	0.00
2 C 5, Lead Production	CO2	157.87	77.20	5.10	36.42	36.78	0.00	0.00	0.00	0.00	0.00	0.00
2 C 6, Zinc Production	CO2	670.80	302.51	0.00	41.07	41.07	0.00	0.00	0.00	0.00	0.01	0.00

A	B	C	D	E	F	G	H	I	J	K	L	M
2 D 1, Lubricant Use	CO2	188.10	215.43	0.00	33.32	33.32	0.00	0.00	0.00	0.00	0.01	0.00
2 D 2, Paraffin Wax Use	CO2	248.40	564.03	20.00	50.00	53.85	0.00	0.00	0.00	0.01	0.03	0.00
2 D 2, Paraffin Wax Use	N2O	0.61	1.38	20.00	50.00	53.85	0.00	0.00	0.00	0.00	0.00	0.00
2 D 3, Other	CO2	2552.00	1372.53	0.00	7.43	7.43	0.00	0.00	0.00	0.00	0.01	0.00
2 E, Electronics Industry	SF6	47.28	21.98	0.00	17.00	17.00	0.00	0.00	0.00	0.00	0.00	0.00
2 E, Electronics Industry	NF3	C	C	0.00	17.00	17.00	0.00	0.00	0.00	0.00	0.00	0.00
2 E, Electronics Industry	HFC-23	C	C	0.00	17.00	17.00	0.00	0.00	0.00	0.00	0.00	0.00
2 E, Electronics Industry	HFC-32	C	C	0.00	17.00	17.00	0.00	0.00	0.00	0.00	0.00	0.00
2 E, Electronics Industry	CF4	C	C	0.00	13.74	13.74	0.00	0.00	0.00	0.00	0.00	0.00
2 E, Electronics Industry	C2F6	C	C	0.00	17.00	17.00	0.00	0.00	0.00	0.00	0.00	0.00
2 E, Electronics Industry	C3F8	C	C	0.00	17.00	17.00	0.00	0.00	0.00	0.00	0.00	0.00
2 E, Electronics Industry	c-C4F8	C	C	0.00	17.00	17.00	0.00	0.00	0.00	0.00	0.00	0.00
2 E, Electronics Industry	C6F14	C	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2 F, Product Uses as Substitutes for ODS	HFC-23	C	C	0.00	12.71	12.71	0.00	0.00	0.00	0.00	0.00	0.00
2 F, Product Uses as Substitutes for ODS	HFC-32	C	C	0.00	7.69	7.69	0.00	0.00	0.00	0.00	0.00	0.00
2 F, Product Uses as Substitutes for ODS	HFC-43-10mee	C	C	0.00	2.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00
2 F, Product Uses as Substitutes for ODS	HFC-125	C	C	0.00	7.13	7.13	0.00	0.00	0.00	0.00	0.02	0.00
2 F, Product Uses as Substitutes for ODS	HFC-134a	C	C	0.00	5.55	5.55	0.00	0.00	0.00	0.00	0.04	0.00
2 F, Product Uses as Substitutes for ODS	HFC-152a	C	C	0.00	2.62	2.62	0.00	0.00	0.00	0.00	0.00	0.00
2 F, Product Uses as Substitutes for ODS	HFC-143a	C	C	0.00	9.41	9.41	0.00	0.00	0.00	0.00	0.02	0.00
2 F, Product Uses as Substitutes for ODS	HFC-227ea	C	C	0.00	6.65	6.65	0.00	0.00	0.00	0.00	0.00	0.00
2 F, Product Uses as Substitutes for ODS	HFC-236fa	C	C	0.00	9.42	9.42	0.00	0.00	0.00	0.00	0.00	0.00
2 F, Product Uses as Substitutes for ODS	HFC-245fa	C	C	0.00	9.25	9.25	0.00	0.00	0.00	0.00	0.00	0.00
2 F, Product Uses as Substitutes for ODS	HFC-365mfc	C	C	0.00	8.84	8.84	0.00	0.00	0.00	0.00	0.00	0.00
2 F, Product Uses as Substitutes for ODS	C2F6	0.00	2.38	0.00	22.63	22.63	0.00	0.00	0.00	0.00	0.00	0.00
2 F, Product Uses as Substitutes for ODS	C3F8	19.91	3.57	0.00	19.17	19.17	0.00	0.00	0.00	0.00	0.00	0.00
2 F, Product Uses as Substitutes for ODS	C6F14	C	C	0.00	20.00	20.00	0.00	0.00	0.00	0.00	0.00	0.00

A	B	C	D	E	F	G	H	I	J	K	L	M
2 G, Other Product Manufacture and Use	CH4	4.53	33.28	20.00	20.00	28.28	0.00	0.00	0.00	0.00	0.00	0.00
2 G, Other Product Manufacture and Use	N2O	C	C	0.00	40.22	40.22	0.00	0.00	0.00	0.00	0.01	0.00
2 G, Other Product Manufacture and Use	SF6	C	C	0.00	8.56	8.56	0.00	0.00	0.00	0.00	0.04	0.00
2 G, Other Product Manufacture and Use	HFC-134a	C	C	0.00	22.36	22.36	0.00	0.00	0.00	0.00	0.00	0.00
2 G, Other Product Manufacture and Use	HFC-245fa	C	C	0.00	21.90	21.90	0.00	0.00	0.00	0.00	0.00	0.00
2 G, Other Product Manufacture and Use	HFC-365mfc	C	C	0.00	22.30	22.30	0.00	0.00	0.00	0.00	0.00	0.00
