German Greenhouse Gas Inventory 1990 - 2003

National Inventory Report 2005

Submission under the United Nations Framework Convention on Climate Change

Federal Environmental Agency
(Umweltbundesamt)

Berlin, April 2005

Contact

This report is the result of work by the Federal Environmental Agency (UBA) to develop the *National System of Emissions Inventories* (NaSE) and the *Quality System for Emissions Inventories* (QSE). The information on agriculture, land use changes and forestry was provided by the Federal Ministry of Consumer Protection, Food and Agriculture (BMVEL) and the Federal Agricultural Research Institute *(Bundesforschungsanstalt für Landwirtschaft, FAL)*.

The electronic version of this report, along with the pertinent emissions data in the Common Reporting Format (CRF), is available on the Website of the Federal Environmental Agency:

http://www.umweltbundesamt.de/

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Imprint

Published by: Umweltbundesamt (*Federal Environmental Agency*), Bismarckplatz 1, 14193 Berlin, Germany

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List of abbreviations

(The abbreviations for CSE structural elements are listed in Table 16)

AbfAblV	Ordinance on Environmentally Compatible Storage of Waste from Human Settlements and on Biological Waste-Treatment Facilities (Abfallablagerungsverordnung - AbfAblV)
ABL	Old German Länder
AGEB	Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen)
AK	Working group (Arbeitskreis)
ALH	BWI tree-species group: all other deciduous trees with high life expectancies
ALN	Tree-species group as defined within the Federal Forest Inventory (BWI): all other deciduous trees with low life expectancies
ANCAT	Abatement of Nuisances from Civil Air Transport
AR	Activity rate
AWMS	Animal Waste Management System
B_0	Maximal CH_4-production capacity
BAFA	Federal Office of Economics and Export Control (Bundesamt für Wirtschaft und Ausfuhrkontrolle)
BAT	Best Available Technique
BDZ	Federal Association of the German Cement Industry (Bundesverband der Deutschen Zementindustrie)
BEF	Biomass expansion factors
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 Natural Resources (Bundesanstalt für Geowissenschaften und Rohstoffe)
BGW	Federal Association of the German Gas and Water Industry (Bundesverband der deutschen Gas- and Wasserwirtschaft)
BHD	Breast-height diameter: tree-trunk diameter at a height of 1.30 m above the ground
BImSchV	Statutory Ordinance under the Federal Immission Control Act
BML	see BMVEL
BMU	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BMVEL	Federal Ministry of Consumer Protection, Food and Agriculture
BMVG	Federal Ministry of Defence
BMWA	Federal Ministry of Economics and Labour
BMWi	see BMWA
BOHE	Main survey on soil use (Bodennutzungshaupterhebung)
BREF	BAT (Best Available Technique) Reference Documents
BSB	Biological oxygen demand (BOD)
BV Kalk	German Lime Association (Bundesverband der Deutschen Kalkindustrie)
BWI	Bundeswaldinventur (Federal Forest Inventory)
BZE	Survey of soil condition (Bodenzustandserhebung)

C_2F_6	Hexafluoroethane
CAPIEL	Coordinating Committee for the Associations of Manufacturers of Industrial Electrical Switchgear and Controlgear in the European Union
CFC	Chlorofluorocarbons (= Fluorchlorkohlenwasserstoffe (FCKW))
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)
D7	Tree-trunk diameter at a height of 7 m above the ground
DESTATIS	Federal Statistical Office (Statistisches Bundesamt Deutschland)
DFIU	Franco-German Institute for Environmental Research, at the University of Karlsruhe
DG	Landfill gas (DG) – amount formed
DGMK	German Scientific Society for Petroleum, Natural Gas and Coal (Deutsche Wissenschaftliche Gesellschaft für Erdöl, Erdgas und Kohle e.V.)
DIN	Deutsche Industrienorm (DIN standard)
DIW	German Institute for Economic Research (Deutsches Institut für Wirtschaftsforschung)
DLR	German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt)
DMKW	Diesel-engine power stations
D_N	N in wastewater
DOC	Degradable organic carbon
DOC_F	Fraction of DOC dissimilated
DTKW	Steam-turbine power stations
DVGW	German Association of Gas and Water Professionals (Deutsche Vereinigung des Gas- und Wasserfachs e.V.)
EEA	European Environment Agency
EECA	European Electronic Component Manufacturers Association
EF	Emission factor
EI	Emissions index = Emission factor
E_{KA}	Einwohner mit Kläranlagenanschluss (Inhabitants connected to wastewater-treatment systems)
EL	Extra light (heating oil)
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)
ESIA	European Semiconductor Industry Association
EU	European Union

EUROCONTROL	European Organisation for the Safety of Air Navigation
EUROSTAT	Statistical Office of the European Communities
EW	Population equivalents (Einwohnerzahl)
FA	Combustion systems
FAL	Federal Agricultural Research Institute
FAO	Food and Agriculture Organisation
FCKW	Chlorofluorocarbons (CFCs; Fluorchlorkohlenwasserstoffe)
F gases	Fluorinated hydrocarbons
FHW	District heating stations
FKW	Perfluorocarbons (PFCs; Fluorkohlenwasserstoffe)
FKZ	Research index (Forschungskennziffer)
FWL	Thermal output from combustion (Feuerungswärmeleistung)
GAS-EM	GASeous EMissions – A calculation programme for emissions from agriculture
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)
GMKW	Gas-engine power stations
GPG	Good Practice Guidance
GT	Gas turbines
GTKW	Gas-turbine power stations
GuD	Gas and steam turbine power stations
GWP	Global Warming Potential
HFC	Hydrofluorocarbons (= Wasserstoffhaltige Fluorkohlenwasserstoffe (HFKW))
HFCKW	Hydrochlorofluorocarbons (HCFCs; Wasserstoffhaltige Fluorchlorkohlenwasserstoffe)
HFC	Hydrofluorocarbons (= HFCs; Wasserstoffhaltige Fluorkohlenwasserstoffe)
HQG	Key source
HS-GIS	High-voltage gas-insulated switching systems
IAI	International Aluminium Institute
ICAO	International Civil Aviation Organisation
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
IMA	Interministerial Working Group (Interministerielle Arbeitsgruppe)
IPCC	Intergovernmental Panel On Climate Change
K	Fuel input for power generation (direct drive)
k.A.	keine Angabe (no entry)
KP	Kyoto Protocol

KS	Sewage sludge
l	Level (= Level assessment pursuant to IPCC Good Practice Guidance)
LF	Landwirtschaftlich genutzten Flächen (agriculturally used land)
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 (Mechanisch-Biologische Abfallbehandlung)
MCF	Methane conversion factor
MFC	Factor for quality of landfill-gas management (methane correction factor)
MS	Medium voltage
MSW	Amount of municipal waste stored
MVA	Waste incineration plant
MW	Megawatt
N_2O	Nitrous oxide (laughing gas)
NA	Not applicable
NASA	National Aeronautics and Space Administration
NaSE	National System of Emissions Inventories
NBL	New German Länder
NE	Not estimated
NEAT	Non-energy Emission Accounting Tables
NEC Directive	Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on national emission ceilings for certain air pollutants
NEV	Non-energy-related consumption
NFR	Nomenclature for Reporting (new format for reporting to UN ECE)
NFZ	Utility vehicles
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; factor for determining the proportion of CH_4 that is oxidised
PAH	Polycyclic aromatic hydrocarbons (= Polycyclische aromatische Kohlenwasserstoffe (PAK))
PAK	Polycyclische aromatische Kohlenwasserstoffe
PARTEMIS	Measurement and prediction of emissions of aerosols and gaseous precursors from gas turbine engines
PCCD/F	Polychlorinated dibenzo-dioxins/- furans
PF	Process furnaces
PFC	Perfluorocarbons
PKW	Automobile (Personenkraftwagen)

PU	Polyurethane
QK	Quality control (QC)
QS	Quality assurance (QA)
QSE	Quality System for Emissions Inventories
RSt	Raw steel
RWI	Rheinisch-Westfälisches Institut für Wirtschaftsforschung (RWI)
S	Fuel input for power generation
S	Heavy (schwer) (heating oil)
SARS+A	Synthesis and Assessment Report
SA	Heavy (schwer), low in sulphur (schwefelarm)(heating oil)
SF_6	Sulphur hexafluoride
SKE	Hard-coal units (Steinkohleneinheiten)
SNAP	Selected Nomenclature for Air Pollution
SO_2	Sulphur dioxide
STEAG	STEAG stock corporation: large electricity producer in Germany
t	Trend (= trend assessment pursuant to IPCC Good Practice Guidance, in the source-category overview tables)
TA Luft	Technical instructions on air quality control; First General Administrative Provision on the Federal Immission Control Act
TAN	Total Ammoniacal Nitrogen
THG	Greenhouse gases (Treibhausgase = GHG)
TM	Dry mass (Trockenmasse)
TOC	Total Organic Carbon
TREMOD	Traffic Emission Estimation Model
TÜV	Technischer Überwachungs-Verein (Certifying body for technical and product safety)
UBA	Federal Environmental 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)
VDEW	Electricity Industry Association (Verband der Elektrizitätswirtschaft e.V.)
VDI	Association of German Engineers (Verein Deutscher Ingenieure e.V.)
VDN	Association of network operators (Verband der Netzbetreiber)
VDZ	German Cement Works Association (Verein Deutscher Zementwerke e.V.)
VfmD	Solid cubic meters of standing timber (Vorratsfestmeter Derbholz)
VGB	Technical association of operators of large power stations (Technische Vereinigung der Großkraftwerksbetreiber e.V.)
VIK	Verband der Industriellen Energie- and Kraftwirtschaft e.V. (VIK) (Association of the Energy and Power Industry), Essen
VOC	Volatile Organic Compounds
W	Fuel input for heat generation
WS	WS = Portion of a specific waste water treatment system (e.g. aerobic, anaerobic)
XPS	Extruded polystyrene
ZSE	Central System of Emissions (CSE)

Units, etc.

Multiplication factors, abbreviations, prefixes and symbols

Multiplication factor	Abbreviation	Prefix	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
0,000.001	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

Unit	is equivalent to
1 tonne (t)	1 megagram (Mg)
1 kilotonne (kt)	1 gigagram (Gg)
1 megatonne (Mt)	1 teragram (Tg)

0 SUMMARY

As a Party to the United Nations Framework on Climate Change, 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, for the first time ever the international community of nations is required to implement binding action targets and instruments for global climate protection. This leads to very extensive obligations vis-à-vis the preparation, reporting and review of emissions inventories. As a result of Europe's own implementation of the Kyoto Protocol, via the adoption of EU Decision 280/2004, these requirements became legally binding for Germany in spring 2004.

Inter alia, the Conference of the Parties, in adopting Decision 3/CP.5, resolved that all Parties are required to prepare and submit an annual National Inventory Report (NIR) 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 of inventories and support the independent review process. The Secretariat of the Framework Convention of Climate has made submission of the inventory report a pre-requisite for performance of the agreed inventory reviews. With its inventory for 2005, Germany is submitting its third National Inventory Report. In comparison to the report from 2004 (UBA, 2004), it has been extensively revised in the areas of agriculture (CRF sector 4) and changes in forest resources and other biomass stocks (CRF sector 5.A). For the first time, *IPCC Good Practice Guidance for Land Use, Land Use Change and Forestry* (IPCC-GPG LULUCF, 2003) has been applied to the latter of these two sectors. In addition, the NIR 2005 has been made more concise, in the interests of clarity and reader-friendliness. These changes have been made in response to key criticism voiced by an independent team of experts that, in September 2004, reviewed the German inventories under commission the Climate Secretariat. As part of the changes, highly detailed descriptions of methods and relevant considerations have been moved into the Annex. Plans call for continuation of these activities, which are primarily of an editorial nature, and for their completion in 2005. Ultimately, the National Inventary Report will consist of a main section and a separate Annex that will be linked with each other via suitable referencing.

National greenhouse gas emission inventories for the years 1990 to 2003 have been submitted to the Secretariat of the Framework Convention on Climate. This report refers to those annual emission inventories and outlines the methodology and the data sources on which the calculations are based. The report and the report tables in the Common Reporting Format (CRF) have been prepared in accordance with the UN FCCC guideline on annual inventories (*FCCC/SBSTA/2004/8*) and, as far as possible, in accordance with the *IPCC Good Practice Guidance* (IPCC-GPG, 2000) and IPCC-GPG LULUCF (2003).

Chapter 1 describes the National System of Emissions Inventories in Germany, which is designed to aid compliance with all reporting obligations with respect to atmospheric emissions and storage in sinks. Apart from the Kyoto Protocol requirements, this also covers other legal obligations (the UN ECE Geneva Convention on Long-range Transboundary Air Pollution, the EU Directive on National Emission Limits) that Germany has entered into. In addition, it describes the basic principles and methods with which the emissions and sinks of the IPCC categories are calculated, and it describes the Quality System of Emissions Inventories. Over the past three years, the participating institutions, via considerable efforts,

have helped improve the relevant database and close gaps in the data. Efforts to systematically improve the inventory continue and are being given high priority.

Chapter 2 provides a general overview of development of emissions of greenhouse gases and their storage in sinks.

Chapters 3 to 9 contain detailed information about the main groups of emissions sources and sinks; this information is designed to enhance the transparency of calculations of German greenhouse-gas emissions and sinks. In comparison to the National Inventory Report for 2004, this year's report has been improved in the following areas:

Energy:

- New N_2O emission factors in keeping with a new study of large combustion plants
- New CH_4 and N_2O emission factors that reflect significant improvements in the fuel efficiency of aircraft engines
- New CH_4 and N_2O emission factors for stationary sources; standardisation of methods
- New activity rates for road traffic
- New CH_4 activity rates as a result of technological changes in fugitive emissions from fuels

Industrial processes:

- New activity rates for cement production
- New activity rates for lime production
- Change in aggregation
- Use of unrounded activity rates
- First inclusion of calcium-carbide production, methanol and ethylene dichloride

Agriculture:

- New CH_4 emission factors and activity rate, inclusion of new data for cows; Berlin, Bremen, Hamburg
- New CH_4 emission factors and activity rate; inclusion of new data
- New N_2O emission factors and activity rate; inclusion of new data

Land-use changes and forestry:

- New data; the increase in stocks (increase of timber) is higher than in earlier estimates
- Inclusion of belowground biomass, improved methods of calculation, and changed estimates of the original stocks

- First survey of carbon storage in mineral soils

The *In Country Review* carried out by experts of the Climate Secretariat identified additional need for improvement. The intensive national process of inventory improvement needs to be continued in 2005. The methodological changes being made to implement the *Good Practice Guidance* (GPG) in the inventories have not yet been completed. More detailed information about specific relevant issues is presented in the literature listed in **Chapter 11**.

Detailed information on recalculations and improvements can be found in **Chapter 10.**

The Federal Environmental Agency makes all calculations for the greenhouse-gas inventory and carries out all relevant compilation. Emissions and sinks from agriculture, changes in land use and forestry were provided by the Federal Ministry of Consumer Protection, Food and Agriculture (BMVEL) and the Federal Agricultural Research Institute (Bundesforschungsanstalt für Landwirtschaft, FAL).

0.1 Background information on greenhouse-gas inventories and climate change

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 30 % compared with the levels in pre-industrial times, whilst those of methane (CH_4) have increased by 145 % and those of nitrous oxide (N_2O) by 15 %. Furthermore, a number of brand-new substances such as chlorofluorocarbons (CFCs), halons, perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulphur hexafluoride (SF_6) have entered the atmosphere which almost never occur in nature and are generated almost exclusively by humans.

As a Party to the United Nations Framework on Climate Change, since 1994 Germany has been obliged to prepare, publish and regularly update national emission inventories of greenhouse gases. By adopting the Kyoto Protocol in 1997, the international community of nations reached agreement, for the first time ever, on binding aims and implementation instruments for global climate protection. This leads to extensive obligations vis-à-vis the preparation, reporting and review of emissions inventories.

In the framework of the Kyoto Protocol, the European Union has committed to reducing its greenhouse-gas emissions by 8% by the 2008–2012 period, in comparison to their base-year levels. This commitment has been divided between the EU Member States in the framework of a burden-sharing arrangement[1]. Under this agreement, Germany has agreed to reduce its emissions by 21 % in comparison to the base year and thus has agreed to make a substantial contribution to fulfillment of the EU's commitment. Consequently, Germany's relevant measures, and its calculations relative to emissions reductions, are being followed with considerable interest.

1 Burden-sharing agreement; adopted via Council decision 2002/358/EC

0.2 Greenhouse-gas emissions and their storage in sinks (with respect to GWP) over time: 1990-2003

In the framework of burden-sharing agreed internally within the EU, the Federal Government has made a commitment to reduce Germany's emissions of all six Kyoto gases by 21 % in comparison to the base year (1990 and 1995[2]), by the end of the first commitment period, which runs from 2008 to 2012. The development of greenhouse-gas emissions in Germany since 1990 is shown in Table 1 for the various individual greenhouse gases and graphically as totals in Figure 1.

Table 1: Greenhouse-gas emissions in Germany – changes with regard to the base year[3] [CO_2 equivalents]

Greenhouse gas emissions	Base year	1990	1995	2000	2001	2002	2003
	CO_2 equivalent [Gg]						
Net CO_2 emissions/removals	986.088	986.088	870.540	825.670	838.667	828.660	829.677
CO_2 emissions *	1.015.031	1.015.031	902.213	860.091	873.862	863.877	865.367
CH_4	132.099	132.099	104.912	82.908	79.308	76.477	75.220
N_2O	86.388	86.388	80.886	62.199	62.481	61.767	63.694
HFCs	6.360	3.510	6.360	6.630	8.130	8.247	8.247
PFCs	1.759	2.696	1.759	790	723	786	786
SF_6	6.633	3.967	6.633	4.018	3.325	4.197	4.197
Total #	**1.219.326**	**1.214.748**	**1.071.090**	**982.214**	**992.634**	**980.134**	**981.821**
Total *	**1.248.270**	**1.243.692**	**1.102.763**	**1.016.636**	**1.027.829**	**1.015.351**	**1.017.511**

*) without CO_2 from LUCF #) without net CO_2 emissions / removals

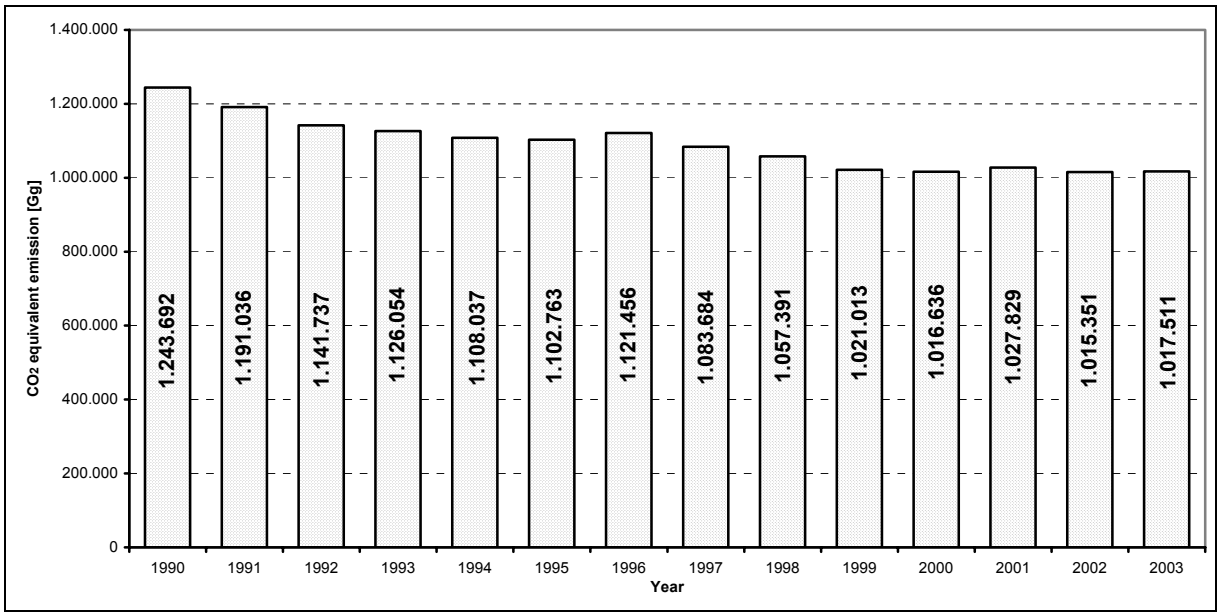


Figure 1: Overall development of greenhouse gases in Germany, in CO_2 equivalents (without CO_2 from LUCF)

By 2003, Germany reduced its emissions by 18.5 % in comparison to the base year, thereby already fulfilling much of its its commitments within the framework of European burden-sharing. The individual greenhouse gases contributed to this development to varying degrees

2 For HFC, PFC and SF_6
3 Base year 1990 for CO_2, CH_4, N_2O; 1995 for HFC, PFC, SF_6

(see Table 1). This is hardly surprising given that, in any given year, the various greenhouse gases account for varying proportions of total emissions (see Table 2).