2 G, Other Product Manufacture and Use	C10F18	C	C	0.00	24.94	24.94	0.00	0.00	0.00	0.00	0.00	0.00
3 A, Enteric Fermentation	CH4	19074.71	14337.51	4.00	20.00	20.40	0.08	0.00	0.01	0.06	0.32	0.11
3 A, Enteric Fermentation	CH4	14866.45	10042.41	2.48	12.40	12.64	0.02	0.00	0.01	0.03	0.14	0.02
3 A, Enteric Fermentation	CH4	1411.78	1155.73	3.46	12.37	12.84	0.00	0.00	0.00	0.00	0.02	0.00
3 B, Manure Management	CH4	2640.57	2209.96	4.00	20.00	20.40	0.00	0.00	0.00	0.01	0.05	0.00
3 B, Manure Management	CH4	2623.80	1514.40	2.32	11.60	11.83	0.00	0.00	0.00	0.00	0.02	0.00
3 B, Manure Management	CH4	2684.67	2370.33	3.20	15.99	16.31	0.00	0.00	0.00	0.01	0.04	0.00
3 B, Manure Management	CH4	151.19	196.08	4.65	10.19	11.20	0.00	0.00	0.00	0.00	0.00	0.00
3 B, Manure Management	N2O	1028.51	746.05	4.00	100.00	100.08	0.01	0.00	0.00	0.00	0.08	0.01
3 B, Manure Management	N2O	1113.83	818.54	2.16	53.96	54.00	0.00	0.00	0.00	0.00	0.05	0.00
3 B, Manure Management	N2O	376.40	494.29	3.11	77.86	77.92	0.00	0.00	0.00	0.00	0.04	0.00
3 B, Manure Management	N2O	127.70	138.91	4.85	48.38	48.62	0.00	0.00	0.00	0.00	0.01	0.00
3 B, Manure Management	N2O	1256.90	1051.73	40.00	400.00	402.00	0.17	0.00	0.00	0.05	0.47	0.22
3 D, Agricultural Soils	N2O	28654.99	26648.35	26.37	87.00	90.91	5.72	0.01	0.02	0.79	2.60	7.36
3 G, Liming	CO2	2200.79	1939.18	4.12	2.91	5.05	0.00	0.00	0.00	0.01	0.01	0.00
3 H, Urea Application	CO2	479.60	768.75	1.00	1.00	1.41	0.00	0.00	0.00	0.00	0.00	0.00
3 I, Other Carbon-containing Fertilizers	CO2	503.22	216.07	3.00	3.00	4.24	0.00	0.00	0.00	0.00	0.00	0.00
3 J, Other	CH4	0.27	1357.94	10.00	40.00	41.23	0.00	0.00	0.00	0.02	0.06	0.00
3 J, Other	N2O	0.12	266.68	9.52	97.10	97.57	0.00	0.00	0.00	0.00	0.03	0.00
4 A, Forest Land	CO2	-75542.09	-57760.15	0.00	41.41	41.41	5.57	0.00	0.05	0.00	3.07	9.41
4 A, Forest Land	CH4	20.08	19.48	0.00	708.17	708.17	0.00	0.00	0.00	0.00	0.02	0.00
4 A, Forest Land	N2O	265.70	150.06	0.00	116.24	116.24	0.00	0.00	0.00	0.00	0.02	0.00
4 B, Cropland	CO2	12436.44	14506.31	0.00	28.55	28.55	0.17	0.00	0.01	0.00	0.46	0.22
4 B, Cropland	CH4	195.96	249.17	0.00	175.27	175.27	0.00	0.00	0.00	0.00	0.05	0.00
4 B, Cropland	N2O	312.32	359.85	0.00	179.86	179.86	0.00	0.00	0.00	0.00	0.07	0.01
4 C, Grassland	CO2	25543.59	21935.06	0.00	43.38	43.38	0.88	0.00	0.02	0.00	1.37	1.88
4 C, Grassland	CH4	593.83	507.28	0.00	240.37	240.37	0.01	0.00	0.00	0.00	0.14	0.02
4 C, Grassland	N2O	87.80	105.65	0.00	169.88	169.88	0.00	0.00	0.00	0.00	0.02	0.00

A	B	C	D	E	F	G	H	I	J	K	L	M
4 D, Wetlands	CO2	4063.95	3968.72	0.00	29.00	29.00	0.01	0.00	0.00	0.00	0,13	0,02
4 D, Wetlands	CH4	41.76	43.77	0.00	465.05	465.05	0.00	0.00	0.00	0.00	0,02	0,00
4 D, Wetlands	N2O	21.56	22.63	0.00	155.65	155.65	0.00	0.00	0.00	0.00	0,00	0,00
4 E, Settlements	CO2	1810.65	3472.35	0.00	16.89	16.89	0.00	0.00	0.00	0.00	0,10	0,01
4 E, Settlements	CH4	24.02	45.13	0.00	148.00	148.00	0.00	0.00	0.00	0.00	0,01	0,00
4 E, Settlements	N2O	143.05	226.15	0.00	99.56	99.56	0.00	0.00	0.00	0.00	0,03	0,00
4 G, Harvested Wood Products	CO2	-1330.35	-3036.67	0.00	26.80	26.80	0.01	0.00	0.01	0.00	0,24	0,06
5 A, Solid Waste Disposal	CH4	34250.00	8075.00	0.00	50.00	50.00	0.16	0.02	0.01	0.00	0,45	0,20
5 B, Biological Treatment of Solid Waste	CH4	25.34	708.56	1.42	203.41	203.41	0.02	0.00	0.00	0.00	0,16	0,03
5 B, Biological Treatment of Solid Waste	N2O	15.97	310.42	1.47	161.82	161.83	0.00	0.00	0.00	0.00	0,06	0,00
5 D 2, Industrial Wastewater	CH4	9.25	44.74	0.00	50.00	50.00	0.00	0.00	0.00	0.00	0,00	0,00
5 D 2, Industrial Wastewater	N2O	31.59	25.11	50.00	300.00	304.14	0.00	0.00	0.00	0.00	0,01	0,00
5 D 1, Domestic Wastewater	CH4	2629.71	514.58	0.00	24.22	24.22	0.00	0.00	0.00	0.00	0,01	0,00
5 D 1, Domestic Wastewater	N2O	1389.87	429.65	33.19	3884.38	3884.52	2.71	0.00	0.00	0.02	1,87	3,49
5 E, Other	CH4	0.00	4.04	2.00	60.00	60.03	0.00	0.00	0.00	0.00	0,00	0,00
5 E, Other	N2O	0.00	69.41	2.00	60.00	60.03	0.00	0.00	0.00	0.00	0,00	0,00
Total	$\sum C$	1223365.73	$\sum D$ 891426.25			$\sum H$	**19.97**				$\sum M$	**28,73**
				Percentage uncertainty in total inventory:		$\sqrt{\sum H}$	4.47			**Trend uncertainty:**	$\sqrt{\sum M}$	**5.36**

Table 581: Uncertainties by sectors (Tier 2; Monte Carlo simulation pursuant to Table 3.5 of the 2006 IPCC Guidelines)

A		B	C	D	E		F		G		H	I	J	
Category			Base year emissions or removals	Emissions or removals 2016	Activity data uncertainty		Emission factor uncertainty		Combined uncertainty		Contribution to variance 2016	Inventory trend in nationalemissions for 2016 increase with respect to base year	Uncertainty introduced into the trend in total national emissions with respect to base year	
1	2	gas	t CO2 equivalent	t CO2 equivalent	-%	+%	-%	+%	-%	+%	fraction	% of base year	-%	+%
1 A 1 a, Public Electricity and Heat Production	fossil fuels	CO2	338451.16	277858.61	3.83	3.94	1.11	1.13	3.97	4.09	0.08	-17.90	62.91	67.12
1 A 1 a, Public Electricity and Heat Production		CH4	172.17	2845.58	9.26	11.01	28.79	51.63	32.89	51.79	0.00	1552.79	49.58	73.64
1 A 1 a, Public Electricity and Heat Production		N2O	2407.46	2309.28	3.39	3.48	20.40	20.26	23.37	23.81	0.00	-4.08	301.74	416.38
1 A 1 b, Petroleum Refining	fossil fuels	CO2	20165.56	20301.34	2.96	3.06	4.75	4.74	5.56	5.76	0.00	0.67	256.76	274.47
1 A 1 b, Petroleum Refining		CH4	16.06	15.06	2.05	2.17	15.93	16.83	18.96	19.07	0.00	-6.26	922.98	1139.33
1 A 1 b, Petroleum Refining		N2O	100.39	64.59	2.63	2.76	33.45	33.32	36.34	36.75	0.00	-35.66	1594.86	2240.44

A		B	C	D	E		F		G		H	I	J	
1 A 1 c, Manufacture of Solid Fuels and Other Energy	fossil fuels	CO2	65289.06	9719.00	4.54	4.51	3.38	3.33	5.59	5.65	0.00	-85.11	2.43	2.52
1 A 1 c, Manufacture of Solid Fuels and Other Energy		CH4	91.98	180.61	21.66	26.29	56.10	100.93	58.10	108.80	0.00	96.36	212.18	426.71
1 A 1 c, Manufacture of Solid Fuels and Other Energy		N2O	659.23	152.93	4.96	5.12	21.81	21.95	26.09	26.64	0.00	-76.80	23.49	28.69
1 A 2 a, Iron and steel	fossil fuels	CO2	35269.33	38437.65	4.79	5.13	3.73	3.74	5.87	6.29	0.00	8.98	51.64	55.66
1 A 2 a, Iron and steel		CH4	62.45	60.12	5.01	5.23	25.54	25.42	25.88	25.99	0.00	-3.73	11374.46	15381.43
1 A 2 a, Iron and steel		N2O	155.10	111.58	2.92	3.07	33.79	33.91	36.53	36.99	0.00	-28.06	8470.65	13220.74
1 A 2 b, Non-ferrous metals	fossil fuels	CO2	1629.22	1818.52	7.44	7.96	0.88	0.85	7.50	8.06	0.00	11.62	71.42	76.43
1 A 2 b, Non-ferrous metals		CH4	1.39	2.05	7.41	7.85	62.24	61.45	63.08	63.52	0.00	47.53	267.34	562.80
1 A 2 b, Non-ferrous metals		N2O	17.14	10.60	6.33	6.69	54.28	54.41	59.35	59.62	0.00	-38.14	314.09	538.31
1 A 2 d, Pulp, Paper and Print	fossil fuels	CO2	3.65	3.88	5.16	5.20	2.21	2.23	5.58	5.63	0.00	6.39	10.14	10.68