Table 2: Greenhouse-gas emissions in Germany – annual contributions of the various greenhouse gases, [Gg CO_2 equivalents]

Greenhouse gas emissions (CO_2-Eqivalent)	Base year		1990		1995		2000		2003	
	[Gg]	[%]	[Gg]	[%]	[Gg.]	[%]	[Gg]	[%]	[Gg]	[%]
CO_2 emissions *	1.015.031,5	81,3	1.015.031,5	81,6	902.212,8	81,8	860.091,4	84,6	865.367,3	85,0
CH_4	132.099,2	10,6	132.099,2	10,6	104.912,5	9,5	82.908,0	8,2	75.219,9	7,4
N_2O	86.388,0	6,9	86.388,0	6,9	80.886,0	7,3	62.198,8	6,1	63.693,8	6,3
HFCs	6.360,0	0,5	3.510,0	0,3	6.360,0	0,6	6.630,0	0,7	8.247,2	0,8
PFCs	1.758,8	0,1	2.696,0	0,2	1.758,8	0,2	789,7	0,1	786,0	0,1
SF_6	6.632,8	0,5	3.967,4	0,3	6.632,8	0,6	4.018,0	0,4	4.197,1	0,4
Total *	**1.248.270,2**		**1.243.692,1**		**1.102.374**		**1.016.636,0**		**1.017.511,2**	

*) without CO_2 from LUCF

Stationary and mobile combustion processes, accounting for 85.0 % of released carbon dioxide, are the main sources of emissions. In particular, as a result of disproportionately large reductions of other greenhouse gases, CO_2 emissions' share of total emissions has increased by 3.7 % since the base year. Emissions of methane (CH_4) caused by animal husbandry, fuel distribution and landfill emissions account for 7.4 %. Emissions of nitrous oxide (N_2O), caused primarily by agriculture, industrial processes and transport, contribute 6.3 % of greenhouse-gas releases. The other so-called "Kyoto" or "F" gases contribute only slightly more than 1 % to total emissions. The distribution of Germany's greenhouse-gas emissions is typical for a highly developed and industrialised country.

Emissions are calculated component-specifically for the source categories and sinks defined by the IPCC. The greenhouse-gas inventories do not take account of chemical reactions, in the atmosphere, of C-containing compounds (such as NMVOC solvents).

0.3 Overview of emissions estimates and trends for source and sink categories

Figure 2 shows the contributions of individual source and sink categories to total greenhouse-gas emissions. It highlights the relative constancy of the shares of the various source and sink categories and the absolute dominance of energy-related emissions. In fact, these have continuously decreased over time. The slight re-increases in 1996, 2001, and 2003 are temperature-related. These years had lower winter temperatures, leading to intensified energy consumption for indoor heating and, thereby, to higher emissions. This is documented by independently calculated temperature corrections for energy-related CO_2 emissions (ZIESING, 2004: Tab. 5).

Overall, greenhouse-gas emissions have decreased considerably since 1990 (decrease of CO_2-equivalent emissions by 18.5 %). This is also substantiated by considerations of the individual relevant components. For example, the emissions changes since the base year, 1990, for the most important greenhouse gases by amount are as follows: -14.7 % for CO_2, -43.1 % for CH_4 (methane) and -26.3 % for N_2O (nitrous oxide / laughing gas). The corresponding trends for the so-called "F" gases, which contribute about 1 % of greenhouse-gas emissions overall, have not been as clearly similar to each other, however. Since the base year, 1995, as a result of introduction of new technologies, and of trends in use of these

substances as substitutes, emissions decreased for SF_6 (- 36.7 %), CF_4 (- 66.2 %) and C_2F_6 (-38.9 %), while they increased for HFCs (+ 29.7 %) and C_3F_8 (+ 1269 %).

Overall, emissions increased slightly over the previous year, 2002, by + 0.2 %. This increase is due to the aforementioned increase in energy consumption for heating and, in the industrial-processes sector, to increased cement and nitric acid production.

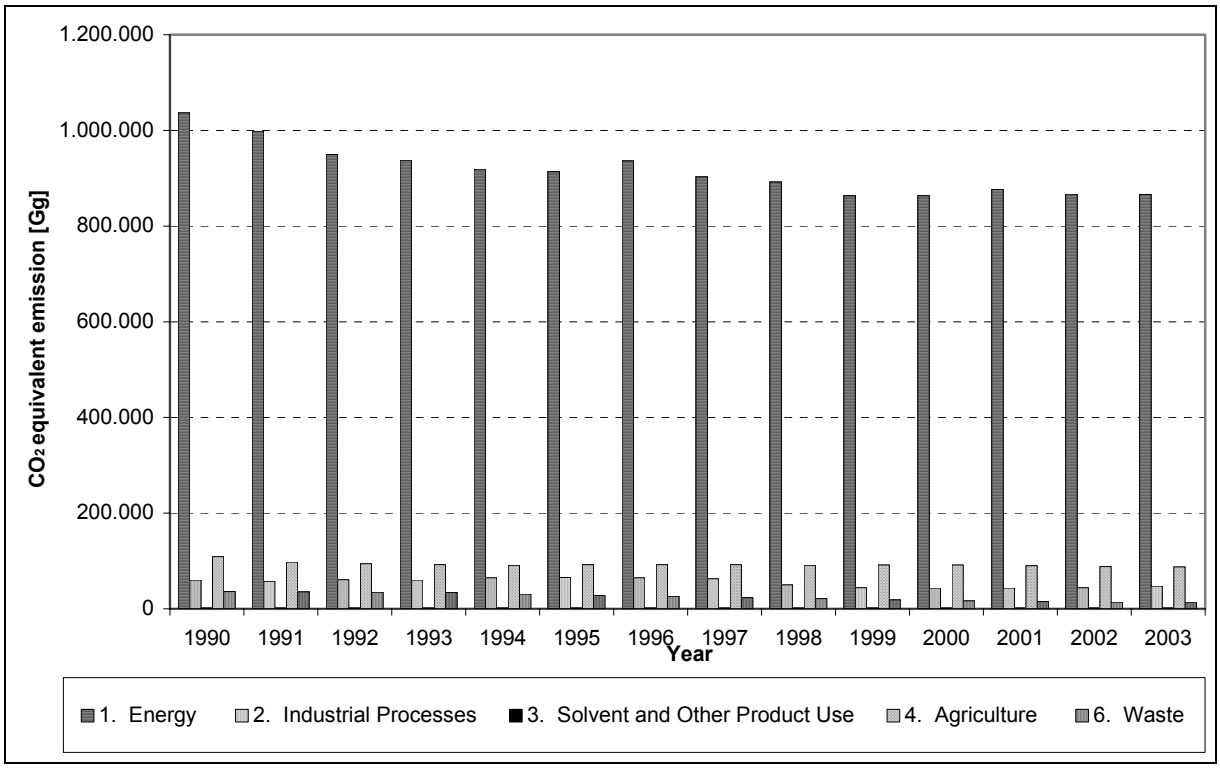


Figure 2: Greenhouse-gas emissions trends, by source categories, in CO_2 equivalents[4]

Figure 3 shows the relative developments of emissions from source categories since 1990. The most significant reduction occurred in the area of waste emissions. Despite the many methodological difficulties (cf. Chapter 8.1), the introduction of more widespread recycling of recoverable materials (Packaging Ordinance) and reuse as compost (Biowaste Ordinance) have led to a reduction in the quantity of waste that is landfilled and hence to a reduction in landfill emissions. In the area of emissions from industrial processes, the emission-reducing effects of measures in the field of adipic acid production in 1997 were substantial. Emissions from solvent and other product use are not very high in absolute terms; the constancy of these emissions can be explained by the updating of the figure calculated for 1990 from the narcotic use of N_2O. Current pertinent data is being obtained in the framework of a research project. The trend in emissions from agriculture essentially follows the development of livestock figures.

[4] CO_2 emissions and storage in soils are reported under land-use changes and forestry.

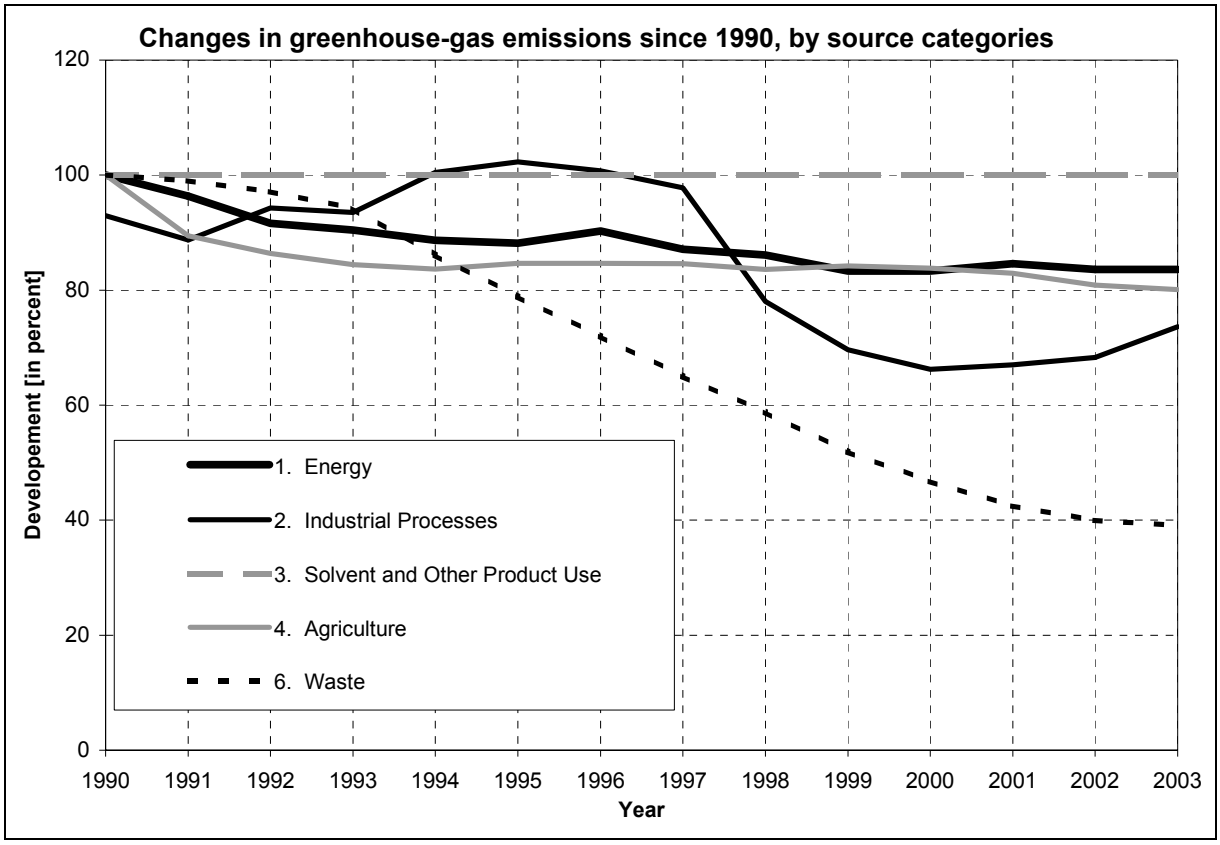


Figure 3: Relative development of greenhouse-gas emissions since 1990, by source categories[5]

[5] CO_2 emissions and storage in soils are reported under land-use changes and forestry.

1 INTRODUCTION

1.1 Background information on climate change and on greenhouse-gas inventories

1.1.1 The greenhouse effect

Climate change consists of changes in average weather conditions over an extended period of time; it can occur in a particular area or be global. Paleo-climate research has shown that major climate changes, with fluctuations of the global mean temperature ranging from 9°C to 16°C, have occurred naturally in the past millions of years. Climate change may be attributable to the following causes:

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

Greenhouse gases, which also include water vapour – the most important natural greenhouse gas – and ozone, have a particular property. They allow the energy-rich radiation falling onto 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. In simplified terms, this is the nature of the greenhouse effect.

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

1.1.2 Climate change

Ever since the start of industrialisation, significant supra-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 30 % compared with the levels in pre-industrial times, whilst those of methane (CH_4) have increased by 145 % and those of nitrous oxide (N_2O) by 15 %. Furthermore, a number of brand-new substances such as chlorofluorocarbons (CFCs), halons, perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulphur hexafluoride (SF_6) have entered the atmosphere which almost never occur in nature and are generated almost exclusively by humans.

Although the triggers of the greenhouse effect are minimal in volume terms, their effects are substantial. The increase in the concentration of greenhouse gases serves to reinforce the (natural) greenhouse effect and hence leads to an increase in ground-level temperature. The natural greenhouse effect is essential to life; however, its reinforcement as a result of human intervention is cause for concern. The change in one climate factor in the composition of the atmosphere may lead to far-reaching and rapid changes in the entire climate system via multiple interactions. Because ecosystems and civilisation itself are adapted to the current climate conditions, such changes may have threatening consequences.

In its most recent report of 2001, the IPCC (Intergovernmental Panel on Climate Change) ascertained, *inter alia*, that the average global air temperature has increased by between 0.4 and 0.8°C over the past 100 years. The past few years have been among the warmest since 1861 (beginning of regular record-keeping in Germany).

1.1.3 Reduction obligations and reporting of greenhouse gases

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 on Climate. Such inventories must include data on emissions and sinks for the base year (1990 for CO_2, N_2O, CH_4; 1995 for HFC, PFC, SF_6) and for all years until the year preceding the year of the relevant report.

At the third Conference of the Parties, held in Kyoto, legally binding obligations on emissions limitations and reductions were defined, for the first time, for industrialised countries. Pursuant to the Kyoto Protocol, industrialised nations must reduce their emissions of the six greenhouse gases carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFC), perfluorocarbons (PFC) and sulphur hexafluoride (SF_6) by an average of 5.2 percent by 2012. In the framework of the Kyoto Protocol, the European Union has committed to reducing its greenhouse-gas emissions by 8 % by the 2008–2012 period, in comparison to their 1990 levels. Within the EU, this commitment has been divided up between the Member States via a burden-sharing arrangement [6] whereby Germany is called on to make a substantial contribution of a 21 % emissions reduction in comparison to the base year. Consequently, Germany's relevant measures, and its calculations relative to emissions reductions, are being followed with considerable interest.

The effectiveness of the Kyoto Protocol with regard to the reduction of global greenhouse gas emissions will depend on two key factors: Whether the Member States will abide by the rules of the Protocol and meet their obligations, and whether the emissions data used for compliance control is reliable. As such, national reporting and the subsequent international review of emissions inventories play a key role.

6 Burden-sharing agreement; adopted via Council decision 2002/358/EC

1.2 Institutional specifications and framework conditions for inventory preparation

In Germany, emissions reporting is co-ordinated by the Federal Environmental Agency. Since the mid-1990s, when reporting obligations for preparation of emissions inventories of air pollutants and climate gases increased sharply, efforts to harmonise emissions calculation and reporting have been intensified. At the same time, requirements from reporting obligations relative to the UN ECE Geneva Convention on Long-range Transboundary Air Pollution and its protocols, and to the EU NEC Directive, must be taken into account. The provisions of the Kyoto Protocol require a fundamental review and reorientation of German emissions reporting. Since 2002, the Federal Environmental Agency has been carrying out this task energetically.

As an overarching aim, all reporting obligations require that Member States carry out transparent, comparable, complete, consistent and precise emissions calculations. In particular, as a result of integration of flexible instruments within the Kyoto Protocol, specific requirements have been formulated for implementation of the aforementioned aims. Introduction of Joint Implementation, Clean Development Mechanisms and emissions trading will ultimately give emissions monetary value, with the result that a number of procedures will be required to make the Protocol's provisions enter into force and to deal with issues of monitoring and control of compliance. Only when independent review of a Member State's inventories has been completed, with no objections raised, can the state be certified for use of flexible instruments (cf. Figure 4).

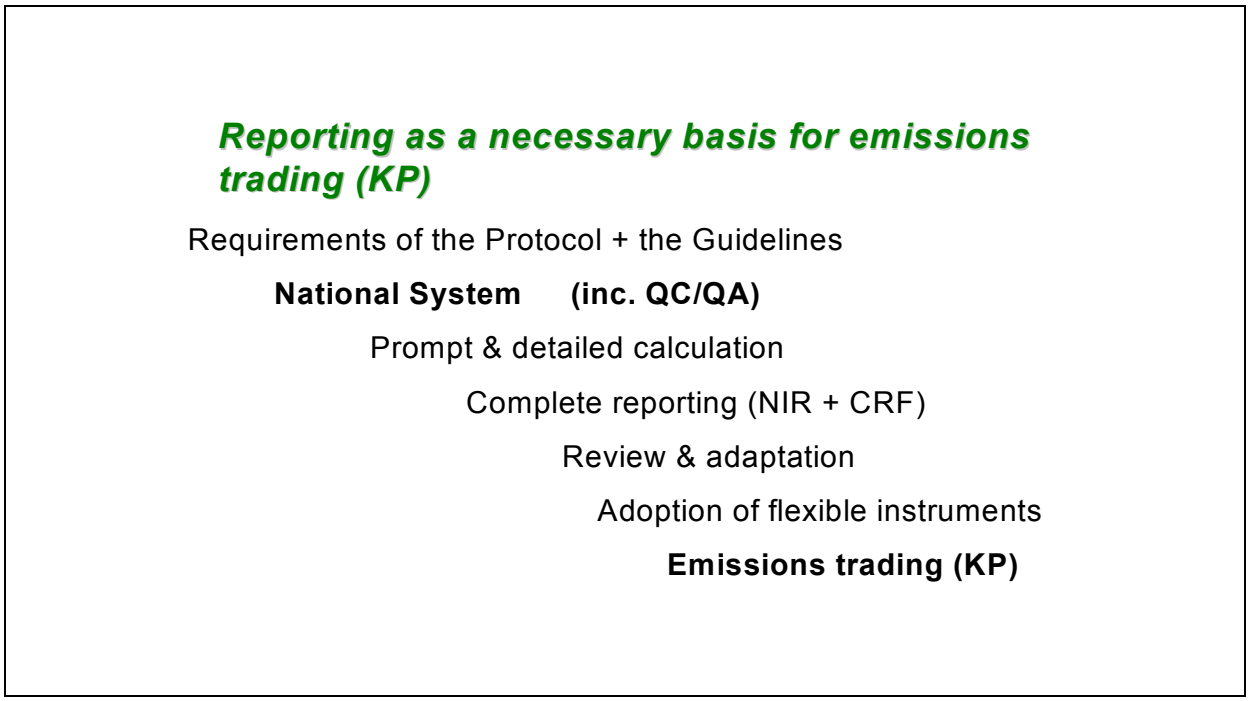


Figure 4: Pre-requisites for the use of the KP's flexible instruments

The requirements are not limited to preparation of inventories; they also comprise the entire relevant process, from data collection to reporting. Quality management plays a particularly important role. In order to create a defined framework for the process of greenhouse-gas reporting, the Member States are obligated to establish national systems, for inventory preparation, that permit continual inventory improvement.

In Germany, the National System has the purpose of ensuring that emissions inventories are properly organised and undergo quality assurance, as well as of serving as a network for all national and *Land* institutions, research institutes, associations and organisations which could contribute to improving the inventory calculations. Work began on the necessary measures to develop the National System in 2002, and planning calls for this work to be completed by the year 2005. In particular, it also involves the formulation of a proposal for suitable institutionalisation of the National System in Germany. This proposal must ensure that the system can function effectively, with little red tape and with binding, sufficiently reliable procedures (for further information about the National System, see Chapter 17.1).

1.2.1 Institutional specifications for inventory preparation

At present, the following institutional links and specifications apply to inventory preparation in Germany:

1. The *co-ordinating office of the National System* – the "Single National Entity" (SNE) – is housed within Section I 4.6 of the Federal Environmental Agency. There is as yet no legally binding specification in this respect. The SNE is charged with serving as the central point of contact and information for all participants in the National System. It is required to provide a framework for transparent, consistent, complete, comparable and precise inventories.

2. A *Working Group on Emissions Inventories* has been set up to co-ordinate relevant work within the Federal Environmental Agency; it will incorporate all of the agency's employees who are involved in inventory preparation.

3. A *Working Group on Emissions Reporting*, founded in 2002 within the CO_2 Reduction Interministerial Working Group[7], is charged with implementing emissions-reporting requirements within federal agencies. Interministerial discussion on central tasks in emissions inventories, as identified to date, is being carried out in this framework. Co-ordination is being carried out by the BMU. Plans call for the working group to meet three times annually. Working Group VI will focus on discussing possibilities for institutionalising the Kyoto requirements – for example via an act on implementation.

4. The *framework departmental agreement between the Federal Ministry of Consumer Protection, Food and Agriculture (BMVEL) and the Federal Ministry of the Environment, Nature Conservation and Nuclear Safety (BMU)* regarding data and information exchange and the operation of a joint database on emissions from agriculture, dated 2 April 2001, marked the first-ever inter-departmental agreement on co-operation in calculation of emissions.

5. Data on agriculture and forestry is provided to the Federal Environmental Agency by the Federal Ministry for Consumer Protection, Food and Agriculture (BMVEL), which has the relevant specialised competence.

6. At present, the involvement of the German Länder is being ensured via the *Länder Committee on Immission Protection* (LAI). This is required in particular for validation of the Energy Balance of the Federal Republic of Germany with the energy balances

7 Following a resolution by the Federal Government on 13 June 1990, the IMA on CO_2 Reduction was founded under the auspices of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). The aim is to further develop and implement an overall concept for CO_2 reduction and global warming prevention at the national level.

of the *Länder*, as well as for the process for verification of Federal and *Länder* emissions inventories. In the area of energy, intensive co-operation is also taking place with the Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen - AGEB) and with the German Institute for Economic Research (DIW), which prepares the Energy Balance of the Federal Republic of Germany under commission to the AGEB.