1 A 2 d, Pulp, Paper and Print		CH4	0.65	2.64	4.24	4.30	45.63	45.80	51.36	51.61	0.00	303.73	93.74	130.23
1 A 2 d, Pulp, Paper and Print		N2O	2.81	11.33	4.26	4.31	8.33	8.61	9.31	9.63	0.00	303.73	20.55	22.04
1 A 2 e, Food Processing, Beverages and Tobacco	fossil fuels	CO2	2015.91	241.97	3.05	3.20	1.25	1.20	3.35	3.46	0.00	-88.00	0.71	0.73
1 A 2 e, Food Processing, Beverages and Tobacco		CH4	4.48	0.19	3.47	3.70	34.50	34.61	36.79	37.03	0.00	-95.67	5.41	8.85
1 A 2 e, Food Processing, Beverages and Tobacco		N2O	24.65	2.31	3.04	3.19	33.96	41.91	40.35	44.22	0.00	-90.61	8.55	15.69
1 A 2 f, Non-Metallic Minerals	fossil fuels	CO2	18507.38	15233.50	2.44	2.57	1.16	1.15	2.72	2.78	0.00	-17.69	20.44	20.85
1 A 2 f, Non-Metallic Minerals		CH4	50.28	17.31	2.31	2.44	20.59	20.74	24.17	24.20	0.00	-65.57	1905.80	2570.33
1 A 2 f, Non-Metallic Minerals		N2O	205.26	142.49	2.00	2.09	19.06	22.55	22.72	24.05	0.00	-30.58	202.32	308.55
1 A 2 g, Other	fossil fuels	CO2	127682.07	78617.30	2.73	2.89	0.86	0.86	2.90	2.98	0.00	-38.43	29.93	31.24
1 A 2 g, Other		CH4	132.30	213.15	2.63	2.79	14.95	22.85	18.04	22.03	0.00	61.11	71.47	86.24
1 A 2 g, Other		N2O	944.69	635.40	2.68	2.71	10.36	11.15	12.51	12.84	0.00	-32.74	704.56	791.23
1 A 3 a, Domestic Aviation	fossil fuels	CO2	2238.52	2056.18	7.56	7.52	3.81	3.81	8.37	8.43	0.00	-8.15	117.85	127.32
1 A 3 a, Domestic Aviation		CH4	2.30	1.74	9.57	9.69	54.37	96.61	54.59	97.95	0.00	-24.18	733.77	1512.99
1 A 3 a, Domestic Aviation		N2O	22.33	20.45	7.41	7.45	51.84	110.14	57.55	108.45	0.00	-8.38	1365.12	3003.95
1 A 3 b, Road Transport	fossil fuels	CO2	151880.55	160082.89	9.21	9.17	0.79	0.79	9.33	9.19	0.14	5.40	333.64	367.37
1 A 3 b, Road Transport		CH4	1316.84	134.93	22.02	22.06	27.97	37.26	34.52	45.93	0.00	-89.75	11.95	18.02
1 A 3 b, Road Transport		N2O	1113.49	1601.20	9.64	9.64	16.95	26.23	21.19	26.26	0.00	43.80	2301.02	3087.44
1 A 3 c, Railways	fossil fuels	CO2	2900.52	1045.25	9.87	9.77	2.87	2.86	10.12	10.13	0.00	-63.96	11.19	12.47
1 A 3 c, Railways		CH4	2.60	0.36	9.08	9.17	30.70	31.01	31.55	32.72	0.00	-85.97	9.84	14.74
1 A 3 c, Railways		N2O	6.68	2.56	9.16	9.19	38.57	56.49	39.02	57.45	0.00	-61.68	56.50	92.82
1 A 3 d, Domestic Navigation	fossil fuels	CO2	3644.53	1721.28	16.55	16.65	2.24	2.21	16.67	16.91	0.00	-52.77	40.59	53.93
1 A 3 d, Domestic Navigation		CH4	1.83	0.61	19.30	19.65	31.42	31.18	36.16	38.10	0.00	-66.76	38.19	57.73
1 A 3 d, Domestic Navigation		N2O	34.17	17.89	7.52	7.65	34.27	48.97	35.87	49.07	0.00	-47.64	118.43	176.04

A		B	C	D	E		F		G		H	I	J	
1 A 3 e, Other Transportation	fossil fuels	CO2	1083.27	1249.47	1.03	1.53	0.92	0.91	1.47	1.76	0.00	15.34	33.62	36.15
1 A 3 e, Other Transportation		CH4	5.31	6.11	1.04	1.52	39.31	57.95	39.36	58.00	0.00	15.03	1957.38	3006.62
1 A 3 e, Other Transportation		N2O	14.49	10.84	1.08	1.58	47.95	48.01	47.99	47.98	0.00	-25.20	102.42	167.46
1 A 4 a, Commercial/Institutional	fossil fuels	CO2	64105.89	38110.99	5.51	5.92	0.90	0.91	5.67	5.89	0.00	-40.55	21.70	22.82
1 A 4 a, Commercial/Institutional		CH4	1461.53	24.16	24.26	24.08	62.19	91.48	44.32	68.13	0.00	-98.35	7.77	14.36
1 A 4 a, Commercial/Institutional		N2O	145.05	85.15	5.43	5.88	43.05	57.83	35.12	41.44	0.00	-41.30	51.01	72.04
1 A 4 b, Residential	fossil fuels	CO2	128635.75	91807.53	6.09	6.29	1.04	1.04	6.18	6.41	0.02	-28.63	22.15	24.25
1 A 4 b, Residential		CH4	2483.93	777.25	11.69	13.37	56.53	79.42	40.04	57.23	0.00	-68.71	475.00	764.72
1 A 4 b, Residential		N2O	768.86	308.26	6.60	7.21	37.83	48.97	32.18	37.58	0.00	-59.91	88.87	126.30
1 A 4 c, Agriculture/Forestry/Fishing	fossil fuels	CO2	10270.09	6356.45	13.08	12.98	1.96	1.94	13.19	13.17	0.00	-38.11	72.98	80.03
1 A 4 c, Agriculture/Forestry/Fishing		CH4	240.02	394.84	10.57	10.85	38.68	56.84	39.35	58.83	0.00	64.50	57.08	88.33
1 A 4 c, Agriculture/Forestry/Fishing		N2O	61.89	83.45	11.48	11.44	27.05	41.90	30.80	42.31	0.00	34.82	114.35	168.17
1 A 5, Other: Military	fossil fuels	CO2	11797.50	848.42	3.67	3.84	1.24	1.23	3.93	4.04	0.00	-92.81	1.35	1.41
1 A 5, Other: Military		CH4	279.43	1.51	3.65	3.68	37.21	37.98	37.38	38.17	0.00	-99.46	5.79	8.79
1 A 5, Other: Military		N2O	61.33	3.10	2.58	2.65	28.35	48.41	29.79	44.37	0.00	-94.95	6.48	9.09
1 B 1, Solid Fuels	fossil fuels	CO2	1832.80	693.40	1.26	1.27	20.98	20.71	35.88	36.16	0.00	-62.17	146.55	218.27
1 B 1, Solid Fuels		CH4	25553.44	2484.45	0.10	0.10	1.20	1.19	36.32	37.49	0.00	-90.28	6.48	9.22
1 B 2 a, Öl		CO2	282.70	309.78	20.56	20.53	20.77	20.92	30.34	36.71	0.00	9.58	331.63	468.07
1 B 2 a, Öl		CH4	404.31	217.40	0.68	0.67	1.35	1.37	28.74	28.89	0.00	-46.23	76.92	92.18
1 B 2 b, Gas		CO2	1407.72	1020.10	0.02	0.02	0.01	0.01	22.23	22.42	0.00	-27.54	46.17	60.26
1 B 2 b, Gas		CH4	7939.92	4790.60	12.31	12.38	12.76	12.87	20.35	24.52	0.00	-39.66	25.98	31.62
1 B 2 c, Venting and Flaring		CO2	543.52	380.68	0.00	0.00	0.00	0.00	16.81	16.87	0.00	-29.96	165.95	198.72
1 B 2 c, Venting and Flaring		CH4	1.65	2.74	0.00	0.00	0.00	0.00	25.33	25.42	0.00	65.92	105.15	141.69
1 B 2 c, Venting and Flaring		N2O	1.06	0.13	0.00	0.00	0.00	0.00	15.30	15.29	0.00	-87.48	6.66	7.85
2 A 1, Cement Production		CO2	15297.27	13408.15	2.50	2.49	2.02	2.01	3.16	3.22	0.00	-12.35	27.38	28.72
2 A 2, Lime Production		CO2	5986.62	4777.29	2.41	2.39	6.61	5.32	7.14	6.12	0.00	-20.20	32.75	35.29
2 A 3, Glass Production		CO2	780.48	926.84	3.11	3.11	11.05	11.02	11.45	11.48	0.00	18.75	288.98	313.76
2 A 4, Other Process Uses of Carbonates		CO2	1457.67	1088.32	4.99	4.88	13.77	13.72	14.47	14.89	0.00	-25.34	28.18	33.30
2 B 1, Ammonia Production		CO2	6025.00	4228.00	0.00	0.00	0.00	0.00	1.01	0.99	0.00	-29.83	2.57	2.64
2 B 2, Nitric Acid Production		N2O	3258.45	492.82	1.00	1.01	5.02	5.02	5.10	5.11	0.00	-84.88	1.21	1.28
2 B 3, Adipic Acid Production		N2O	18076.68	200.86	2.02	2.05	5.96	5.96	6.32	6.32	0.00	-98.89	0.09	0.09
2 B 5, Carbide Production		CO2	443.16	4.31	10.08	10.09	10.07	9.96	13.93	14.48	0.00	-99.03	3.70	4.33

A		B	C	D	E		F		G		H	I	J	
2 B 7, Soda Ash Production		CO2	C	C	0.00	0.00	0.00	0.00	2.51	2.51	0.00	-31.04	20.94	21.39
2 B 8, Petrochemical and Carbon Black Production		CO2	973.97	885.47	11.19	11.49	13.84	13.69	17.20	18.63	0.00	-9.09	1082.17	1322.66
2 B 8, Petrochemical and Carbon Black Production		CH4	333.69	501.68	15.82	15.79	13.62	13.59	20.55	21.43	0.00	50.34	177.03	227.11
2 B 9 a, By-product Emissions		HFC-23	C	C	0.00	0.00	0.00	0.00	2.99	2.96	0.00	-99.96	0.00	0.00
2 B 9 b, Fugitive Emissions		SF6	159.60	78.75	0.00	0.00	0.00	0.00	2.97	2.97	0.00	-50.66	4.06	4.22
2 B 9 b, Fugitive Emissions		HFC-134a	C	C	0.00	0.00	0.00	0.00	3.00	2.97	0.00	107.03	8.12	8.35
2 B 9 b, Fugitive Emissions		HFC-227ea	C	C	0.00	0.00	0.00	0.00	3.05	3.01	0.00			
2 B 9 b, Fugitive Emissions		CF4	C	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