7. *Involvement of associations* and other independent organisations has been achieved primarily via the sections of divisions I and III, at the Federal Environmental Agency, responsible for concrete issues. The *Single National Entity* supports the specialist departments in discussion of reporting requirements and in determination of requirements for data-sharing by associations. Work to raise awareness and provide information has been intensified since 2003.

8. Inventory preparation has always made use of the expertise of *research institutions*, via execution of research and development projects in the UFOPLAN framework. This occurs via work on specific issues, and it takes place via overarching projects, which primarily support harmonisation of individual results, for the overall inventory, as well as identification of gaps in lists of emission-relevant activities. Since UFOPLAN 2002, the Single National Entity has had a global project *on updating emissions-calculation methods*, a project within which it can initiate measures for continuous inventory improvement. Individual measures for improving inventories are initiated and financed via establishment of sub-projects.

9. The average length of time required for commissioning via the UFOPLAN, from problem identification (project initiation) to solution (acceptance of the final report), is 3.5 years. Since inventories must be reviewed annually by independent experts of the Climate Secretariat, and since improvements relative to deficiency reports must be initiated promptly, the response time for eliminating priority deficiencies must be one year, however. For this reason, a separate budget position for the National System, over and above research funding, has been established within the Federal Environmental Agency as of 2005 (Title 526 02, Chapter 1605, No. 4.15). This position can be used to fund short-term projects for inventory improvement, within the Agency's responsibility.

1.2.2 Framework conditions for inventory preparation

Inventory preparation necessitates extensive preliminary work from the specialist departments of the Federal Environmental Agency and other institutions. Since 2003, the Single National Entity has been working, by providing suitable specifications for inventory preparation and quality assurance, to create a standardised framework for the various relevant players.

The framework conditions for inventory preparation in Germany are currently as follows:

1. In 2002, the Federal Environmental Agency began establishing a Quality System for Emissions Inventories (QSE) that will provide the necessary framework for compliance with good inventory practice and for execution of routine quality assurance. This system will be designed to meet the requirements of *IPCC Good*

Practice Guidance, and it will be adapted to national circumstances in Germany and to the internal structures and procedures of the Federal Environmental Agency, the reporting institution. Within the QSE framework, a concept for structural and procedural organisation was developed that defines binding responsibilities and the necessary QC and QA measures. The Quality System of Emissions Inventories, which is currently under development, is described in greater detail in Annex 6 (Chapter 17.2). Since 2003, measures to improve emission inventories have been initiated systematically via the QSE.

2. The database of the Federal Environmental Agency's *Central System on Emissions* (CSE) is used for central storage of all information required for emissions calculation (methods, activity rates, emission factors). The CSE is the main instrument for documentation and quality assurance at the data level. A more detailed description of the CSE is provided in Annex 6 (Chapter 17.3).

3. A binding schedule for preparation of emissions inventories and of the NIR is announced to all relevant internal and external players via the Federal Environmental Agency's Website and via publication within the NIR itself. In 2005, and for all subsequent years, the following schedule holds for inventory data (all pollutants) and for the pertinent descriptions in the National Inventory Report (initially, covering only GHG):

05. May	The Federal Environmental Agency's national co-ordinating agency (Single National Entity) requests the source category specific contact person to submit data and report texts
01. September	Deliveries from Federal Environmental Agency and from external institutions of the NaSE
02. September	Validation / discussion of deliveries by the experts resonsible for inventory preparation and qualitiy control, taking account of review results
01. October	Preparation of CRF time series; final editing by the Single National Entity within the Federal Environmental Agency
01. November	Internal co-ordination within the Federal Environmental Agency
15. November	Final quality assurance
30. November	Report to the ministry for initiation of inter-ministerial co-ordination
15. January	Report to the European Commission (within the framework of the CO_2-monitoring mechanism)
15. April	Report to the Secretariat of the FCCC
May	Initial check by the FCCC Secretariat
June	Synthesis and assessment report I (by the FCCC Secretariat)
August	Synthesis and assessment report II (country-specific; by the FCCC Secretariat)

1.3 Short description of inventory preparation

Inventory preparation is carried out under the direction of Section I 4.6 of the Federal Environmental Agency, which also serves as the Single National Entity. Inventory preparation is closely linked with preparation of the National Inventory Report and with quality assurance (cf. Figure 5).

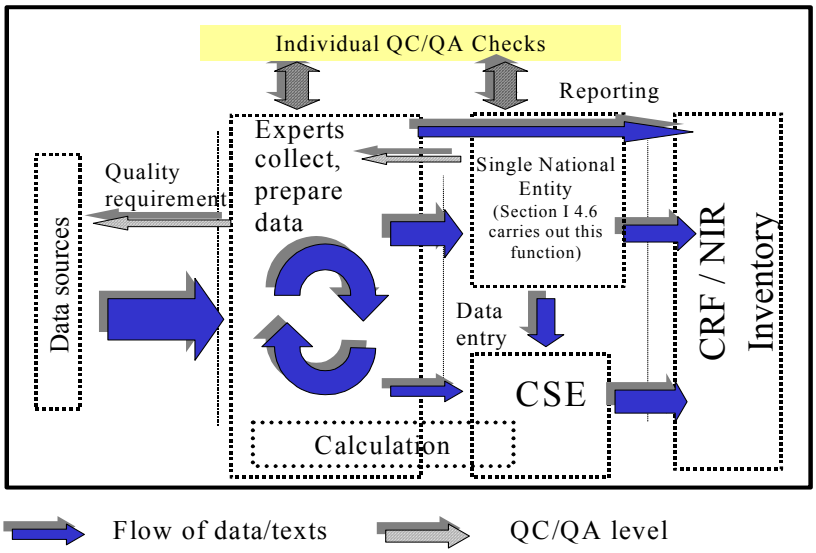


Figure 5: Current process of emissions reporting

Emissions reporting is a process that takes place regularly – as a rule, once per year. Apart from routine, ongoing sub-processes such as data collection, data preparation, emissions calculation and report preparation, definition of the bases for calculation plays a particularly important role in this overall process (cf. Figure 6). Such definition may be required at any time as a result of certain types of events (such as changes in main source categories, issue of new IPCC requirements, identification of deficits pursuant to the inventory plan, identification of potential for improvement, etc.). On an annual basis, in connection with the other routine sub-processes, it is determined whether such events have occurred. In future, suitable QC/QA measures will be assigned to each step of the overall process.

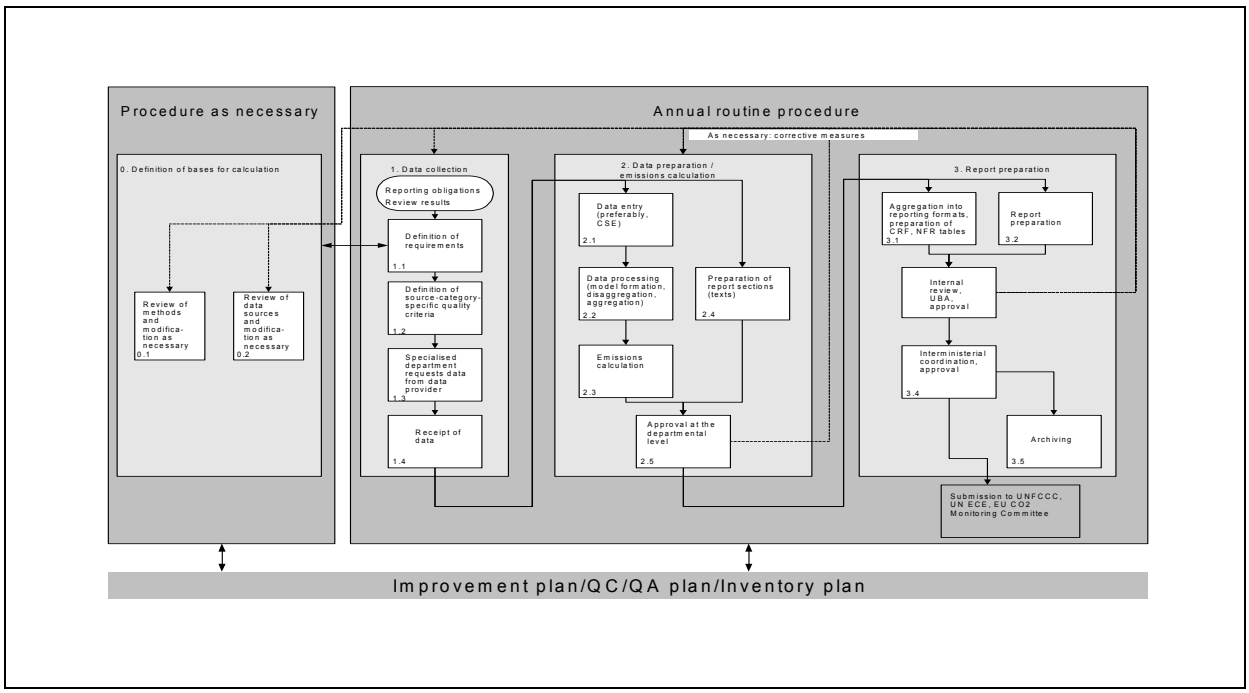


Figure 6: Overview of the overall emissions-reporting process

1.3.1 Definition of bases for calculation

Selection of calculation methods for determining emissions affects the entire emissions-reporting process. For this reason, the overall process must begin with review of the suitability of the methods to be used. IPCC Good Practice Guidance specifies, via use of decision trees, what methods are to be used for the various source categories. In each case, such methods selection depends on whether the group in question is a key source or not. Any use of different – *country-specific* – methods, instead of the prescribed methods, must be justified. 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 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 rates, emission factors or emissions for/of a specific source 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-control and quality assurance measures,
- Identification of uncertainties,
- Representative nature of the data in question, and
- Completeness of the expected data.

Data-source selection must be oriented to these criteria. On the other hand, in each case, selection of a specific data source must be made on a case-specific basis, by the parties responsible for the subject area in question. In practice, where a choice between use of poorly documented data or no data at all presents itself, use of the poorly documented data must always be considered. In each case, it is vital that the reasons for choosing a particular data source be documented and, where the data source has known 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 Environmental Agency, as the customer for such services, must be able to influence such projects.

1.3.2 Data collection

Data collection and documentation takes place under the responsibility of the relevant experts. An organisation may collect data by evaluating official statistics or statistics from associations, studies, periodicals or external research projects, by conducting its own research projects, by obtaining information from relevant persons, or by acquiring data from the German *Länder*. 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,
- Specification of the source-category-specific quality and verification criteria for the data,
- Requesting of data from data providers (carried out by the section of the responsible experts), and
- Receipt of data.

In each case, the National Single Entity (national co-ordinating agency) requests inventory input from the experts responsible for the source category in question, via the experts' superiors. In future, this will occur within the framework of an inventory plan. 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). Via information events of the Working Group on Emissions Inventories, and the Website for the Federal Environmental Agency's emissions reporting, involved experts are informed about the relevant reporting requirements, review results, current key-source analysis and current data status for each source category in question. In each case, the responsible expert must interpret the **applicable requirements** on the basis of such reference sources.

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 (in future, such information will be provided in the inventory plan).

Before any third parties begin with data collection – after the requirements pertaining to data sources and methods have been defined – **the source-category-specific quality and**

review criteria for such third-party data should be defined, in order to support the QC process on the data level. Data validation is carried out by the relevant expert.

In **requesting data** from third parties, the responsible expert unit should describe the expected amount of data to be provided by the data provider and the form in which the data is to be documented. Upon **receipt of data,** the data is checked for completeness, compliance with quality criteria and currentness.

1.3.3 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 texts, and
- Approval by the relevant experts.

Report texts are prepared along with the time series – which enter into the table sections – for activity rates, 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.

Considerable portions of **data entry and preparation** (preparation of data and emissions calculations in the narrower sense of the term) take place in the CSE. Some QC measures at the data level can be integrated, in automatic form, within the CSE (formulation of checking conditions within the CalQlator), with the result that use of the CSE eliminates the need for manual execution of certain QC measures. 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 rate * 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.

Before data – including both texts and results of calculations – is forwarded to the Single National Entity (national co-ordinating agency), **it must be approved at the experts' level,** by the QC/QA manager for the area in question and by the QC/QA managers of other NaSE participants.

1.3.4 Report preparation

Report preparation includes the following steps:

- Aggregation of emissions data into the relevant report formats, and preparation of data tables (CRF, NFR),
- Calculation of CO_2 equivalents for the greenhouse-gas emissions,

- Compilation of submitted report texts to form a report draft (NIR), and editing of the complete NIR,
- Review of the draft by the Federal Environmental Agency, followed by approval as appropriate,
- Forwarding to the BMU,
- Inter-ministerial co-ordination, followed by
- Submission to the UNFCCC Secretariat and
- Archiving.

Before emissions data can be transferred into the report tables for the Framework Convention on Climate Change (CRF = Common reporting Format) and for 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 source-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 sources. Aggregation takes place automatically.

Following mathematical aggregation, activity data, emission factors and emissions are automatically entered into the IPCC's CRF report tables.

At present, all emissions data not included in the CSE is still entered manually into the CRF tables. This process involves an increased risk of error, and thus report tables must be cross-checked by an independent reviewer.

Mathematical conversion of greenhouse gases into CO_2 equivalents takes place pursuant to Art. 20 of the *IPCC Guidelines on Reporting and Review* (FCCC/CP/2002/8), on the basis of the GWP published in the *Second Assessment Report* and listed in Table 3.

Table 3: 1995 IPCC GWP values based on the effects of greenhouse gases over a 100-year time horizon (FCCC/CP/2002/8, S.15)

Greenhouse gas	Chemical formula	1995 IPCC GWP
Carbon dioxide	CO_2	1
Methane	CH_4	21
Nitrous oxide	N_2O	310
Hydrofluorocarbons (HFCs)		
HFC-23	CHF_3	11700
HFC-32	CH_2F_2	650
HFC-41	CH_3F	150
HFC-43-10mee	$C_5H_2F_{10}$	1300
HFC-125	C_2HF_5	2800
HFC-134	$C_2H_2F_4$ (CHF_2CHF_2)	1000
HFC-134a	$C_2H_2F_4$ (CH_2FCF_3)	1300
HFC-152a	$C_2H_4F_2$ (CH_3CHF_2)	140
HFC-143	$C_2H_3F_3$ (CHF_2CH_2F)	300
HFC-143a	$C_2H_3F_3$ (CF_3CH_3)	3800
HFC-227ea	C_3HF_7	2900
HFC-236fa	$C_3H_2F_6$	6300
HFC-254ca	$C_3H_3F_5$	560
Perfluorocarbons (PFCs)		
Perfluoromethane	CF_4	6500
Perfluoroethane	C_2F_6	9200
Perfluoropropane	C_3F_8	7000
Perfluorobutane	C_4F_{10}	7000
Perfluorocyclobutane	c-C_4F_8	8700
Perfluoropentane	C_5F_{12}	7500
Perfluorohexane	C_6F_{14}	7400
Sulphur hexafluoride		
Sulphur hexafluoride	SF_6	23900

The report co-ordinator **compiles the submitted report texts to form the NIR draft**. Experts in the Single National Entity (national co-ordinating agency), assigned to cover specific source categories, then carry out **internal review of the data and report sections**, 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. Following such revision, the report co-ordinator carries out overall editing of the NIR.

Formal approval takes place for the CRF-reporting tables and the NIR, and of the inventory plan to be included in future. Within the Federal Environmental Agency, this is granted via a co-signing process. The documents are then **forwarded to the BMU** for **inter-ministerial co-ordination**. The ministry arranges for translation of the NIR and for **its submission to the UNFCCC Secretariat**.

The data tables and the related NIR, in the version provided for inter-ministerial co-ordination, are then transferred onto a CD and archived with clear identification information. The content of the CSE database used for calculation purposes is likewise copied and archived. The final version submitted to the Secretariat of the Framework Convention on Climate is also **archived**.

1.4 Brief general description of methodologies and data sources used

1.4.1 Data sources

1.4.1.1 Energy

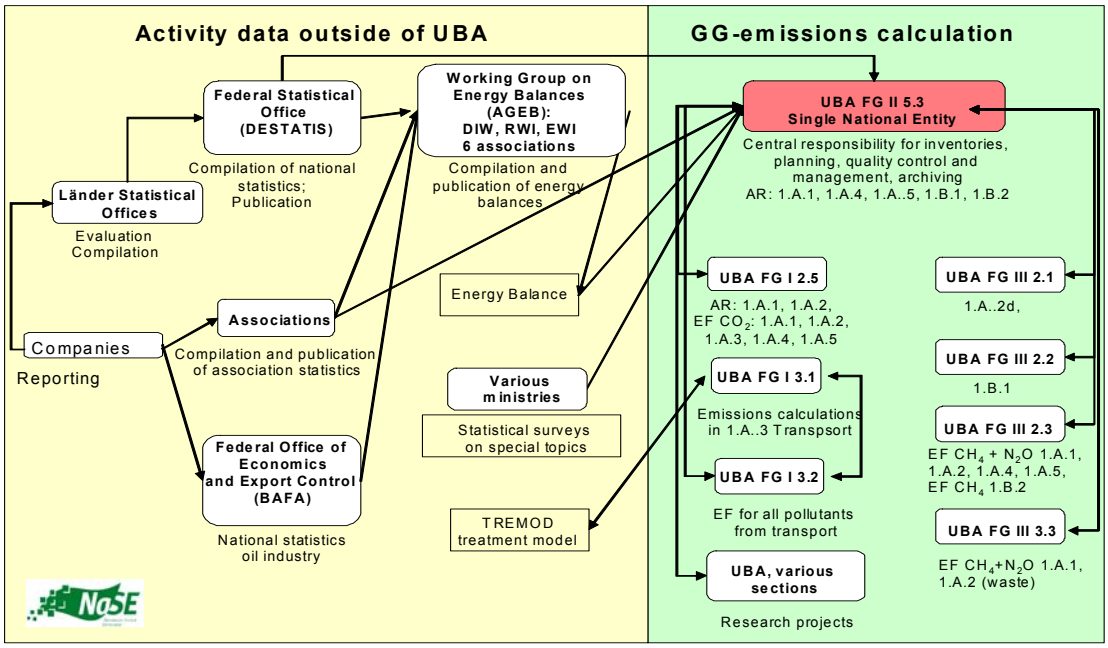


Figure 7: Responsibilities and data flows for calculation of greenhouse-gas emissions in the energy sector (ÖKO-INSTITUT, 2004a)

In all likelihood, the most important data sources for determination of activity rates in the CSE are the *"Energiebilanzen der Bundesrepublik Deutschland"* (Energy Balances of the Federal Republic of Germany, hereinafter referred to as: Energy Balance), which are published by the *Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen)*. An energy balance provides an overview of the links within Germany's energy sector, and it supports breakdowns in accordance with fuels and source categories. The Energy Balance receives data from a wide range of other sources. As a result, publication of the Energy Balance is subject to some delay. The most current of the available Energy Balance describes the year 2000.

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 at the same time as the Energy Balance.

Also along with the Energy Balance, the Working Group on Emissions Balances (AGEB) also publishes "Evaluation Tables for the Energy Balance" (*Auswertetabellen zur Energiebilanz*, hereinafter referred to as: Evaluation Tables). In the area of fuels, these tables only list those fuels with the highest activity levels and aggregate lower activity levels to form sum values (such as *other solid fuels*). Breakdowns according to specific source categories are limited

largely to source categories in which final energy is consumed (such as the *manufacturing sector* or *transport*). Some source categories are not listed (such as *production of district heat*). The evaluation tables are published relatively promptly (in the summer of the relevant subsequent year). The tables can be used to determine aggregated activities at the source-category levels for the most commonly used fuels. Further disaggregation can be achieved via formation of relevant differences using other statistics.

At short intervals (one to two years), the Association of Industrial Energy and Power Producers (*Verband der Industriellen Energie- und Kraftwirtschaft (VIK) e.V.*) publishes Energy-Sector Statistics (*Statistik der Energiewirtschaft*, hereinafter referred to as: VIK Statistics). The VIK Statistics include data on power generation, types of facilities and fuel consumption. Their data is broken down extensively, in accordance with both source categories and types of facilities. The VIK Statistics are normally published within a little over a year after the relevant data has been collected.

Another important data source for determining activity rates in the CSE consists of the *Fachserien 4 (technical series) Reihe (series) 4.1.1, Reihe 6.4 and Reihe 8.1* (hereinafter referred to as: Fachserie 4) of the *Federal Statistical Office*. These publications contain data on production-related fuel consumption, and on facilities and plants, in the manufacturing and mining sectors. This data is published relatively promptly after collection (about one year), and it is broken down finely in accordance with various areas of the manufacturing sector. Some of this data is also included in the VIK Statistics.

Calculations with the Federal Environmental Agency's module (cf. Chapter 3) are also based on the statistics *Leistung und Arbeit* ("Performance and Work") and *Betriebsmittel* ("Operating Equipment") of the German Electricity Association (*Verband der Elektrizitätswirtschaft; VDEW e.V.*, hereinafter referred to as: VDEW Statistics). These statistics include performance data for power stations and steam production, as well as data on electricity generation. The VDEW Statistics have been discontinued. For this reason, it is not possible to update their data in the near term.

Yet another data source is the publication "Petroleum Data" (*Mineralöl-Zahlen)* of the Association of the German Petroleum Industry (*Mineralölwirtschaftsverband; MWV e.V.*, hereinafter referred to as: MWV Statistics). This publication contains data on supply and consumption of petroleum in Germany, and it is broken down by source categories. The statistical data as published is very current (publication takes place within just a few months after the relevant survey).