2 B 10, Other		N2O	C	C	302.79	302.76	74.51	75.34	312.21	370.75	0.00	0.00	16940.73	15683.57
2 C 1, Iron and Steel Production		CO2	22810.29	18060.12	6.40	6.49	5.07	5.02	8.14	8.42	0.00	-20.82	173.05	189.30
2 C 1, Iron and Steel Production		CH4	4.67	5.29	0.13	0.13	10.13	10.40	66.34	66.11	0.00	13.40	356.49	664.04
2 C 1, Iron and Steel Production		N2O	26.54	15.55	7.59	7.54	63.65	63.39	65.90	66.85	0.00	-41.43	675.02	1651.98
2 C 2, Ferroalloys Production		CO2	429.00	6.07	50.28	50.17	6.99	7.01	50.60	50.06	0.00	-98.59	155.34	277.09
2 C 2, Ferroalloys Production		CH4	8.58	1.65	50.31	50.23	49.72	50.07	62.27	80.05	0.00	-80.72	266.72	606.10
2 C 3, Aluminium Production		CO2	1011.92	751.84	0.99	0.99	50.12	49.81	50.13	49.66	0.00	-25.70	1828.16	3349.58
2 C 3, Aluminium Production		SF6	11.40	10.74	0.00	0.00	0.00	0.00	50.12	50.48	0.00	-5.76	2516.91	4433.10
2 C 3, Aluminium Production		CF4	1544.51	70.15	0.00	0.00	0.00	0.00	15.13	14.97	0.00	-95.46	0.94	1.10
2 C 3, Aluminium Production		C2F6	256.20	14.02	0.00	0.00	0.00	0.00	15.11	14.86	0.00	-94.53	1.16	1.35
2 C 4, Magnesium Production		SF6	176.63	86.00	0.00	0.00	0.00	0.00	17.26	10.95	0.00	-51.31	20.56	24.58
2 C 4, Magnesium Production		HFC-134a	0.00	25.76	0.00	0.00	0.00	0.00	20.72	12.88	0.00			
2 C 5, Lead Production		CO2	157.87	77.20	4.13	4.28	36.40	36.58	36.19	37.01	0.00	-51.10	97.45	143.60
2 C 6, Zinc Production		CO2	670.80	302.51	0.00	0.00	0.00	0.00	41.19	41.19	0.00	-54.90	52.08	78.91
2 D 1, Lubricant Use		CO2	188.10	215.43	14.86	14.70	30.09	30.04	31.55	35.69	0.00	14.53	203.73	305.49
2 D 2, Paraffin Wax Use		CO2	248.40	564.03	19.61	19.83	50.43	50.22	51.70	56.45	0.00	127.06	134.32	238.18
2 D 2, Paraffin Wax Use		N2O	0.61	1.38	20.21	20.05	50.11	50.80	51.89	56.31	0.00	127.06	131.38	243.95
2 D 3, Other		CO2	2552.00	1372.53	2.84	2.86	1.43	1.43	7.33	7.53	0.00	-46.22	139.07	173.84
2 E, Electronics Industry		SF6	47.28	21.98	0.00	0.00	0.00	0.00	6.95	7.40	0.00	-53.51	8.45	9.13
2 E, Electronics Industry		NF3	C	C	0.00	0.00	0.00	0.00	6.96	7.27	0.00	72.66	23.16	24.65
2 E, Electronics Industry		HFC-23	C	C	0.00	0.00	0.00	0.00	7.13	7.44	0.00	-24.84	29.92	32.42
2 E, Electronics Industry		HFC-32	C	C	0.00	0.00	0.00	0.00	7.00	7.43	0.00			
2 E, Electronics Industry		CF4	C	C	0.00	0.00	0.00	0.00	6.60	6.77	0.00	-33.78	17.72	18.95
2 E, Electronics Industry		C2F6	C	C	0.00	0.00	0.00	0.00	7.08	7.40	0.00	-64.31	5.52	5.88
2 E, Electronics Industry		C3F8	C	C	0.00	0.00	0.00	0.00	7.01	7.42	0.00			
2 E, Electronics Industry		c-C4F8	C	C	0.00	0.00	0.00	0.00	6.96	7.39	0.00			
2 E, Electronics Industry		C6F14	C	C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-100.00		

A	B	C	D	E		F		G		H	I	J	
2 F, Product Uses as Substitutes for ODS	HFC-23	C	C	0.00	0.00	0.00	0.00	12.84	12.68	0.00	395.39	24.54	29.79
2 F, Product Uses as Substitutes for ODS	HFC-32	C	C	0.00	0.00	0.00	0.00	7.75	7.77	0.00	21780.72	13.53	15.60
2 F, Product Uses as Substitutes for ODS	HFC-43-10mee	C	C	0.00	0.00	0.00	0.00	2.00	1.99	0.00			
2 F, Product Uses as Substitutes for ODS	HFC-125	C	C	0.00	0.00	0.00	0.00	7.17	7.07	0.00	1417.60	17.04	21.04
2 F, Product Uses as Substitutes for ODS	HFC-134a	C	C	0.00	0.00	0.00	0.00	5.51	5.49	0.00	167.24	15.71	17.37
2 F, Product Uses as Substitutes for ODS	HFC-152a	C	C	0.00	0.00	0.00	0.00	2.63	2.62	0.00	-60.06	7.68	9.21