Transport emissions are calculated primarily with the TREMOD model (“Transport Emission Estimation Model”; IFEU, 2003b)[8]. For calculation with TREMOD, extensive basic data from generally accessible statistics and special surveys was used, co-ordinated, and supplemented.

8 To permit derivation and evaluation of reduction measures, TREMOD is also used to calculate the energy consumption and CO_2 emissions of the individual vehicle categories. The values are subsequently aligned with total consumption and total emissions of CO_2.

1.4.1.2 Industrial processes

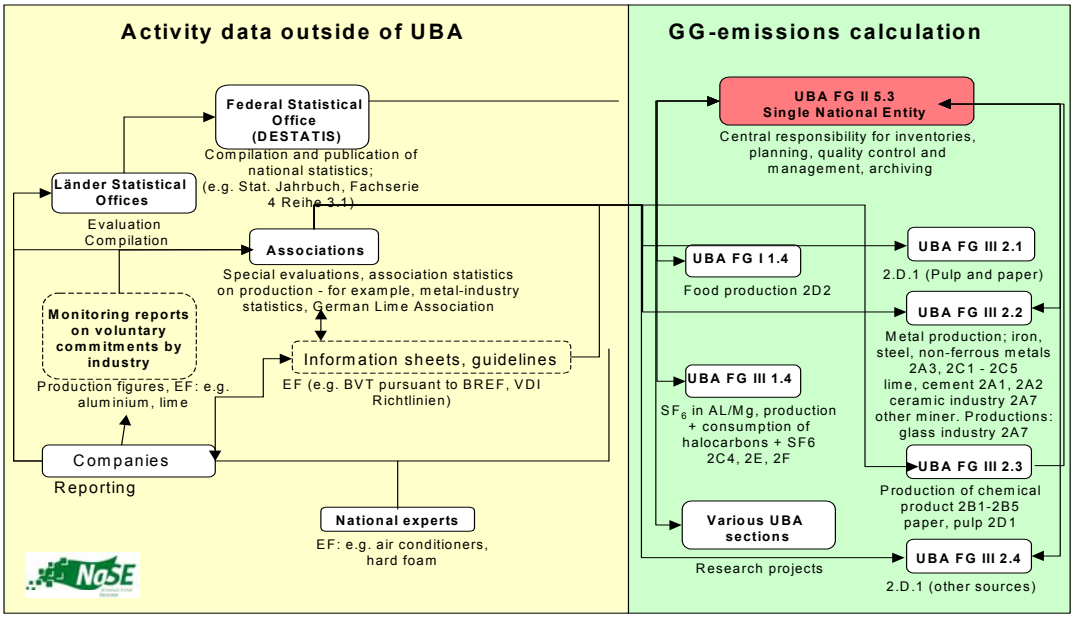


Figure 8: Responsibilities and data flows for calculation of greenhouse-gas emissions from industrial processes (ÖKO-INSTITUT, 2004a)

Various different sections within the Federal Environmental Agency are responsible for providing data for calculation of emissions from industrial processes.

Activity data is calculated on the basis of *Fachserie 4 Reihe 3.1* (Produktion im Produzierenden Gewerbe; Production in the manufacturing sector) and *Reihe 8.1* (Fachstatistik Eisen und Stahl; technical statistics for iron and steel) of the *Federal Statistical Office (DESTATIS Fachserie 4 Reihe 3.1, 1991-2004; DESTATIS Fachserie 4 Reihe 8.1, 1991-2004)*. These publications contain production data for the manufacturing sector. Reihe (Series) 3.1 appears on a quarterly and yearly basis, while Reihe 8.1 appears monthly and quarterly – i.e. both provide very current statistics.

Calculation of emissions from some industrial processes also draws on production data in *Verbandsstatistiken* (Association Statistics) and data from *Monitoringberichten* (Monitoring Reports*)* (cement clinkers, lime, primary aluminium production), data which industry, in the framework of monitoring of industry's compliance with its voluntary commitment on climate protection, has reported for several years and has been compiled and published by RWI (Rheinisch-Westfälisches Institut für Wirtschaftsforschung). The monitoring reports, however, are also based partly on data from industry *associations*. Prior to using such data sources, the Federal Environmental Agency checks the extent to which the relevant data covers all of the production for the source category in question.

In the area of consumption and production of halogenated hydrocarbons and SF_6, direct use is made of *manufacturers' data* and *surveys of manufacturers*, due to a lack of reliable statistical data. The great majority of the activity rates were researched directly in accordance with the inventory requirements, in the framework of a research project. Each of the various sub- source categories contains only a few companies.

Emission factors are obtained from national and international fact sheets and directives or via surveys of experts; where necessary, default values are used. More detailed pertinent information is presented in the descriptions of methods for the various source categories.

1.4.1.3 Solvent and other product use

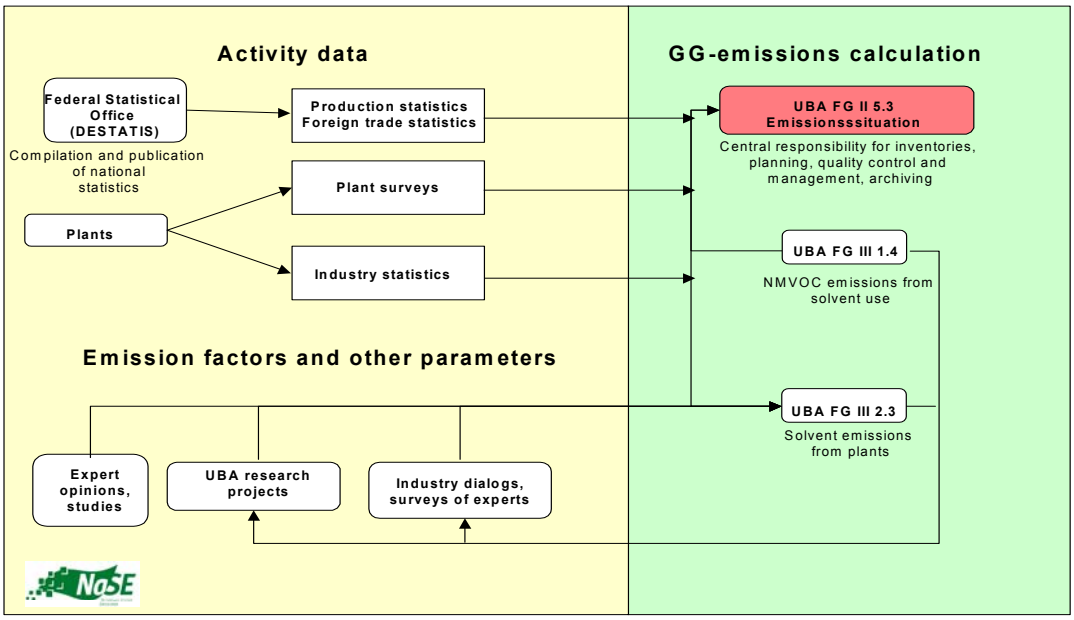


Figure 9: Responsibilities and data flows for calculation of greenhouse-gas emissions from use of solvents and other products (ÖKO-INSTITUT, 2004a)

In the area of calculation of emissions from use of solvents and other products, the Federal Environmental Agency's section (FG) III 1.4 is responsible for selecting the methods, parameters and data used for calculating NMVOC emissions. The Federal Environmental Agency's section III 2.4, which supports section III 1.4 in the framework of that section's "global responsibility", is responsible for the sub-group of solvent emissions from facilities (such as painting, printing, etc.). The Federal Environmental Agency has not yet specified internal responsibilities for determining N_2O emissions from products.

Activity data is drawn mainly from published statistics of the Federal Statistical Office (DESTATIS), especially from its statistics on production and foreign trade. In some source categories and industry sectors, industry statistics are also used. Older surveys of facilities are used in the area of N_2O emissions from narcotic uses.

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

1.4.1.4 Agriculture

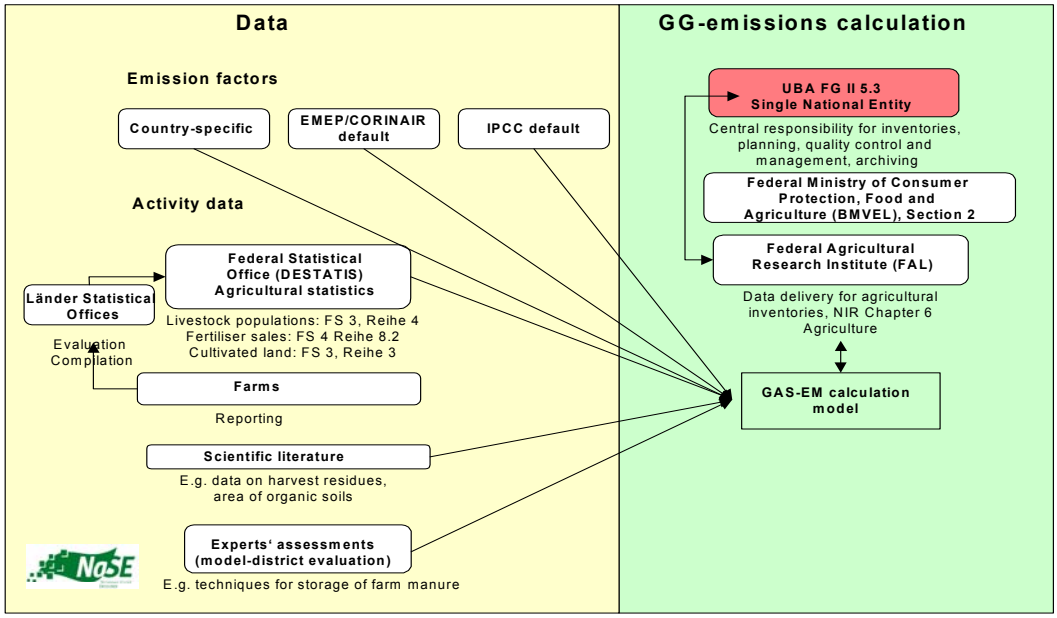


Figure 10: Responsibilities and data flows for calculation of greenhouse-gas emissions from agriculture (ÖKO-INSTITUT, 2004a)

Calculation of emissions for Chapter 6 (agriculture) is carried out by the Federal Agricultural Research Institute (FAL). For calculation of agricultural emissions in Germany, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and the Federal Ministry of Consumer Protection, Food and Agriculture (BMVEL) initated a suitable joint project, in the framework of which the FAL developed a modular model for relevant spread-sheet calculation (GASeous Emissions, GAS-EM) (Dämmgen et al, 2002). The BMU and BMVEL now have a framework ministerial agreement in place for management of relevant data and information exchange and for operation of a joint database at the UBA and the FAL.

Agricultural statistics of the Federal Statistical Office are another important data source for calculation of agricultural emissions. Animal statistics have been taken from the Federal Statistical Office's relevant specialised *Fachserie* 3, *Reihe* 4 (DESTATIS Fachserie 3 Reihe 4: no year). Other specialised series present statistics on fertiliser sales and on agricultural areas under cultivation. In some areas, such data is supplemented by figures from the pertinent literature (for example, harvest residues and area of organic soils). Additional data is available from experts' estimations (for example, an evaluation of model districts with regard to techniques for storing farm fertilisers).

In many areas, calculations for the agricultural sector are based on simpler methods (EMEP/CORINAIR) or on Tier 1 methods – on methods that use standard emission factors from the Revised 1996 IPCC Guidelines or from the EMEP/CORINAIR manual of the United Nations Economic Commission for Europe (UN ECE). In addition, in a number of areas *country-specific* factors and parameters are used that have been taken from research projects and the literature and that the FAL has also compiled and integrated within the calculation model.

1.4.1.5 Land-use changes and forestry

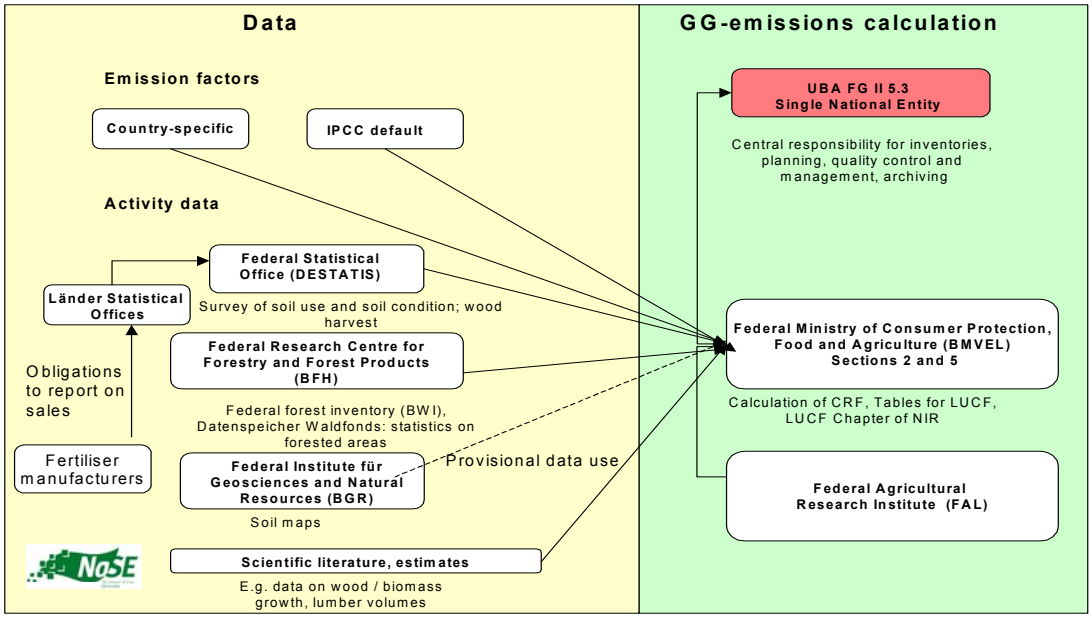


Figure 11: Responsibilities and data flows for calculation of greenhouse-gas emissions from the area of land-use changes and forestry (ÖKO-INSTITUT, 2004a)

Calculation of changes in carbon-stocks in forest biomass was carried out by Baden-Württemberg's Forest Research Institute (Forstliche Versuchs- und Forschungsanstalt (FVA) Baden-Württemberg), under commission to the Federal Ministry of Consumer Protection, Food and Agriculture (BMVEL). For the first time, data from two Federal Forest Inventories (BWI) was evaluated for this purpose. It was thus possible to derive the changes from a direct comparison of the stocks measured in the two inventories. Since no BWI I data was available for the new Länder, forest-management data from the BML (then Federal Ministry for Food, Agriculture and Forestry; 1994), for that area, was used for comparison purposes. For further information, cf. Chapter 7.1. The activity data is based on figures from the Federal Forest Inventory (BWI) and the Datenspeicher Waldfonds.

As to determination of usage changes on agricultural areas, no activity data is yet available that fully meets quality requirements in this category. The activity data on CO_2 emissions and CO_2 storage in the soil need to be supported by data on agricultural areas, as well as by quantitative and qualitative information (differentiated by types of usage and cultivation) for identification of land-use changes and by data for determination of carbon stocks in soils and in biomass. The relevant data used in these areas, which was taken from the area survey and from the main survey on soil use (Bodennutzungshaupterhebung; managed by the Federal Statistical Office), is available only aggregated by area; for this reason, the data can be used only in combination with additional data sources (e.g. remote sensing: CORINE Landcover) and with mathematical models developed especially for this case (and based on legal requirements and on empirical data). Soil carbon stocks are estimated with the help of soil maps provided by the Federal Institute for Geosciences and Natural Resources (BGR), while use-related changes in these stocks are estimated using emission factors derived from the scientific literature via multiple regression.

Changes in biomass carbon stocks are estimated on the basis of harvest statistics, the main survey on soil use (Bodennutzungshaupterhebung) and specific factors given in the pertinent

scientific literature. Emissions from liming of soils are determined with the help of data, taken from Federal fertiliser statistics, on domestic sales of mineral fertilisers that contain lime and other nutrients. The fertiliser industry is legally required to disclose its sales. In the first survey of the condition of forest soils (1987-1993) measured soil-carbon stocks in forests in the early 1990s, but it did not determine changes in stocks over time.

1.4.1.6 Waste and wastewater

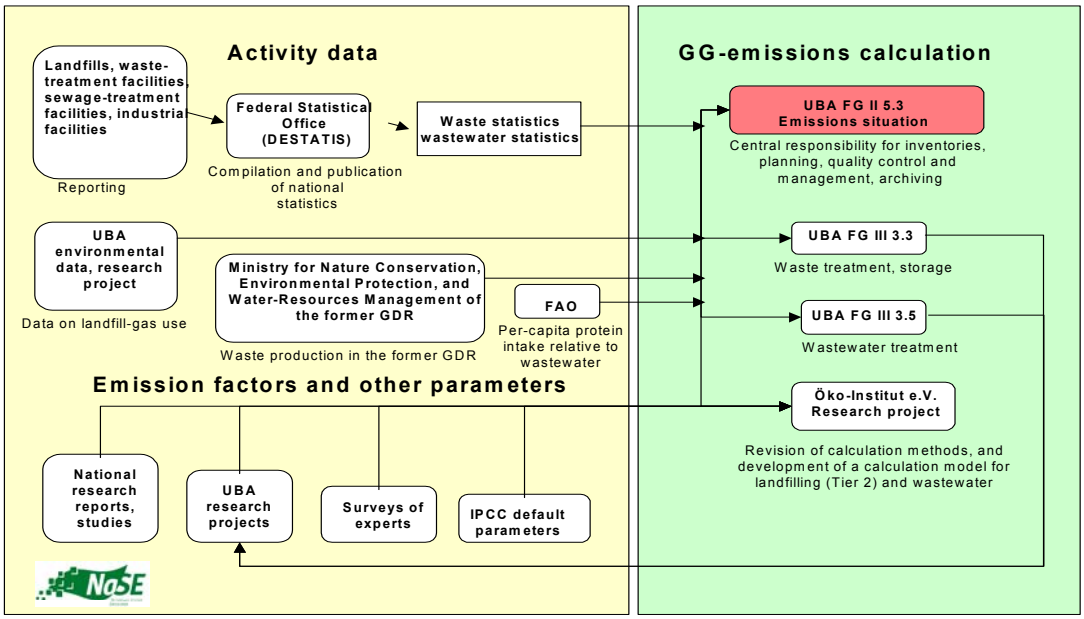


Figure 12: Data flows for calculation of greenhouse-gas emissions from the area of waste (ÖKO-INSTITUT, 2004a)

Section FG III 3.3 is responsible for selecting the methods, parameters and data for calculating emissions from the waste sector. In recalculation of landfill emissions in 2003, the Federal Environmental Agency was supported by a research project (development of the Tier 2 method for the Federal Republic of Germany) (ÖKO-INSTITUT, 2004b).

Activity data in the waste sector is drawn mainly from published data of the Federal Statistical Office (DESTATIS), 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 on landfill-gas use are based on data from the publication "Daten zur Umwelt" (environmental data), which is published regularly by the Federal Environmental Agency. For 2001, data was also taken from a current research project.

The emission factors and other parameters that enter into calculation of emissions from waste landfilling and composting were taken from national studies and research reports conducted/prepared in research projects commissioned directly by the Federal Environmental Agency. IPCC default parameters were also used for this purpose. Individual 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.

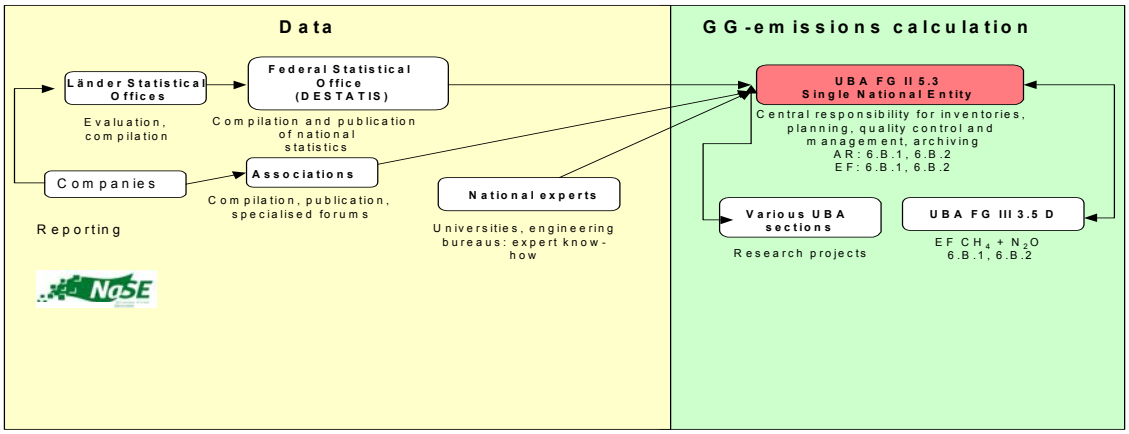


Figure 13: Data flows for calculation of greenhouse-gas emissions from the area of wastewater (ÖKO-INSTITUT, 2004a)

Section FG III 3.5 is responsible for selecting the methods, parameters and data for calculating emissions from the wastewater and sludge-treatment sector.

Activity data in the wastewater sector is drawn mainly from published data of the Federal Statistical Office (DESTATIS), 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 has been 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 reports conducted/prepared in research projects commissioned directly by the Federal Environmental Agency. IPCC default parameters were 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).

1.4.2 Methods

The methods used for the individual source categories are outlined in the overview tables for the various source categories and in summary tables 3s1 and 3s2 of the CRF reporting tables. For the individual calculation methods, a distinction is made between country-specific (cs) methods and IPCC "*Tiers",* in keeping with the source category[9].

With the exception of CO_2 emissions, road-transportation greenhouse-gas emissions were calculated with the help of the TREMOD model, which is based on a bottom-up Tier 2/3 approach. In compliance with the information from the Energy Balance for the Federal Republic of Germany, CO_2 emissions are calculated on the basis of a top-down Tier 1 approach.

For industrial processes, in many areas detailed IPCC tiers were used for the greenhouse gases HFC, PFC and SF_6. This was possible, in particular, because emissions for these greenhouse gases were surveyed specifically for emissions reporting, within the context of a new R&D project, and the relevant data was collated specifically with a view to application of the IPCC methods.

9 *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.

For agriculture, emissions were calculated primarily on the basis of the CORINAIR Guidebook, using IPCC default emission factors. country-specific methods were applied only for agricultural soils (4.D).

In the framework of the R&D project 201 42 258, calculation for the waste sector was modified in line with the IPCC Tier 2 approach, and relevant new national data sources were developed (ÖKO-INSTITUT, 2004a).

All other source categories were shown in the IPCC Summary Tables as country-specific calculation methods. In this respect, it should be noted that the German inventories are currently being subjected to an intensive review process in which compliance of the applied methods with the IPCC approach is being systematically reviewed for the first time, and methodological changes are being implemented in order to conform to the Good Practice Guidance. As this methodological review is not yet complete, certain methods in the Summary Tables have been listed as country-specific even if it is not yet known whether IPCC conformity exists or which tier has been used. However, in the case of energy-related activity data, it can be assumed that Tier 1 has been used as a minimum. For other areas, too, classification will change from "country-specific" to IPCC tiers, since methodological conformity will either be ascertained or created during the course of the year.

1.5 Brief description of key sources

The key sources were defined by applying two Tier 1 procedures, Level (for 1990 and 2003) and Trend (for 2003, as compared to 1990), to German greenhouse-gas emissions in the source categories pursuant to Annex A of the Kyoto Protocol.

For 2003, this approach identified 30 source categories, out of a total of 177 source categories studied, as key sources. Only 23 of these were identified, by both Trend and Level analysis, as key sources. In addition, 5 source categories were identified as key sources solely by Trend analysis, and 3 source categories were so identified solely by Level analysis. Combination of the results of both types of analysis shows that a total of 96.3 % of greenhouse-gas emissions – 982,242 Gg CO_2-equivalent emissions – in 2003 were released by the key sources. Identification of these source categories was based to a degree of 85 % on release of CO_2, to a degree of 9.7 % on CH_4 emissions, to a degree of 4.1 % on release of N_2O and to a degree of only about 1.2 % on F-gas emissions. This is largely in keeping with the relevant overall relationships in the greenhouse-gas inventory.

The result of the Level analysis for 1990, which is included for purposes of comparison, is largely in keeping with results for 2003. An overview of the results of the key-source analysis is provided in Table 4. Annnex 1 (Chapter 12) of this report presents detailed explanations of the key-source analysis carried out.

Table 4: Key sources for Germany pursuant to the Tier 1 approach

IPCC SOURCE CATEGORIES	ACTIVITY	EMISSIONS OF	LEVEL 1990	LEVEL 2003	TREND 2003
1A1a Public electricity and Heat production	Gaseous Fuels	CO_2	●	●	
1A1a Public electricity and Heat production	Liquid Fuels	CO_2	●	●	●
1A1a Public electricity and Heat production	Solid Fuels	CO_2	●	●	●
1A1b. Petroleum Refining	Liquid Fuels	CO_2	●	●	●
1A1b. Petroleum Refining	Solid Fuels	CO_2			●
1A1c. Manufacture of Solid Fuels and Other Energy Industries	Solid Fuels	CO_2	●	●	●
1A2a-f. Manufacturing Industries and Construction total	Gaseous Fuels	CO_2	●	●	●
1A2a-f. Manufacturing Industries and Construction total	Liquid Fuels	CO_2	●	●	●
1A2a-f. Manufacturing Industries and Construction total	Other Fuels	CO_2			●
1A2a-f. Manufacturing Industries and Construction total	Solid Fuels	CO_2	●	●	●
1A3a. Transport Civil Aviation	Aviation Gasoline	CO_2		●	●
1A3b. Transport Road Transportation	Diesel Oil	CO_2	●	●	●
1A3b. Transport Road Transportation	Gasoline	CO_2	●	●	●
1A3b. Transport Road Transportation	Gasoline	N_2O			●
1A3e. Transport Other Transportation	Liquid Fuels	CO_2	●		
1A4a. Other Sectors Commercial/Institutional	Gaseous Fuels	CO_2	●	●	●
1A4a. Other Sectors Commercial/Institutional	Liquid Fuels	CO_2	●	●	●
1A4a. Other Sectors Commercial/Institutional	Solid Fuels	CO_2	●		●
1A4b. Other Sectors Residential	Gaseous Fuels	CO_2	●	●	●
1A4b. Other Sectors Residential	Liquid Fuels	CO_2	●	●	●
1A4b. Other Sectors Residential	Solid Fuels	CO_2	●		●
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Liquid Fuels	CO_2	●	●	
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Solid Fuels	CO_2	●		●
1A5 Other Include Military fuel use under this category	Liquid Fuels	CO_2	●		●
1A5 Other Include Military fuel use under this category	Solid Fuels	CO_2	●		●
1B1a. Fugitive Emissions from Fuels Coal Mining and Handling	Solid Fuels	CH_4	●	●	●
1B2b. Fugitive Emissions from Fuels Natural Gas	Natural Gas	CH_4	●	●	●
2A1. Mineral Products Cement Production		CO_2	●	●	●
2A2. Mineral Products Lime Production		CO_2	●	●	
2B2 Chemical Industry	Nitric Acid Production	N_2O	●	●	●
2B3 Chemical Industry	Adipic Acid Production	N_2O	●	●	●
2C3. Aluminium Production		PFC´s			●
2C4. SF_6 Used in Aluminium and Magnesium Foundries		SF_6			●
2E. Production of Halocarbons and SF_6	production of HCFC-22	HFC´s	●		●
2F. Industrial Processes	Consumption of Halocarbons and SF_6	HFC´s		●	●
2F. Industrial Processes	Consumption of Halocarbons and SF_6	SF_6	●		
4A.1. Enteric Fermentation	Dairy Cattle	CH_4	●	●	
4A.1. Enteric Fermentation	Non-Dairy Cattle	CH_4	●	●	●
4B1. Manure Management	Dairy Cattle	CH_4	●	●	
4B1. Manure Management	Non-Dairy Cattle	CH_4	●	●	●
4B8. Manure Management	Swine	CH_4	●	●	●
4D3. Agricultural Soils	Indirect Emissions	N_2O	●	●	
4D1. Agricultural Soils	Direct Soil Emissions	N_2O	●	●	●
6A1 Managed Waste Disposal on Land	Solid Waste Disposal on Land	CH_4	●	●	●
6B2. Wastewater Handling	Domestic and Commercial Wastewater	CH_4			●

1.6 Information on the QA/QC plan

Although to date the individual data stocks of the inventory have been continuously reviewed and updated, there has so far been no systematic evaluation of all inventory data up until the year 2002. Research project 202 42 266 (UBA, 2004), which is aimed at implementing the *Good Practice Guidance* requirements in inventory preparation, is carrying out relevant systematic evaluation and determining the pertinent uncertainties (cf. Chapter 1.7).

As part of the same overall effort, a central quality-assurance and quality-control plan for the German inventory is being prepared. This work had not been completed by the time the present report was prepared, however.

Pursuant to the IPCC *Good Practice Guidance* requirements, 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.

A QC/QA plan is to have the following basic structure:

- Annually updated overview of QC/QA measures implemented throughout the process from data collection to reporting, and consisting of:
  a) Routine QC/QA measures pursuant to Tier 1,
  b) Source-category-specific QC/QA measures pursuant to Tier 2,
  c) Process-oriented QA measures;
- Annual schedule planning, from data collection to final reporting;
- Matrix showing responsibility for carrying out QC and QA measures, including managing the QC/QA plan and the pertinent improvement plan.

A QC/QA plan applies to the relevant report year. It is prepared, managed and annually updated by the QC/QA co-ordinator.

Since November 2003, the National Single Entity (national co-ordinating agency) has carried out its data and report evaluations immediately upon receiving the relevant documents from experts for specific source categories. During trial operation, checking is carried out with the help of a checklist showing the general checking criteria (cf. Chapter 17.2.2). In general, the following materials are taken into account:

- Review report by the Climate Secretariat (reference to problem areas, errors)
- Key-source analysis (for assessing relevance)
- Previous year’s data stock in the CSE and related description in the NIR (as a basis for work)
- Previous year's CRF report tables (as a basis for work)
- Rules for aggregation and for correlation between the CSE and CRF structures (as a basis for work)
- Source-specific information which has come to the attention of the Single National Entity in the interim.

1.7 General assessment of uncertainties

IPCC Good Practice Guidance characterises determination of uncertainties as a key element of any complete inventory. As a result of the GPG's focus on continual inventory improvement, 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. Annex I countries must thus first quantify the uncertainties for all source categories and sinks, in order to enhance their understanding of inventory quality – which understanding is the key to effective inventory planning.

Uncertainties are quantified for emissions factors and activity data. This necessitates determination of 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' estimations.

In general, two methods for determining uncertainties are differentiated. The Tier 1 method combines, in a simple way, the uncertainties in activity rates and emission factors, for each source category and greenhouse gas, and then aggregates these uncertainties, for all source 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.

Research project 202 42 266 (UBA, 2004) carried out improved uncertainties determination in keeping with Tier 1 and Tier 2, pursuant to Chap. 6 of GPG[10)]. Plans for 2005 call for further improving this database and for completing uncertainties information for the greenhouse-gas inventory, to make it possible to report the inventory's uncertainty pursuant to the Tier 2 method. The relevant basis for this effort is currently being created.

In the current NIR, Germany reports uncertainties that have been calculated pursuant to the Tier 1 method. In determination of uncertainties in accordance with Tier 1, the uncertainties were estimated, wherever possible, by data-providing experts of the relevant Federal Environmental Agency sections and by external institutions. Table 5 provides an overview of the current known national uncertainties, as identified via completed experts' judgements:

10 **G**ood **P**ractice **G**uidance and **U**ncertainty **M**anagement in National Greenhouse Gas Inventories

Table 5: Completed experts' judgements for determining uncertainties pursuant to Tier 1

CRF	Name	Sub - source category	AR	EF CO_2	EF CH_4	EF N_2O	EF PFC	Remarks
1A	Energy - fuel combustion activities	stationary sources	-	2002	2002 1990	2002 1990	NE	Complete uncertainty information (apart from small gaps)
1B2	Energy – fugitive emissions from fuels - oil and natural gas		2002 1990	NE	2002 1990	NE	NE	Complete uncertainty information, except for gas-distribution networks
2A1.	Industrial processes - cement production		-	2002	NE	NE	NE	
2A2	Industrial processes – lime production		-	2002	NE	NE	NE	
2C1	Industrial processes - iron and steel production		-	2002 1990	2002 1990	NE	NE	
2C3	Industrial processes - aluminium production		-	2002 1990	NE	NE	2002 1995	

For source categories that have not yet been assessed, the uncertainties underlying the adjustment procedure's "Conservativeness Factors" were used as provisional aids (FCCC/SBSTA/2003/ 10/Add.2). The results of the Tier 1 uncertainties analysis are described in detail in Annex 7, Chapter 18. The values used as provisional aids are marked with the quality indicator "D" (default).

1.7.1 Procedure for determining uncertainties pursuant to Tier 1, Chap. 6 of the GPG

For determination of uncertainties pursuant to Tier 1, experts' judgements were carried out in keeping with the guidelines in the GPG Chap. 6.2.5, "Expert Judgement". Experts' judgements were carried out in accordance with a manual, and they made use of the current time series in the CSE for the years 1990 and 2003 and of all relevant available information. This includes the following questions:

- Are there comparable emissions sources with known uncertainties (transferability)?
- How well is the emissions process in question understood? Have all sources been taken into account?
- Do any physical limits apply to the emission factor (for example, as a result of the relevant mass balance, of the observed immissions values or of other process data)?
- Is the emissions data consistent with the observed immissions values?

Before the actual experts' judgement is carried out, the relevant source category's boundaries and its spatial and chronological references have to be precisely defined. This is accomplished by taking the current time series in the CSE into account, along with the time-series dimensions defined for the CSE. In the actual experts' judgement, intervals are defined. This process consists of estimating upper and lower limits, along with a most probable value. Then, these values are assigned a distribution. The distributions to select from include normal, log-normal and triangular distributions.

Where very little information is available for a given source category, only the extreme values are estimated. A uniform distribution of probabilities is then assumed for this interval.

Where adequate information is available, the experts' judgement can also be made step-by-step.

The results of the experts' judgement are recorded in a formalised way. In the process, reasons are provided for the assessment and the pertinent underlying information is documented.

With regard to degree of detail, uncertainties analysis was also carried out at the "key-source-analysis" level.

At present, uncertainties analysis does not cover the LULUCF area.

1.7.2 Results of assessment of uncertainties

Pursuant to the Tier 1 analysis carried out for the year 2003, the overall uncertainty of the greenhouse-gas inventory amounts to +/- 5.6 %. Furthermore, the analysis has found an uncertainty of +/- 4.3 % for emissions development since 1990 (trend).

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

- Pursuant to the results from 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 monitored in normal cases. The same applies to the emission factors for CH_4.

- The uncertainties in the transport source category (primarily CRF 1 A 3) can generally be considered to be small, since precise relevant data on fuel use and vehicle fleets is 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 source category of fugitive emissions from fuels (CRF 1.B), the activity rates for oil and natural gas (CRF 1.B.2) include slight uncertainties of +/- 1 %, resulting from the fuels' being subject to taxation. The uncertainty for flaring of natural gas, at +/- 10 %, is an exception. The activity rates for coal mining (CRF 1.B.1) are also well-represented by production volumes. The uncertainties for emission factors for fugitive emissions are considerably higher. On the one hand, this results from the many different technical factors that affect fugitive emissions in transport, storage and

processing of oil and natural gas. On the other hand, fugitive CH_4 emissions from coal mining have thus far been taken into account only as lump sums.

- Considerable uncertainties must be expected in the area 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 in the association in question is organised. Among EF emission factors, uncertainties – which can be considerable, depending on the greenhouse gas in question – result, from strong technical dependence, coupled with extensive technical 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 provide relevant consolidated information. In addition, the uncertainties can be increased in that processes whereby non-combustion-related activities generate emissions are often very complex, in that too little is known about certain emissions-generating processes and in that too little is known about the relevant contributions of individual activities.

- In the area of production of alcoholic beverages, within the area of food and drink production (CRF 2.D.2), the activity-rate uncertainties must be considered very small, since production of such beverages is subject to taxation regulations that require production volumes to be determined very precisely. The uncertainties for the relevant emission factors are considerably larger, due to the industry's extensive technological diversification.

- The uncertainties for emissions parameters for the source categories managed waste disposal on land (CRF 6.A.1) and industrial wastewater (CRF 6.B.1) are presumed to be large. This applies especially to waste landfilling, since the diversity of the waste types involved tends to reduce the reliability of data for the relevant emissions parameters. The uncertainties for the activity rates are also disproportionately high, since the underlying statistics make use of non-standardised waste and recycling definitions. The general assumptions relative to the uncertainties of activity rates also apply to thermal treatment of waste.

Detailed information about the applicable uncertainties is provided in Annex 7 (cf. Chapter 18).

1.8 General checking of completeness

In 1998, the Federal Environmental Agency began to identify data gaps in the emission inventories and to examine the opportunities for closing these gaps. This work was stepped up particularly against the background of the development of the CSE, since it was important to transfer the existing decentralised data stocks on the inventories into the central database. Hence, in two R&D projects (FKZ: 298 42 759 and 298 42 289), a concept was developed for the reorganisation of data records on emissions and sinks. Apart from an overall concept on data maintenance, the results included a clear representation of current reporting capabilities, as well as a catalogue of gaps. The overall documentation concept has now

been integrated within the prepared CSE and, in the framework of a research project (FKZ 298 42 259), has been adapted to harmonised international reporting obligations (NFR and CRF). It is being taken into account in the national review that is now in progress. In addition, the catalogue of gaps has been updated in keeping with new research findings.

Details of completeness for the individual source categories are represented in CRF Tables 7s1, 7s2 and 7s3. A distinction is made between source-specific emissions and sinks not occurring (NO) in Germany, source-specific emissions and sinks not estimated (NE) in Germany because they are either quantitatively irrelevant or because the necessary data for an estimate is not available, and source-specific emissions and sinks which are completely (all / full) recorded according to the current status of knowledge, or partially recorded (part).

The following section touches on a few source-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). The separation of combustion-related and non-combustion-related emissions from industry has posed a number of difficulties; here, however, the avoidance of duplicate counting is generally an integral component of quality assurance.

Whereas fuel use for heat and power generation in the manufacturing sector, along with the relevant emissions, is recorded completely in the inventory, uncertainties persist in assignment of fuel use to the six source categories the inventory requires (1.A.2a through f). This can be partly attributed to contradictions between the Energy Balance and the Federal Statistical Office's data with regard to certain fuels (such as waste). To date, even experts in the field have been unable to resolve the discrepancies completely. These difficulties do not affect total fuel use or emissions in the manufacturing sector, however.

In analysis of gaps, considerable additional clarification is needed especially with regard to activity rates, in the areas of coking plants and refineries, for blast-furnace gas, top gas and refinery gas, and with regard to data on pit-gas use.

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 source-category definitions and data-collection methods will continue to receive priority. In the area of industrial processes, no calculations are currently being made for the source categories 2.A.3 (limestone and dolomite use), 2.A.4 (soda ash production and use), 2.A.5 (asphalt roofing) and 2.C.2 (ferroalloys production). These source categories are not covered by the IPCC Good Practice Guidance, since the emissions from these categories are considered insignificant and since data for these source categories is usually not available. Both of the reasons that the IPCC gives for not covering these groups also apply to Germany.

In the area of agriculture, while survey data from a past research project on management systems in animal husbandry is available, an effort is being made to carry out periodic, representative data surveys, in the interest of the inventory's continuing completeness and consistency.

Some of the emissions data available to the Federal Environmental Agency is confidential, due to data-protection requirements, and thus is reported only in aggregated form – although it is reported completely. For review of inventory data, the Federal Environmental Agency is searching for ways to be able to check data completely, secrecy requirements notwithstanding.

In the framework of the R&D project 201 42 258, other countries' inventory data under the category "other sources" was analysed (ÖKO-INSTITUT, 2004a) in support of systematic review of completeness of national emissions data. This study was designed to show which of the source categories other countries report on are also emissions-relevant in Germany – in order to expand German inventories accordingly, if necessary. This analysis showed that systematic review for completeness needs to be expanded, especially in the area of industrial processes, and it revealed that other countries treat geothermal systems – which Germany's reporting does not cover – as emissions-relevant. The results of this analysis will be incorporated in inventory planning.

2 TRENDS IN GREENHOUSE GAS EMISSIONS

Table 6: Emissions of direct and indirect greenhouse gases and SO_2 in Germany since 1990

Emissions of greenhouse gases and of SO_2 in Germany, 1990 – 2003 [Gg]#)														
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Directly acting greenhouse gases														
CO_2	1015031	976937	929451	920046	905626	902213	924908	893529	885201	857419	860091	873862	863877	865367
CH_4	6290	5766	5592	5372	5175	4996	4786	4628	4374	4212	3948	3777	3642	3582
N_2O	279	267	272	261	262	261	265	255	212	200	201	202	199	205
HFC 1)	3510	3547	3677	4950	5178	6360	5768	6356	6979	7280	6630	8130	8247	8247
CF_4 [Mg]	*355*	*308*	*278*	*260*	*214*	*224*	*214*	*161*	*172*	*137*	*72*	*69*	*76*	*76*
C_2F_6 [Mg]	*42*	*38*	*36*	*35*	*31*	*32*	*34*	*32*	*34*	*31*	*24*	*18*	*20*	*20*
C_3F_8 [Mg]	*0*	*0*	*0*	*0*	*0*	*1*	*3*	*5*	*8*	*10*	*14*	*15*	*16*	*16*
SF_6 [Mg]	*166*	*182*	*204*	*226*	*243*	*278*	*266*	*262*	*253*	*193*	*168*	*139*	*176*	*176*
CO_2-equivalent emission	1243692	1191036	1141737	1126054	1108037	1102763	1121456	1083684	1057391	1021013	1016636	1027829	1015351	1017511
Indirectly acting greenhouse gases														
NO_X 2)	2846	2611	2418	2299	2130	2000	1918	1823	1766	1717	1634	1560	1497	1428
NMVOC	3534	3082	2807	2581	2404	2248	2110	2042	1966	1842	1697	1592	1494	1460
CO	11212	9528	8351	7701	7080	6581	6166	5994	5554	5200	4913	4561	4300	4155
Aerosol precursor														
SO_2	5326	3996	3307	2945	2473	1937	1339	1039	836	735	636	643	611	616

#) [Gg], except CF_4, C_2F_6, C_3F_8 und SF_6: [Mg]

1) in CO_2 equivalent emission

2) as NO_2

Table 6 shows the total emissions, as determined for this inventory, of direct and indirect greenhouse gases and of the acid precursor SO_2. The associated annual progress over time compared with the base year of the Kyoto Protocol and 1990 is depicted in Table 7. With the exception of HFCs and of C_3F_8, significant reductions in emissions have been achieved for all the emissions calculated here. In total, emissions of greenhouse gases calculated as CO_2 equivalent emissions were down by 18.5 % compared to the base year. Overall, emissions increased slightly over the previous year, 2002, by + 0.2 %. This increase is due to the increase in energy consumption for heating and, in the industrial-processes sector, to increased cement and nitric acid production. In the years 1996, 2001 and 2003, which were cold by comparison to the development since 1990, additional energy had to be used for indoor heating, and this considerably increased CO_2 emissions in particular in these years, in comparison to the relevant previous years. This is also illustrated by Table 8 below.