2 F, Product Uses as Substitutes for ODS	HFC-143a	C	C	0.00	0.00	0.00	0.00	9.41	9.40	0.00	2481.74	13.76	15.30
2 F, Product Uses as Substitutes for ODS	HFC-227ea	C	C	0.00	0.00	0.00	0.00	6.62	6.61	0.00	15716.89	18.60	24.36
2 F, Product Uses as Substitutes for ODS	HFC-236fa	C	C	0.00	0.00	0.00	0.00	9.36	9.33	0.00			
2 F, Product Uses as Substitutes for ODS	HFC-245fa	C	C	0.00	0.00	0.00	0.00	9.31	9.15	0.00			
2 F, Product Uses as Substitutes for ODS	HFC-365mfc	C	C	0.00	0.00	0.00	0.00	8.75	8.88	0.00			
2 F, Product Uses as Substitutes for ODS	C2F6	0.00	2.38	0.00	0.00	0.00	0.00	22.59	22.42	0.00			
2 F, Product Uses as Substitutes for ODS	C3F8	19.91	3.57	0.00	0.00	0.00	0.00	19.15	19.54	0.00	-82.05	6.02	8.09
2 F, Product Uses as Substitutes for ODS	C6F14	C	C	0.00	0.00	0.00	0.00	20.30	19.95	0.00	#ZAHL!		
2 G, Other Product Manufacture and Use	CH4	4.53	33.28	20.20	20.34	19.80	20.09	27.11	29.73	0.00	634.90	52.97	70.26
2 G, Other Product Manufacture and Use	N2O	C	C	0.39	0.39	0.13	0.12	40.16	40.43	0.00	-83.59	14.19	24.10
2 G, Other Product Manufacture and Use	SF6	C	C	0.00	0.00	0.00	0.00	8.57	8.54	0.00	-37.20	17.22	18.31
2 G, Other Product Manufacture and Use	HFC-134a	C	C	0.00	0.00	0.00	0.00	22.26	22.71	0.00			
2 G, Other Product Manufacture and Use	HFC-245fa	C	C	0.00	0.00	0.00	0.00	21.69	21.75	0.00			
2 G, Other Product Manufacture and Use	HFC-365mfc	C	C	0.00	0.00	0.00	0.00	21.98	21.54	0.00			
2 G, Other Product Manufacture and Use	C10F18	C	C	0.00	0.00	0.00	0.00	24.53	25.11	0.00			

A		B	C	D	E		F		G		H	I	J	
3 A, Enteric Fermentation	diary cows	CH4	19074.71	14337.51	3.99	4.04	20.05	20.09	20.18	20.47	0.01	-24.83	212.52	263.37
3 A, Enteric Fermentation	non-diary cattle	CH4	14866.45	10042.41	2.47	2.47	12.40	12.43	12.60	12.72	0.00	-32.45	71.90	82.20
3 A, Enteric Fermentation	other animals	CH4	1411.78	1155.73	3.46	3.48	12.31	12.32	12.71	13.00	0.00	-18.14	161.10	190.16
3 B, Manure Management	diary cows	CH4	2640.57	2209.96	3.96	4.01	20.01	20.06	20.12	20.43	0.00	-16.31	108.09	135.12
3 B, Manure Management	non-diary cattle	CH4	2623.80	1514.40	2.31	2.32	11.63	11.40	11.87	11.95	0.00	-42.28	37.58	42.84
3 B, Manure Management	swine	CH4	2684.67	2370.33	3.21	3.20	15.96	15.92	16.34	16.16	0.00	-11.71	326.83	379.59
3 B, Manure Management	other animals	CH4	151.19	196.08	4.64	4.62	10.26	10.19	11.06	11.56	0.00	29.69	73.80	85.08
3 B, Manure Management	diary cows	N2O	1028.51	746.05	4.03	3.98	49.83	80.22	49.94	80.50	0.00	-27.46	634.31	1234.77
3 B, Manure Management	non-diary cattle	N2O	1113.83	818.54	2.16	2.16	26.91	42.44	30.17	39.77	0.00	-26.51	270.64	383.23
3 B, Manure Management	swine	N2O	376.40	494.29	3.09	3.10	38.99	60.79	39.99	60.46	0.00	31.32	153.77	255.62
3 B, Manure Management	other animals	N2O	127.70	138.91	4.85	4.86	24.09	37.96	27.13	36.30	0.00	8.78	1209.91	1664.68
3 B, Manure Management	deposition	N2O	1256.90	1051.73	39.49	39.70	80.08	203.57	81.79	213.81	0.00	-16.32	226.10	815.37
3 D, Agricultural Soils		N2O	28654.99	26648.35	12.76	23.51	30.14	73.18	41.81	74.47	0.18	-7.00	407.86	725.89
3 G, Liming		CO2	2200.79	1939.18	4.15	4.17	2.89	2.88	5.03	5.01	0.00	-11.89	47.44	58.06
3 H, Urea Application		CO2	479.60	768.75	1.01	1.01	1.01	1.03	1.40	1.43	0.00	60.29	5.26	5.37
3 I, Other Carbon-containing Fertilizers		CO2	503.22	216.07	2.99	3.02	3.02	2.99	4.22	4.30	0.00	-57.06	6.59	6.96
3 J, Other		CH4	0.27	1357.94	9.91	9.88	40.46	39.80	40.96	41.62	0.00	500718.99	49.93	77.67