Table 7: Changes in emissions in comparison to the base year of the Kyoto Protocol

Emissions trends in Germany with respect to the base year																
				1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
	Base year	**Emission**		**[+/- %]**												
Directly acting greenhouse gases																
CO_2	1990	1015031	[Gg]	-3,8	-8,4	-9,4	-10,8	-11,1	-8,9	-12,0	-12,8	-15,5	-15,3	-13,9	-14,9	-14,7
CH_4	1990	6290	[Gg]	-8,3	-11,1	-14,6	-17,7	-20,6	-23,9	-26,4	-30,5	-33,0	-37,2	-40,0	-42,1	-43,1
N_2O	1990	279	[Gg]	-4,2	-2,6	-6,4	-6,1	-6,4	-4,9	-8,6	-23,8	-28,2	-28,0	-27,7	-28,5	-26,3
HFC [1)]	1995	6360	[Gg]					0,0	-9,3	-0,1	9,7	14,5	4,2	27,8	29,7	29,7
CF_4	1995	224	[Mg]					0,0	-4,2	-27,9	-23,0	-38,9	-67,8	-69,0	-66,2	-66,2
C_2F_6	1995	32	[Mg]					0,0	5,0	-1,0	4,1	-3,7	-25,7	-43,4	-38,9	-38,9
C_3F_8	1995	1	[Mg]					0,0	131,7	310,7	547,6	774,7	1136,1	1165,1	1269,2	1269,2
SF_6	1995	278	[Mg]					0,0	-4,1	-5,4	-9,0	-30,6	-39,4	-49,9	-36,7	-36,7
CO_2-equivalent emission		**1247881**	[Gg]	-4,6	-8,5	-9,8	-11,2	-11,6	-10,1	-13,2	-15,3	-18,2	-18,5	-17,6	-18,6	-18,5
Indirectly acting greenhouse gases																
NO_X [2)]		2846	[Gg]	-8,3	-15,0	-19,2	-25,2	-29,7	-32,6	-35,9	-37,9	-39,6	-42,6	-45,2	-47,4	-49,8
NMVOC		3534	[Gg]	-12,8	-20,6	-27,0	-32,0	-36,4	-40,3	-42,2	-44,4	-47,9	-52,0	-54,9	-57,7	-58,7
CO		11212	[Gg]	-15,0	-25,5	-31,3	-36,9	-41,3	-45,0	-46,5	-50,5	-53,6	-56,2	-59,3	-61,7	-62,9
Aerosol precursor																
SO_2		5326	[Gg]	-25,0	-37,9	-44,7	-53,6	-63,6	-74,9	-80,5	-84,3	-86,2	-88,1	-87,9	-88,5	-88,4

[1)] in CO_2 equivalent emission

[2)] as NO_2

Table 8: Change in emissions in comparison to the previous year

Emissions changes in Germany since 1990 [+/- %] (percentage changes in comparison to the relevant previous year and, for 2003, to the base year)															
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2003 / Basisjahr**
Directly acting greenhouse gases															
CO_2	1015031	-3,8	-4,9	-1,0	-1,6	-0,4	2,5	-3,4	-0,9	-3,1	0,3	1,6	-1,1	0,2	-14,7
CH_4	6290	-8,3	-3,0	-3,9	-3,7	-3,5	-4,2	-3,3	-5,5	-3,7	-6,3	-4,3	-3,6	-1,6	-43,1
N_2O	279	-4,2	1,7	-4,0	0,4	-0,3	1,6	-3,9	-16,6	-5,8	0,3	0,5	-1,1	3,1	-26,3
HFC	3510	1,1	3,6	34,6	4,6	22,8	-9,3	10,2	9,8	4,3	-8,9	22,6	1,4	0,0	29,7
CF_4	355	-13,3	-9,7	-6,5	-17,7	4,5	-4,2	-24,7	6,7	-20,7	-47,3	-3,6	9,0	0,0	-66,2
C_2F_6	42	-8,4	-6,5	-2,8	-11,4	4,2	5,0	-5,7	5,1	-7,4	-22,9	-23,8	8,1	0,0	-38,9
C_3F_8	0	-	-	-	-	-	131,7	77,3	57,7	35,1	41,3	2,3	8,2	0,0	1269,2
SF_6	166	9,6	12,1	10,8	7,5	14,2	-4,1	-1,3	-3,8	-23,7	-12,8	-17,2	26,2	0,0	-36,7
CO_2-equivalent emission	1243692	-4,2	-4,1	-1,4	-1,6	-0,5	1,7	-3,4	-2,4	-3,4	-0,4	1,1	-1,2	0,2	-18,7
Indirectly acting greenhouse gases															
NO_X [1)]	2846	-8,3	-7,4	-4,9	-7,4	-6,1	-4,1	-4,9	-3,2	-2,7	-4,8	-4,5	-4,1	-4,6	-49,8
NMVOC	3534	-12,8	-8,9	-8,0	-6,9	-6,5	-6,1	-3,3	-3,7	-6,3	-7,9	-6,2	-6,2	-2,3	-58,7
CO	11212	-15,0	-12,3	-7,8	-8,1	-7,0	-6,3	-2,8	-7,3	-6,4	-5,5	-7,2	-5,7	-3,4	-62,9
Aerosol precursor															
SO_2	5326	-25,0	-17,2	-10,9	-16,0	-21,7	-30,9	-22,4	-19,5	-12,0	-13,5	1,1	-5,1	0,9	-88,4

[1)] as NO_2

2.1 Description and interpretation of the progress of aggregated greenhouse-gas emissions

By 2003, the above-described obligation to reduce greenhouse-gas emissions, in the framework of EU burden-sharing, had been largely fulfilled, via a reduction of 18.5 %. The individual greenhouse gases contributed to this development to varying degrees (see Table 1). This is hardly surprising when one considers that the individual greenhouse gases account for varying proportions of total emissions in a given year. Among direct greenhouse gases, emissions of the gases that predominate by amount were considerably reduced; CO_2 emissions decreased by 14.7 % and CH_4 and N_2O emissions were reduced by 43.1 % and by 26.3 %, respectively. The reasons for these reductions are found in an entire group of measures, in basic categories such as fuel conversions, enhanced economic efficiency, changes in ways of keeping animals and reductions of numbers of animals kept. These measures are discussed in detail in the discussion below of trends for the various components.

Release of carbon dioxide, predominantly from the processes of stationary and mobile combustion, is by far the principal cause of emissions, accounting for 85.0 % 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 from 81.6 % to over 85 % since 1990 (cf. Table 2). Emissions of methane, which are caused primarily by animal husbandry, fuel distribution and landfill emissions, accounted for 7.4 % in 2003. Emissions of nitrous oxide, caused primarily by agriculture, industrial processes and transport, account for 6.3 % of greenhouse gas releases. The other so-called "Kyoto" or "F" gases account for a total of only slightly over 1 % of total greenhouse-gas emissions. This spectrum of distribution of greenhouse-gas emissions is typical for a highly developed and industrialised country.

2.2 Description and interpretation of emission trends, by greenhouse gases

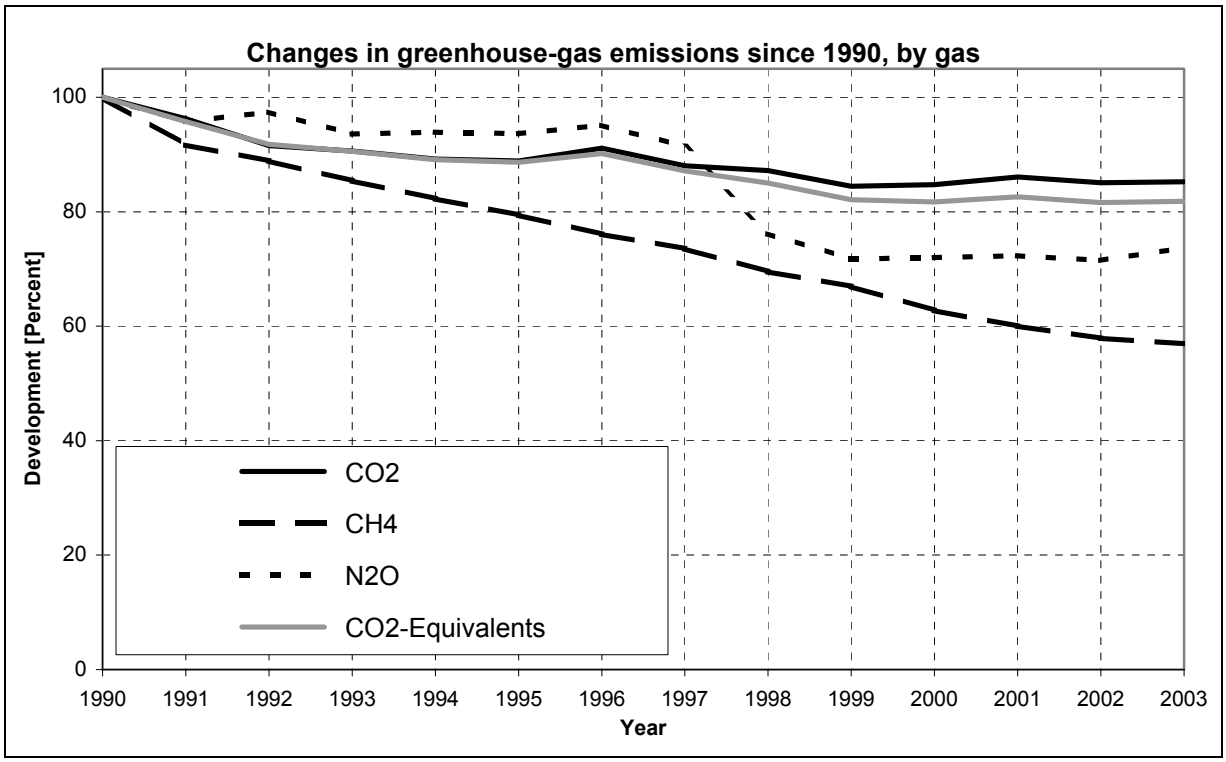


Figure 14: Relative development of greenhouse gases in comparison to 1990

Figure 14 shows 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 source category. The reduction in CO_2 emissions is closely linked to the development in the energy sector. In this sector, fuel conversions, efficiency improvements via construction of new facilities – especially in the new German Länder – and extensive energy-saving measures led to a considerable emissions decrease. For example, CO_2 emissions from public power and district-heat generation decreased by 12 million t since 1990. In the process, the mix of fuels used changed considerably – while energy-sector emissions from use of solid and liquid fuels sank by 5 and 45 %, respectively, CO_2 emissions from use of gaseous fuels increased by 41 %. This trend is even more pronounced in the residential and commercial/institutional areas. In these areas, emissions decreased by a total of 13 % – from 204 million t CO_2 to about 178 million t CO_2 – between 1990 and 2003. Whereas in 1990 these emissions were spread nearly evenly among use of solid, liquid and gaseous fuels (33, 45 and 22 %), by 2003 this spectrum had shifted considerably (2, 48 and 50 %). Similar developments have also taken place in the transport sector – although in this sector emissions have been increasing markedly overall. CO_2 emissions increased from 162 to about 170 million t, and use of diesel fuel increased disproportionately. In 1990 nearly 2/3 of all road-traffic emissions were still caused by petrol consumption. By 2003, the ratio between petrol-related and diesel-related emissions was balanced.

N_2O emissions decreased by over 26 % in the period under consideration. The main sources were use of nitrogen-containing fertilisers in agriculture, industrial processes in the chemical

sector, stationary and mobile combustion processes and animal husbandry in agriculture. Smaller amounts of emissions are caused by wastewater treatment and product use of N_2O (for example, as an anesthetic). Industry has the greatest influence on emissions reductions, especially in the area of adipic acid production. In this respect, in 1997 producers in Germany completed a process of retrofitting their production systems with emissions-reduction equipment. This measure reduced total emissions by over 20 % with respect to 1990. Decreased fertiliser use in agriculture also contributed to the reduction of total emissions.

Methane emissions are caused mainly by animal husbandry in agriculture, waste landfilling and distribution of liquid and gaseous fuels. These emissions loads play an almost negligible role in comparison to that of energy-related and process-related emissions. These emissions have been decreased by over 43 % since 1990. This trend has been the result of political environmental protection measures (green dot on recyclable products, yellow sacks for recycling pickups, increased recycling overall and increasing energy recovery from waste) that reduced amounts of waste for landfilling. A second important reason for the emissions reductions consisted of reductions of livestock populations in the new German Länder, especially in the first half of the 1990s. Repairs and modernisations of outdated gas-distribution networks in this part of Germany, along with introduction of vapour-recovery equipment in fuel distribution, brought about further reductions of total emissions.

2.3 Description and interpretation of emission trends, by source categories

Table 9: Relative development of greenhouse gases, by source categories, in comparison to 1990

Relative development of greenhouse gases, by source categories, in comparison to 1990 [%]														
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Energy	0,0	-3,7	-8,4	-9,5	-11,4	-11,8	-9,7	-12,9	-13,9	-16,7	-16,7	-15,4	-16,4	-16,4
Industrial processes	0,0	-4,5	1,5	0,6	8,1	10,1	8,4	5,2	-16,0	-25,1	-28,8	-27,9	-26,5	-20,7
Solvent and other product use	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
Agriculture	0,0	-10,6	-13,6	-15,6	-16,4	-15,3	-15,3	-15,4	-16,4	-15,8	-16,2	-17,0	-19,1	-19,9
Land-use changes and forestry *)	0,0	2,4	4,3	6,4	8,6	9,4	10,9	12,2	13,1	14,6	18,9	21,6	21,7	23,3
Waste and wastewater	0,0	-1,0	-2,9	-5,7	-13,9	-21,1	-28,0	-35,0	-41,3	-48,2	-53,2	-57,5	-60,0	-60,9

*) This category is a net sink.

Among energy-sector emissions, which have been decreasing, combustion-related emissions are driven primarily by CO_2 emissions from stationary and mobile combustion systems (cf. also the results of the key-source analysis). On the other hand, emissions of other greenhouse gases are negligible in this sector. The situation is exactly the opposite for energy-related emissions that are not combustion-related. In this area, CO_2 emissions play a negligible role, 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 over 16.4 % since 1990. For combustion-related emissions, this has been achieved through fuel conversions and higher energy and technical efficiencies, whereas for distribution emissions it is due to modernisation of gas-distribution networks and the introduction of vapour-recovery systems in fuel distribution.

In the area of emissions from industrial processes, CO_2-emissions contributions have been relatively constant in the lime and cement manufacturing sector and in the iron and steel industry. The trend for this source category, in which the reduction amounts to over 20 %, has been shaped primarily by emissions-reducing measures in adipic acid production, which have led to marked reductions in N_2O emissions. Introduction of such measures, by the two producers in Germany, sharply reduced emissions in 1997. Emissions increased over the previous year's level via increased production of cement and, especially, of nitric acid.

Emissions in the area of solvent and product use are not particularly high, in absolute values. The constancy of the relevant emissions figures is due to the continuing use of a value obtained for 1990, for narcotic use of N_2O. The next chapter discusses the relevant solvent emissions themselves.

The trend in emissions from agriculture essentially follows the development of livestock figures. In addition, decreasing use of mineral fertilisers has also reduced emissions.

The increase in the sink "land-use changes and forestry" is due primarily to a reduction of CO_2 emissions from agriculturally cultivated soils and to an increase in the forest area.

The most significant emissions reduction, at over 60 %, occurred in the area of waste emissions. In this area, intensified recycling of recyclable materials ("yellow sack" for recyclable materials, Ordinance on Packaging, etc.) has reduced annual amounts of landfilled waste and thus has reduced landfill emissions. Emissions from wastewater treatment, which also belong to this source category, are considerably lower, in terms of amounts, than landfill emissions.

2.4 Description and interpretation of the progress of emissions of indirect greenhouse gases and of SO_2

The relative development of emissions of the indirect greenhouse gases and of SO_2 are graphically depicted, in each case as time series since 1990, in Figure 15 and in Table 7. Over this period, a number of significant successes have been achieved in reducing these pollutants. For example, emissions of SO_2 were reduced by almost 89 %, those of CO by over 63 %, those of NMVOCs by almost 59 % and those of NO_X by nearly 50 %.

The reasons for this development listed below are more or less relevant for all of the components considered in this context:

- As a result of Germany's reunification in 1990, emissions from the territory of the former GDR in particular made the starting level comparatively high.
- In the years that followed, obsolete and ineffective industrial facilities in the eastern part of Germany were decommissioned. They were replaced, in the great majority of cases, with state-of-the-art new facilities.
- Particularly in eastern Germany, furthermore, there was also a change in the fuel mix used – the proportion of local lignite was reduced in favour of energy carriers such as natural gas and petroleum, which produce fewer emissions.
- In the traffic sector, newer vehicles equipped with pollutant-reducing technology were used.
- 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 were repeatedly adapted in line with the latest state of the art.
- Established legal and market-economic regulations led to thriftier use of energy and raw materials.
- International legislation, particularly from the European Community, has had an emissions-reducing effect (e.g. the NEC Directive).

Descriptions of the emission calculations for these pollutants, along with additional, detailed parameters influencing the emission trends of the individual air pollutants, are provided by the Website of the Federal Environmental Agency.

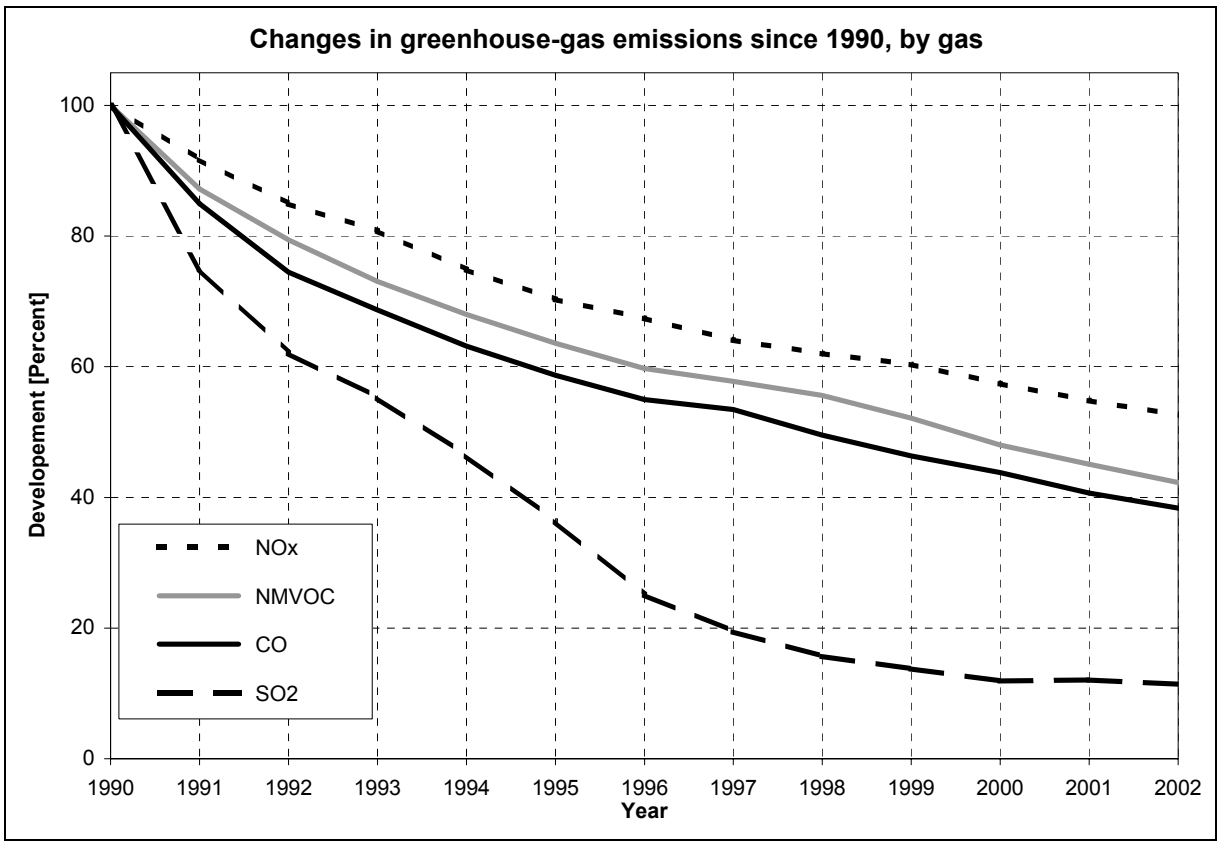


Figure 15: Relative development of emissions of indirect greenhouse gases and of SO_2

3 ENERGY (CRF 1)

In the Federal Republic of Germany, energy statistics are published by numerous agencies, and these statistics differ in part in terms of their representation, delimitation and aggregation. Against this background, in the early 1970s, associations of the Germany energy industry, along with economic research institutions, formed the Working Group on Energy Balances (AGEB), aimed at evaluating statistics from all areas of the energy industry on the basis of uniform criteria, combining the data into a well-rounded picture, and making these figures available to the general public in the form of energy balances (ZIESING et al., 2003). The energy balances of the Federal Republic of Germany command a pivotal position in the energy data system by virtue of their structure and conclusiveness. They therefore form the basis for determination of energy-related emissions and for development of scenarios and forecasts of the effects of energy policy and environmental policy measures.

The members of the Working Group on Energy Balances include six energy-sector associations. A list of members is provided in Chapter 13.1. Further information with regard to the AGEB and its database (Chapter 13.1), to development of energy balances (Chapter 13.2), to reallocation of statistical differences (Chapter 13.3), to preparation of provisional energy balances (Chapter 13.4), to methodological aspects of determination of energy-related activity rates (Chapter 13.5) and to uncertainties and time-series consistency (Chapter 13.6) is provided in Annex 2 (Chapter 13).

The emission factors on which the inventory is based have been derived from the list of CO_2 emission factors for the German National Allocation Plan (cf. Chapter 13.8).

3.1 Combustion of fossil fuels (1.A)

The area of *combustion of fossil fuels* comprises stationary sources with combustion-related emissions. In the energy balance, this refers to the following items:

A: Transformation input

- Public thermal power plants (line 11 of the energy balance in the structure from 1995 onwards)
- Industrial thermal power plants (line 12)
- Heat plants (line 15) and
- District heat plants (line 16)

B: Energy consumption in the transformation sector (own consumption)

- Coke ovens (line 33)
- Hard coal pits and briquette plants (line 34)
- Lignite pits and briquette plants (line 35)
- Crude oil and natural gas production (line 37)
- Refineries (line 38)
- Other energy producers (line 39)
- Sum total of own consumption (line 40)

C: Final energy consumption

- Quarrying of nonmetallic minerals, other mining and manufacturing industry (line 60)
- Residential (line 66)
- Trade, commerce, services and other consumers (line 67)

Regarding the content and delimitation of these items, the following explanations are required:

1. ***Public thermal power plants*** (line 11) are plants that feed produced electricity into the public grid. This also includes industrial plants which operate their power stations together with electricity utility companies as joint 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 plants attributable to electricity production.
2. ***Industrial thermal power plants*** in energy balance line 12 comprises the following operator groups:
   a. Power plants in hard coal mining
   b. Power plants in lignite mining
   c. Power plants in petroleum processing (refinery power stations)
   d. Power plants which generate single-phase electricity for the German national railway, *Deutsche Bahn AG* (facilities owned by the railway, as well as public and industrial power plants which generate electricity on behalf of Deutsche Bahn AG)
   e. Industrial power plants (quarrying, other mining, manufacturing industry)
3. For thermal power plants in line 15 of the energy balance, only the fuel input which can be allocated to district heati generation is given. Adding lines 11 and 15 together produces the total fuel input in public thermal power plants. The district heat generated is fed into the public heating grid. These plants also supply industrial customers with process heat.
4. In energy balance line 16, ***district heat plants*** indicates the fuel input for the public district heating supply. The plants are often used to cover peak loads in district heat networks in which the basic load is met by combined heating and power stations.
5. 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. In this instance, no distinction is made according to the type of heat generation. This means that fuel inputs for heat generation in combined heating and power plants, steam and hot water boilers and process firing installations are combined. There is an inconsistency in the energy balance with respect to lignite pits and briquette plants. The fuel used in combined heat and power generation to generate heat (for drying the crude lignite in lignite briquette plants) is reported together with the transformation input (line 10), even though this is only materially transformed. The emission-causing use of lignite is calculated out during data preparation. 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 this total, of fuel inputs for heat generation in power stations leaves the quantity of fuel used in process firing installations, steam and hot water boilers.
6. ***Final energy consumption by industry*** (line 60 of the energy balance) indicates the fuel used for heat generation which is required for both production purposes and room heating. Here too, no distinction is made according to the type of heat generation. Hence, part of the final energy consumption in these source categories, together with industrial

power stations' fuel input for generating electricity, constitutes the total fuel input in such plants.

7. The data on ***final energy consumption by residential consumers*** (line 66 of the energy balance) lists fuel inputs for heat generation and includes the application areas of heating, hot water production and cooking.
8. The data on ***final energy consumption by trade, commerce, services and other consumers*** (line 67 of the energy balance) comprises fuel inputs used for hot water production, room heating and process heat generation in this sector.

The data in the energy balance is no longer sufficient to accommodate the diverse requirements of national and international energy and emissions reporting. For example, the energy balance combines fuel inputs which

- are used in plants with differing requirements under immission protection legislation (e.g. large furnaces, medium-sized furnaces, small furnaces, waste incineration plants)
- operate according to different technical principles (e.g. steam turbine power stations, gas turbine power stations, motor power stations)
- exhibit regional peculiarities (e.g. different individual mining regions have different qualities of crude lignite)
- are allocated to different source categories in national and international emissions reporting
- are listed in various energy balance lines according to their intended purpose (for electricity or heat generation) but are used in a single plant group (e.g. steam turbine power stations)

These characteristics have impacts on emissions behaviour. In order to make allowance for these differing requirements, the Federal Environmental Agency has developed a model entitled *Balance of Emission Causes* (BEU) and has disaggregated the energy balance using additional statistics as well as its own calculations. In this way, the *fuel combustion module*, which is summarised in 8 lines in the energy balance, can be further sub-divided into 88 lines (tables). Of these, 66 are tied to emissions-causing fuel input in stationary combustion, which is considered in this section.

Balance of Emission Causes (BEU)
• Sector, • Plant type, • Fuel, • Immission protection provision, • Energy balance line, • (Where necessary: regional allocation), • Allocation to the Central System of Emissions (CSE)
The source categories include: • Public thermal power stations, • Hard coal mining, • Lignite mining, • Deutsche Bahn AG *(German national railway),* • Petroleum oil refineries, • District heating stations, • Other transformation sector (may be further sub-classified) • Quarrying of non-metallic minerals, other mining and manufacturing industry (further sub-classification planned) • Residential, • Trade, commerce, services and other consumers
Plant types include: • Steam turbine power stations, • Gas turbine power stations, • Gas and steam turbine power stations (planned) • Motor power stations, • Boiler furnaces (excluding power station boilers), • Process furnaces (sub-classified into 15 processes).
By fuels/energy sources: • 21 energy source materials
On the basis of immission protection legislation provisions, a distinction is made between: • Facilities 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)

Abbreviations stand for:

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 16: Characteristics of the Federal Environmental Agency's structure of the balance of emission causes, for disaggregation of the energy balance

Figure 16 presents the characteristics of the BEU structure, while Table 10 through Table 15 show the BEU structure itself. These basic structures are analysed in greater detail in the following account of activities. The information in Table 10 through Table 15 should be read as follows:

The number in the first column corresponds to the consecutive number in the table in the *Balance of Emission Causes (BEU)*. The number in the third column is the line number of the energy balance from which the basic data for calculation in the *Balance of Emission Causes* table is used. The column "SWK" (S = fuel input for electricity generation, W = fuel input for heat generation, K = fuel input for machine action) shows the use in question. The "file name" in the eighth column refers directly to the database of the *Central System of Emissions (CSE)*.

The purpose of the BEU module is to provide a data structure that can be transferred into the various relevant formats for required national and international reports. Although the manner in which the data is arranged may differ, the same total group of data categories may thus always be assumed to be present. In particular, on this level no differentiation is made between fuel uses that are relevant only with regard to climate protection and uses that are relevant only with regard to immissions control. The relevant importance in each case may be determined from the emission factors.

To date, the time series cover the period from 1987 to 2002 (from 1987 through 1994, for the former territory of the Federal Republic of Germany and the former GDR and, later, the old and new German Länder; as of 1995, for Germany as a whole). In this representation, calculations from 1992 to 1994 for the new *Länder* are not yet complete, which means that no complete data for emission causes from stationary sources is currently available for Germany for this period. Data for the period 1999 to 2002 is provisional.

Despite the conversion of the energy balance to the new classification of industrial sectors (WZ 93) and the altered grouping of energy resources from the year 1995 onwards, we have so far succeeded in fitting the data within the outlined basic structure, thereby facilitating the preparation of consistent time series.

Further documentation on the data in the BEU module is provided in Chapter 13.7.

Planned improvements include continuing work on other source categories and completing the 1990 to 1991 time period. These efforts will also include relevant backward calculations and completion of the data in the BEU structure.

The data for the new German Länder for this period is based on updates of the last available GDR statistics, which date from 1989. Harmonised treatment of energy statistics for the old and new Länder does not become possible until 1992.

The current schedule calls for this work to be completed by spring 2004.

Table 10: Structure of the balance of emissions causes – public services

No.	Process, fuel	EB line	Classification under immissions-control law	Type of facility[1)]	Economic sector	SWK	File name	Remarks
1	Power generation in large combustion systems of public-sector thermal power stations	11	13th BImSchV	DTKW	Public services	S	OEKW13	
2	Power generation in large combustion systems of public-sector raw-lignite power stations	11	13th BimSchV	DTKW	Public services	S	OEKW13	
2a	Power generation in large combustion systems of public-sector hard-lignite power stations	11	13th BimSchV	DTKW	Public services	S		
3	Power generation in MVA of public-sector thermal power stations	11	17th BimSchV	DTKW	Public services	S	OEKW17	
4	Power generation in gas turbines of public-sector thermal power stations	11	TA Luft	GTKW	Public services	S	OEKWGT	
4a	Power generation in gas and steam turbines of public-sector thermal power stations (HKW)	11		GuD	Public services	S		
5	Power generation in gas machines of public-sector thermal power stations	11	TA Luft	GMKW	Public services	S	OEKWGM	
6	Power generation in diesel motors of public-sector thermal power stations	11	TA Luft	DMKW	Public services	S	OEKWDM	
22	Heat generation in large combustion systems of public-sector thermal power stations	15	13th BimSchV	DTKW	Public services	W	HEKW13	

22a	Heat generation in large combustion systems of public-sector lignite-fired power stations (Kassel)	15	13th BImSchV	DTKW	Public services	W	HEKW13	
23	Heat generation in MVA of public-sector thermal power stations	15	17th BImSchV	DTKW	Public services	W	HEKW17	
25	Heat generation in gas turbines of public-sector thermal power stations	15	TA Luft	GTKW	Public services	W	HEKWGT	For the time being, all fuel use in gas turbines is assigned to power generation
25a	Heat generation in gas and steam turbines of public-sector thermal power stations	15	13th BimSchV / TA Luft	GuD	Public services	W		
26	Heat generation in gas machines of public-sector thermal power stations	15	TA Luft	GMKW	Public services	W	HEKWGM	For the time being, all fuel use in gas machines is assigned to power generation
27	Heat generation in diesel motors of public-sector thermal power stations	15	TA Luft	DMKW	Public services	W	HEKWDM	
28	Heat generation in large combustion systems of public-sector district heat stations	16	13th BimSchV	FHW	Public services	W	FEHW13	
29	Heat generation in MVA of public-sector district heat stations	16	17th BImSchV	FHW	Public services	W	FEHW17	
30	Heat generation in TA Luft systems of public-sector district heat stations	16	TA Luft	FHW	Public services	W	FEHWTA	

Table 11: Structure of the balance of emissions causes – coal mining

No.	Process, Fuel	EB line	Classification under immission-control law	Plant type[1)]	Industrial sector	SWK	File name	Remarks
7	Power generation in large combustion plants of STEAG	12	13th BImSchV	DTKW	Coal mining/STEAG	S	STEA13	
8	Power generation in large combustion plants of other mine power stations	12	13th BimSchV	DTKW	Other coal mining	S	ZGSK13	
8a	Power generation in large combustion plants of mine mine-pit power stations	12	13th BimSchV	DTKW	Other coal mining	S	ZGBK13	
9	Power generation in gas turbines of mine (Zeche) and pit (Grube) power stations	12	TA Luft	GTKW	Coal mining	S	ZGKWGT	
10	Power generation in gas machines of mine (Zeche) and pit (Grube) power stations	12	TA Luft	GMKW	Coal mining	S	ZGKWGM	Assumption: natural gas and heating oil, light, are used only in GTKW. For this reason, the file/line is empty. Cf. also Table 60
11	Power generation in diesel engines of mine (Zeche) and pit (Grube) power stations	12	TA Luft	DMKW	Coal mining	S	ZGKWDM	
32	Heat production in large combustion plants of STEAG	40	13th BimSchV	DTKW	Coal mining/STEAG	W	UEST13	
33	Heat production in large	40	13th BimSchV	DTKW	Other coal	W	UEKS13	

	combustion plants of other mine power stations				mining			
33a	Heat production in large combustion plants of mine-pit power stations	40	13th BimSchV	DTKW	Other coal mining	W	UEKB13	
38	Heat production in gas turbines of mine (Zeche) and pit (Grube) power stations	40	TA Luft	GTKW	Coal mining	W	UEKZGT	Fuel allocated completely to power generation
40	Heat production in gas machines of mine (Zeche) and pit (Grube) power stations	40	TA Luft	GMKW	Coal mining	W	UEKZGT	
41	Direct drive by diesel engines of mine and mine-pit power stations	40	TA Luft	DMKW	Coal mining	K	UEKZDM	
43	Production of hard-coal coke (process combustion)	40	TA Luft	PF	Coal mining	W	UEPFKO	
43a	Production of hard-coal coke (17th BimSchV)	40	17th BimSchV	PF	Coal mining	W		

Table 12: Structure of the balance of emissions causes – other industrial power stations

No.	Process, Fuel	EB line	Classification under immission-control law	Plant type[1)]	Industrial sector	SWK	File name	Remarks
12	Power generation in large combustion plants of German Railways' power stations	12	13th BImSchV	DTKW	Deutsche Bahn AG	S	DBKW13	
14	Power generation in large combustion plants of other industrial thermal power stations	12	13th BimSchV	DTKW	Other mining and manufacturing (not including VAW)	S	UIKW13	
14a	Power generation in large combustion plants of Vereinigte Aluminium Werke (VAW), Bonn	12	13th BImSchV	DTKW	Vereinigte Aluminium Werke (VAW)	S	UIKW13	
15	Power generation in waste-incineration plants of other industrial power stations	12	17th BImSchV	DTKW	Other mining and manufacturing	S	UIKW17	
16	Power generation in TA Luft plants of other industrial power stations	12	TA Luft	DTKW	Other mining and manufacturing	S	UIKWTA	
18	Power generation in gas turbines of other industrial thermal power stations	12	TA Luft	GTKW	Other mining and manufacturing	S	UIKWGT	
19	Power generation in gas machines of other industrial thermal power stations	12	TA Luft	GMKW	Other mining and manufacturing	S	UIKWGM	
21	Power generation in	12	TA Luft	DMKW	Other mining	S	UIKWDM	

	diesel engines of other industrial thermal power stations				and manufacturing			
24	Heat production in TA Luft plants of other industrial power stations (only those feeding into public grid); only new German Länder	15	TA Luft	DTKW	Other mining and manufacturing	W	HEKWTA	For the old German Länder, heat generation in thermal power stations has been allocated completely to 13th BimSchV
35	Heat production in large combustion plants of other industrial power stations in the transformation sector (only new German Länder)	40	13th BImSchV		Other energy producers	W	UEKI13	
37	Heat production in TA Luft plants of industrial power stations in the transformation sector	40	TA Luft	DTKW	Other energy producers	W	UEKITA	No entry, since all power stations are of the type allocated to the 13th BimSchV
47	Heat production in large combustion plants of industrial power stations in the manufacturing and other mining sector	60	13th BImSchV	DTKW	Other mining and manufacturing	W	INKW13	
48	Heat production in waste-incineration plant of the manufacturing and other mining sector	60	17th BImSchV	DTKW	Other mining and manufacturing	W	INKW17	
50	Heat production in TA Luft plants of industrial power stations of manufacturing and other mining sector	60	TA Luft	DTKW	Other mining and manufacturing	W	INKWTA	
51	Heat production in gas	60	TA Luft	GTKW	Other mining	W	INKWGT	For the time being,

	turbines of industrial power stations of manufacturing and other mining sector				and manufacturing			fuel use allocated completely to power generation
52	Heat production in gas machines of industrial power stations of manufacturing and other mining sector	60	TA Luft	GMKW	Other mining and manufacturing	W	INKWGM	For the time being, fuel use allocated completely to power generation
53	Heat production in diesel engines of industrial power stations of manufacturing and other mining sector	60	TA Luft	DMKW	Other mining and manufacturing	W	INKWDM	For the time being, fuel use allocated completely to power generation

Table 13: Structure of the balance of emissions causes – refineries

No.	Process, Fuel	EB line	Classification under immission-control law	Plant type[1)]	Industrial sector	SWK	File name	Remarks
13	Power generation in large combustion plants of refinery power stations	12	13th BImSchV	DTKW	Petroleum refining	S	UIKR13	
17	Power generation in gas turbines of refinery power stations	12	TA Luft	GTKW	Petroleum refining	S	UIKRGT	
20	Power generation in diesel engines of refinery power stations	12	TA Luft	DMKW	Petroleum refining	S	UIKRDM	Empty; diesel fuel allocated completely to other mining and manufacturing (UIKWDM)
34	Heat production in large combustion plants of refinery power stations	40	13th BImSchV		Petroleum refining	W	UEKR13	

39	Heat production in gas turbines of refinery power stations	40	TA Luft	GTKW	Petroleum refining	W	UEKRGT	Fuel allocated completely to power generation
42	Heat production in diesel engines of refy power stations	40	TA Luft	DMKW	Petroleum refining	W	UEKRDM	
44	Refinery process combustion (large combustion plants)	40	13th BimSchV	PF	Petroleum refining	W	UEPFRG	
44a	Refinery process combustion (TA Luft)	40	TA Luft	PF	Petroleum refining	W	UEPFRT	

Table 14: Structure of the balance of emissions causes – other energy producers

No.	Process, Fuel	EB line	Classification under immission-control law	Plant type[1)]	Industrial sector	SWK	File name	Remarks
31	Heat production in large combustion plants (industrial boilers) of the other transformation sector	40	13th BImSchV	FA	Other energy producers	W	UEUM13	
36	Heat production in TA Luft plants (industrial boilers) of the transformation sector	40	TA Luft	FA	Other energy producers	W	UEUMTA	

Table 15: Structure of the balance of emissions causes – iron and steel industry

No.	Process, Fuel	EB line	Classification under immission-control law	Plant type[1)]	Industrial sector	SWK	File name	Remarks
54	Production of pig iron (process combustion)	60	TA Luft	Blast furnaces	Iron industry	W	INPFHO	
55	Production of sinter (process combustion)	60	TA Luft	Sinter plants	Iron industry	W	INPFSI	

[1)] DTKW = steam turbine power stations, GTKW = gas turbine power stations, GT = gas turbines, GuD = gas and steam turbine power stations, GMKW = gas engine power stations, DMKW = diesel engine power stations, FHW = district heat stations, FA = combustion systems, PF = process furnaces

Table 16: List of abbreviations of structural elements from the Balance of Emissions Causes

AW HM DEPONI	Landfilled household waste, municipal waste
AW KS ABWASS	Sewage sludge produced in wastewater treatment
AW KS BEHAND	Treatment of sewage sludge
AW KS DEPONI	Landfilled sewage sludge
AW KS LANDWI	Spread sewage sludge (in agriculture)
AW NE ABWASS	Wastewater amount, N-eliminated
DBKW13	Electricity generation in large combustion systems of DB power stations
FEHW13	Heat generation in large combustion systems of public district heat stations
FEHW17	Heat generation in medium-sized combustion systems of public district heat stations
FEHWTA	Heat generation in TA Luft systems of public district heat stations
GRKW13	Electricity generation in large combustion systems of mine-pit power stations
GRKW17	Electricity generation in waste incineration systems of mine-pit power stations
GV AN E/ EÖG	Natural-gas use by households and small consumers: Natural gas / petroleum gas
GV AN SG	City-gas use by households and small consumers: Coking plants and city gas
GV AU E/ EÖG	processing of natural gas and petroleum gas: total amount produced
GV AU SG	City-gas processing: Coking plants and city gas
GV EZ HDKUÜ	High-pressure natural gas network made from plastic / other
GV EZ HDS/ DG	High-pressure natural-gas network made from steel / ductile cast
GV EZ MDGG	Medium-pressure natural-gas network made from gray-cast iron
GV EZ MDKUÜ	Medium-pressure natural-gas network made from plastic / other
GV EZ MDS/ DG	Medium-pressure natural-gas network made from steel / ductile cast
GV EZ NDGG	Low-pressure natural-gas network made from gray-cast iron
GV EZ NDKUÜ	Low-pressure natural gas network made from plastic / other
GV EZ NDS/ DG	Low-pressure natural-gas network made from steel / ductile cast
GV FÖ BERGW	Decommissioned mines: CH4 estimation
GV FÖ BK	Lignite mining: total amount produced
GV FÖ EG	Natural-gas extraction: total amount produced
GV FÖ EÖ	Petroleum extraction: total amount produced
GV FÖ GRUGAS	Pit gas
GV FÖ SK	Hard-coal mining: total amount produced
GV LA SK	Hard-coal storage: total amount stored
GV SZ HDKUÜ	High-pressure city-gas network made from plastic / other
GV SZ HDS/ DG	High-pressure city-gas network made from steel / ductile cast
GV SZ MDGG	Medium-pressure city-gas network made from gray-cast iron
GV SZ MDKUÜ	Medium-pressure city-gas network made from plastic / other
GV SZ MDS/ DG	Medium-pressure city-gas network made from steel / ductile cast
GV SZ NDGG	Low-pressure city-gas network made from gray-cast iron
GV SZ NDKUÜ	Low-pressure city-gas network made from plastic / other
GV SZ NDS/DG	Low-pressure city-gas network made from steel / ductile cast
GV TS E/ EÖG	Long-distance transport and storage of natural gas: Natural gas, petroleum gas
GV VE OK	Distribution of gasoline, total consumption
GVKOMP	Gas turbines in natural-gas-compressor stations
HAUS01	Heat production in small combustion systems of households
HEKW13	Heat generation in large combustion systems of public power stations
HEKW17	Heat generation in medium-sized combustion systems of public power stations
HEKWDM	Heat generation in diesel motors of public power stations
HEKWGM	Heat generation in gas machines of public power stations
HEKWGT	Heat generation in gas turbines of public power stations
HEKWTA	Heat generation in TA Luft systems of other industrial power stations (only production for feeding into public grid)
INDU01	Heat generation in small combustion systems (industrial boilers) of other mining and manufacturing (heating systems)
INDU01P	Heat generation in small combustion systems (industrial boilers) of other mining and manufacturing (production heat)
INDU13	Heat generation in large combustion systems (industrial boilers) of other mining and manufacturing