3 J, Other		N2O	0.12	266.68	9.39	9.41	48.45	77.35	49.46	78.32	0.00	217868.20	63.46	116.33
4 A, Forest Land		CO2	-75542.09	-57760.15	0.00	0.00	0.00	0.00	47.47	47.53	0.49	-23.54	239.04	400.78
4 A, Forest Land		CH4	20.08	19.48	0.00	0.00	0.00	0.00	76.63	275.57	0.00	-3.00	216.32	789.53
4 A, Forest Land		N2O	265.70	150.06	0.00	0.00	0.00	0.00	74.72	219.67	0.00	-43.52	2123.75	6536.80
4 B, Cropland		CO2	12436.44	14506.31	0.00	0.00	0.00	0.00	18.68	16.67	0.00	16.64	171.68	196.86
4 B, Cropland		CH4	195.96	249.17	0.00	0.00	0.00	0.00	54.49	97.32	0.00	27.16	222.86	471.09
4 B, Cropland		N2O	312.32	359.85	0.00	0.00	0.00	0.00	90.85	307.55	0.00	15.22	147.13	669.01
4 C, Grassland		CO2	25543.59	21935.06	0.00	0.00	0.00	0.00	39.97	33.08	0.04	-14.13	419.23	634.97
4 C, Grassland		CH4	593.83	507.28	0.00	0.00	0.00	0.00	44.37	67.23	0.00	-14.57	717.91	1228.77
4 C, Grassland		N2O	87.80	105.65	0.00	0.00	0.00	0.00	86.08	326.17	0.00	20.34	151.31	682.69
4 D, Wetlands		CO2	4063.95	3968.72	0.00	0.00	0.00	0.00	26.48	31.92	0.00	-2.34	884.28	1215.15
4 D, Wetlands		CH4	41.76	43.77	0.00	0.00	0.00	0.00	61.51	142.26	0.00	4.81	299.71	762.45
4 D, Wetlands		N2O	21.56	22.63	0.00	0.00	0.00	0.00	79.43	295.21	0.00	4.94	181.18	640.37
4 E, Settlements		CO2	1810.65	3472.35	0.00	0.00	0.00	0.00	19.06	19.51	0.00	91.77	59.56	78.73
4 E, Settlements		CH4	24.02	45.13	0.00	0.00	0.00	0.00	29.53	39.66	0.00	87.89	89.77	127.93
4 E, Settlements		N2O	143.05	226.15	0.00	0.00	0.00	0.00	83.08	302.05	0.00	58.10	141.39	574.70
4 G, Harvested Wood Products		CO2	-1330.35	-3036.67	0.00	0.00	0.00	0.00	73.08	71.72	0.00	128.26	553.34	642.75
5 A, Solid Waste Disposal		CH4	34250.00	8075.00	0.00	0.00	0.00	0.00	32.27	22.36	0.00	-76.42	11.71	16.62
5 B, Biological Treatment of Solid Waste		CH4	25.34	708.56	1.43	1.41	52.43	121.84	60.92	117.35	0.00	2696.21	97.76	253.34
5 B, Biological Treatment of Solid Waste		N2O	15.97	310.42	1.46	1.47	32.22	48.53	33.77	47.32	0.00	1844.28	80.60	137.88
5 D 2, Industrial Wastewater		CH4	9.25	44.74	0.00	0.00	0.00	0.00	49.50	50.17	0.00	383.61	83.49	185.07
5 D 2, Industrial Wastewater		N2O	31.59	25.11	50.09	50.74	98.06	522.83	99.91	540.09	0.00	-20.53	100.67	188.51

A	B	C	D	E		F		G		H	I	J	
5 D 1, Domestic Wastewater	CH4	2629.71	514.58	1.24	1.24	1.49	1.49	24.25	24.01	0.00	-80.43	23.84	29.86
5 D 1, Domestic Wastewater	N2O	1389.87	429.65	33.08	33.19	71.77	241.81	77.44	245.07	0.00	-69.09	3288.46	13622.24
5 E, Other	CH4	0.00	4.04	2.00	1.99	60.16	59.63	60.19	59.73	0.00		81.53	172.29
5 E, Other	N2O	0.00	69.41	2.01	2.00	60.36	60.63	60.53	60.65	0.00		112.43	536.90
Total		**1,223,365.73**	**891,426.25**					**4.28**	**4.53**	**100.00**	**-27.13**	**28.57**	**30.10**

Uncertainties for categories have been determined successively, within the framework of UBA sections' data deliveries for current emissions reporting. In addition, external experts have carried out additional uncertainties determination, in research projects, for categories for which no uncertainties information, or incomplete information, has been available to date. The results of such uncertainties analysis have been integrated within the current report.

The uncertainties in the categories Agriculture and LULUCF were estimated by experts of the Thünen Institute (TI).

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