INDUTA	Heat generation in TA Luft systems (industrial boilers) of other mining and manufacturing
INDUTAH	Heat generation in TA Luft systems (industrial boilers) of other mining and manufacturing (heating systems)
INDUTAP	Heat generation in TA Luft systems (industrial boilers) of other mining and manufacturing (production heat)
INKW13	Heat generation in large combustion systems of industrial power stations of other mining and manufacturing
INKW17	Heat generation in waste incineration systems of industrial power stations of other mining and manufacturing
INKWDM	Heat generation in diesel motors of industrial power stations of other mining and manufacturing
INKWGM	Heat generation in gas machines of industrial power stations of other mining and manufacturing
INKWGT	Heat generation in gas turbines of industrial power stations of other mining and manufacturing
NKWTA	Heat generation in TA Luft systems of industrial power stations of other mining and manufacturing
INPFCA	Calcium carbide production (process combustion)
INPFGL	Glass production (process combustion)
INPFGU	Manufacturing of iron, steel and malleable cast iron (process combustion)
INPFHO	Manufacturing of pig iron (process combustion)
INPFKA	Lime production (process combustion)
INPFNE	Production of non-ferrous heavy metals (process combustion)
INPFSI	Sinter production (process combustion)
INPFSM	Production of Siemens-Martin steel (process combustion)
INPFWA	Manufacturing of rolled steel (process combustion)
INPFZE	Cement production (process combustion)
INPFZI	Manufacturing of coarse ceramics (process combustion)
INPFZU	Sugar manufacturing (process combustion)
INUEPF	Other process combustion
IP CI ADIPIN	Adipic acid production
IP CI CAC2	Calcium-carbide production
IP CI DÜNGEM	Fertiliser production
IP CI FERROL	Production of ferroalloys
IP CI H2SO4	Sulphuric acid production, chemical industry
IP CI HNO3	Nitric acid production
IP CI N2O	Nitrous oxide production
IP CI NDÜNGE	Nitrogen-containing fertilisers (mononutrient fertilisers)
IP CI NH3	Ammonia production: Synthesis of NH3 based on N
IP CI ORGPRO	Organic product emissions
IP CI RUSS	Soot production
IP CI SODA	Soda production based on NA2CO3
IP CI TIO2	Titanium-dioxide production
IP EN BKBR	Lignite briquetting: Briquette production
IP EN BKSTAU	Lignite-dust processing Production of coal dust and dry coal
IP EN BTTKO	Low-temperature lignite coking: Coke production
IP EN EGABFA	Flaring of natural gas: amount flared
IP EN RAFEIN	Refinery operations: inputs of crude oil and products
IP EN SEG	Desulphurisation of natural gas: Sulphur production
IP EN SKAU	Hard-coal processing: total amount processed
IP EN SKBR	Hard-coal briquetting: Briquette production
IP EN SRAF	Desulphurisation in refineries: Sulphur production
IP ES ELST	Steel production: Electric steel production
IP ES ESTG	Foundries: iron and steel casting (including malleable casting)
IP ES OXST	Steel production: Blown steel production
IP ES ROHFE	Blast furnaces: pig iron production
IP ES SINTER	Sintering plants: sinter production
IP ES SKKOKS	Coking plants: Hard-coal coke production
IP ES SMST	Steel production: Siemens-Martin steel production
IP ES THST	Steel production: Thomas-steel production
IP ES WALZST	Steel production: rolled steel production
IP NE BLEI	lead production: refined lead
IP NE H2SO4	Sulphuric acid production, metallurgical works
IP NE HÜALU	Aluminium production: primary aluminium
IP NE KUPFER	Copper production: Electrolyte copper, fire-refined Copper
IP NE UMALU	Aluminium production: Resmelted aluminium
IP NE ZINK	Zinc production: Primary and resmelted zinc
IP NE ZNSTG	Galvanising: galvanised products
IP NF SPANPL	Particle-board production
IP NF ZELLST	Pulp processing: Paper pulp (including fine and synthetic fibre pulp)
IP NG BIER	Beer production
IP NG BROT	Bread production: Consumption of bread-grain flour
IP NG SPIRIT	Spirits production
IP NG WEIN	Wine production
IP NG ZUCKER	Sugar production
IP SE BITUMG	Asphalt production
IP SE GLAS	Glass production_ Bottle, flat, float glass
IP SE GROBKE	Coarse ceramics: bricks, roof tiles, formed fireproof products
IP SE KALIS	Potassium salt production
IP SE KALK	Lime burning: limestone and calcite, burned; dolomite, burned or sintered
IP SE ÜBSALZ	Other salt production: Rock and metallurgical salt, salt-works salt
IP SE ZEMENT	Cement plants: Cement production
IP SE ZEMKLI	Cement plants: Cement clinker production
LAWI01	Heat generation in small combustion systems in agricultural and horticultural operations
LAWITA	Heat generation in TA Luft systems in agricultural and horticultural operations
MILI01	Heat production in small combustion systems of military agencies
MILITA	Heat generation in TA Luft systems of military agencies
OEBK13	Electricity generation in large combustion systems of public crude-lignite-fired power stations
OEHBKW13	Electricity generation in large combustion systems of public hard-lignite-fired power stations
OEKW13	Electricity generation in large combustion systems of public power stations
OEKW17	Electricity generation in waste incineration systems of public power stations
OEKWDM	Electricity generation in diesel motors of public power stations
OEKWGM	Electricity generation in gas machines of public power stations
OEKWGT	Electricity generation in gas turbines of public power stations
PV LM EF+CHR	Degreasing, dry-cleaning: Emissions
PV LM H+ACHP	Production and use of chemical products: Emissions
PV LM LACK	Lacquering: Emissions
PV LM ÜBRLM	Other solvent use: Emissions
PV ÜB N20	Nitrous oxide: Emissions
PV ÜB NH3SCR	SCR systems: smothered
SNAP 10 01 00	Cultures with fertilisers
SNAP 10 02 00	Cultures without fertilisers

SNAP 10 04 01	Enteric fermentation (dairy cows)
SNAP 10 04 02	Enteric fermentation (other cattle)
SNAP 10 04 03	Enteric fermentation (sheep)
SNAP 10 04 05	Enteric fermentation (horses)
SNAP 10 04 08	Enteric fermentation (laying hens)
SNAP 10 04 09	Enteric fermentation (broilers)
SNAP 10 04 10	Enteric fermentation (poultry)
SNAP 10 05 00	Manure management regarding organic compounds
SNAP 10 05 01	Manure management, dairy cows
SNAP 10 05 02	Manure management, other cattle
SNAP 10 05 05	Manure management, other sheep
SNAP 10 05 06	Manure management, other horses
SNAP 10 05 07	Manure management, laying hens
SNAP 10 05 08	Manure management, broilers
SNAP 10 05 09	Manure management, other poultry
STEA13	Electricity generation in large combustion systems of STEAG
SV BUS KOAB	Conventional buses, fuel consumption on autobahn
SV BUS KOAO	Conventional buses, fuel consumption outside of municipalities
SV BUS KOIO	Conventional buses, fuel consumption in municipalities
SV BUS MTAB	Buses with emissions-reduction equipment, fuel consumption on autobahn
SV BUS MTAO	Buses with emissions-reduction equipment, fuel consumption outside of municipalities
SV BUS MTIO	Buses with emissions-reduction equipment, fuel consumption in municipalities
SV LNFD KOAB	Conventional light commercial diesel vehicles, autobahn
SV LNFD KOAO	Conventional light commercial diesel vehicles, outside of municipalities
SV LNFD KOIO	Conventional light commercial diesel vehicles, municipalities
SV LNFD MTAB	Light diesel commercial vehicles with emissions-reduction equipment, autobahn
SV LNFD MTAO	Light diesel commercial vehicles with emissions-reduction equipment, outside of municipalities
SV LNFD MTIO	Light diesel commercial vehicles with emissions-reduction equipment, in municipalities
SV LNFO KOAB	Conventional light commercial gasoline-engine vehicles, autobahn
SV LNFO KOAO	Conventional light commercial gasoline-engine vehicles, outside of municipalities
SV LNFO KOIO	Conventional light commercial gasoline-engine vehicles, municipalities
SV LNFO KOVD	Evaporation: Conventional gasoline-engine automobiles, fuel consumption in municipalities
SV LNFO MTAB	Light gasoline-engine commercial vehicles with emissions-reduction equipment, autobahn
SV LNFO MTAO	Light gasoline-engine commercial vehicles with emissions-reduction equipment, outside of municipalities
SV LNFO MTIO	Light gasoline-engine commercial vehicles with emissions-reduction equipment, in municipalities
SV LNFO MTVD	Evaporation: Light gasoline-engine commercial vehicles with emissions-reduction equipment, consumption in municipalities
SV MOPED VD	Evaporation: Mopeds, overall consumption
SV MOPED	Mopeds, overall consumption
SV MRAD KOAB	Conventional motorcycles, fuel consumption on autobahn
SV MRAD KOAO	Conventional motorcycles, fuel consumption outside of municipalities
SV MRAD KOIO	Conventional motorcycles, fuel consumption in municipalities
SV MRAD KOVD	Evaporation, motorcycles, fuel consumption in municipalities
SV MRAD MTAB	Motorcycles with emissions-reduction equipment, fuel consumption on autobahn
SV MRAD MTAO	Motorcycles with emissions-reduction equipment, fuel consumption outside of municipalities
SV MRAD MTIO	Motorcycles with emissions-reduction equipment, fuel consumption in municipalities
SV MRAD MTVD	Evaporation, motorcycles with emissions-reduction equipment, fuel consumption in municipalities
SV MRAD VD	Evaporation, motorcycles, overall fuel consumption
SV PKWD KOAB	Conventional diesel automobiles, autobahn
SV PKWD KOAO	Conventional diesel automobiles, outside of municipalities
SV PKWD KOIO	Conventional diesel automobiles, in municipalities
SV PKWD MTAB	Diesel automobiles with emissions-reduction equipment, autobahn
SV PKWD MTAO	Diesel automobiles with emissions-reduction equipment, outside of municipalities
SV PKWD MTIO	Diesel automobiles with emissions-reduction equipment, in municipalities
SV PKWO KOAB	Conventional gasoline-engine automobiles, autobahn
SV PKWO KOAO	Conventional gasoline-engine automobiles, outside of municipalities
SV PKWO KOIO	Conventional gasoline-engine automobiles, in municipalities
SV PKWO KOVD	Evaporation: Conventional gasoline-engine automobiles, fuel consumption in municipalities
SV PKWO MTAB	Gasoline-engine automobiles with emissions-reduction equipment, autobahn
SV PKWO MTAO	Gasoline-engine automobiles with emissions-reduction equipment, outside of municipalities
SV PKWO MTIO	Gasoline-engine automobiles with emissions-reduction equipment, in municipalities
SV PKWO MTVD	Evaporation: Gasoline-engine automobiles with emissions-reduction equipment, fuel consumption in municipalities
SV SNF KOAB	Conventional heavy commercial vehicles, fuel consumption autobahn
SV SNF KOAO	Conventional heavy commercial vehicles, fuel consumption outside of municipalities
SV SNF KOIO	Conventional heavy commercial vehicles, fuel consumption in municipalities
SV SNF MTAB	heavy commercial vehicles with emissions-reduction equipment, fuel consumption on autobahn
SV SNF MTAO	Heavy commercial vehicles with emissions-reduction equipment, fuel consumption outside of municipalities
SV SNF MTIO	heavy commercial vehicles with emissions-reduction equipment, fuel consumption in municipalities
UEGK13	Heat generation in large combustion systems of mine-pit power stations
UEKB13	Heat generation in large combustion systems of power stations of the lignite-mining sector
UEKI13	Heat generation in large combustion systems of other industrial power stations in the transformation sector
UEKITA	Heat generation in TA Luft systems of industrial power stations of the transformation sector
UEKR13	Heat generation in large combustion systems of refinery power stations
UEKRDM	Heat generation in diesel motors of refinery power stations
UEKRGT	Heat generation in gas turbines of refinery power stations
UEKS13	Heat generation in large combustion systems of other power stations of the hard-coal mining sector
UEKV01	Heat generation in small combustion systems of other small consumers

UEKVTA	Heat generation in TA Luft systems of other small consumers
UEKZDM	Direct drive via diesel motors of mine and mine-pit power stations
UEKZGM	Heat generation in gas machines of mine and mine-pit power stations
UEKZGT	Heat generation in gas turbines of mine and mine-pit power stations
UEPFKO	Process combustion in refineries (large combustion systems)
UEPFRG	Production of hard-coal coke
UEPFRT	Process combustion in refineries (TA Luft installations)
UEST13	Heat generation in large combustion systems of STEAG
UEUEPF	Other process combustion (only new German Länder)
UEUM13	Heat generation in large combustion systems (industrial boilers) of the other transformation sector
UEUMTA	Heat generation in TA Luft systems (industrial boilers) of the other transformation sector
UEZK13	Heat generation in large combustion systems other mine-pit power stations
UIKR13	Electricity generation in large combustion systems of refinery power stations
UIKRDM	Electricity generation in diesel motors of refinery power stations
UIKRGT	Electricity generation in gas turbines of refinery power stations
UIKW13	Electricity generation in large combustion systems of other industrial power stations
UIKW17	Electricity generation in waste incineration systems of other industrial power stations
UIKWDM	Electricity generation in diesel motors of other industrial power stations
UIKWGM	Electricity generation in gas machines of other industrial power stations
UIKWGT	Electricity generation in gas turbines of other industrial power stations
UIKWTA	Heat generation in TA Luft systems of other industrial power stations
UVBAWI	Construction-related transport
UVHAUS	Residential, mobile sources
UVHBFI	Blue-water fishing (international)
UVHBIN	Navigation
UVKBFI	Coastal and inland fisheries
UVLAWI	Agricultural transport
UVLUMI	Military air transport
UVLZIN	Civil air transport (international)
UVLZNA	Civil air transport (national)
UVMILI	Military transport
UVSCHI	Railway transport
UVUEKB	Coastal and inland navigation
ZEKW13	Electricity generation in large combustion systems of other mine-pit power stations
ZGBK13	Electricity generation in large combustion systems of power stations of the lignite-mining sector
ZGKWDM	Electricity generation in diesel motors of mine and mine-pit power stations
ZGKWGM	Electricity generation in gas machines of mine and mine-pit power stations
ZGKWGT	Electricity generation in gas turbines of mine and mine-pit power stations
ZGSK13	Electricity generation in large combustion systems of other power stations of the hard-coal mining sector

The stationary combustion-related energy activities are taken from the BEU, entered into the CSE and then properly aggregated, for the various source categories, pursuant to CRF. The road-traffic data comes primarily from the TREMOD database.

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

3.1.1.1 Source-category description (1.A.1a)

CRF 1.A.1a					
Key source by level (l) / trend (t)		Gas (key source)	1990 – contribution to total emissions	2003 – contribution to total emissions	**Trend**
Solid fuels	l / t	CO_2	24,61 %	28,60 %	rising
Gaseous fuels	l / -	CO_2	1,48 %	2,56 %	rising
Liquid fuels	l / t	CO_2	0,68 %	0,46 %	falling

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor[11] (EF)	CS	CS	NO	NO	NO	CS	CS	CS	CS	CS
EF uncertainties in %	< 3	+/-50	-	-	-	+/-50				
Distribution of uncertainties[12]	T	U	-	-	-	U				
Method of EF determination[13]	CS	Tier 2	-	-	-	Tier 2				

For gaseous fuels, in terms of emissions levels, and for solid and liquid fuels, in terms of both emissions levels and trends, the source category "public electricity and heat production" is a key source.

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 Environmental Agency. The numbers themselves are based on a personal communication from an expert.

In the public electricity supply sector, the rated output of installed electrical plants that burn fossil fuels is about 75 GW. Almost 90 % of this plant output is accounted for by steam turbine power stations, approximately 6 GW consists of gas turbine power stations, and the remainder is accounted for by motor power stations. Of the steam turbine power stations, a total representing 48 GW is fired with hard coal and lignite. In the year 1998, all of the plants together produced some 313 TWh of electrical power, accounting for 63 % of public electricity generation.

Thermal power stations contribute an electrical output of 10 GW to the public supply. Their thermal output totals 29 GW. In the year 1998, they produced around 28 TWh of electricity and 235 PJ of district heat. District heating generation is supplemented by district heat plants with a thermal output of 21 GW. These plants supplied just under 64 PJ to the public district heat network. 56 % of district heat plants' output was produced using natural gas, 13 % was produced using hard coal and lignite, 15 % was produced using waste fuels, and 13 % was produced using petroleum products.

11 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
12 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
13 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model

Under source category 1.A.1a, Public electricity and heat production, the CSE includes district heat plants, electricity and heat production of public power stations and public power stations fired with hard lignite.

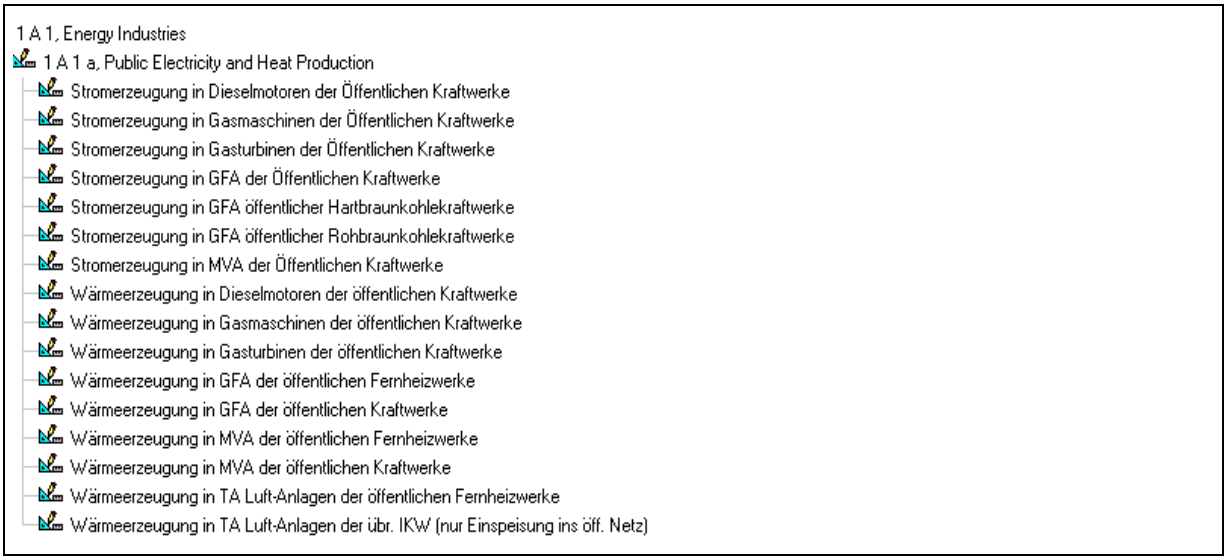


Figure 17: Structural allocation, 1.A.1a Public electricity and heat production

3.1.1.2 Methodological issues (1.A.1a)

Fuel use in power stations for the public supply is stated in line 11 (public thermal power plants) and line 15 (heat/power stations) of the energy balance (AGEB, 2003), while the fuel use in district heat stations is reported in line 16.

Table 10 shows how the fuel inputs in the *Balance of Emission Causes* (BEU) module are structured. This structure makes it possible to provide a complete picture of the sector.

The underlying data for the emission factors used 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). This project has also provided the underlying data for the emission factors presented in Chapters 3.1.2, 3.1.3, 3.1.4.6 and 3.1.5.5, where the factors include power stations, gas turbines or conventionally fired boilers for generation of steam and hot/warm water. This project was carried out by the Franco-German Institute for Environmental Research (Deutsch-Französischen 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 plants in Germany that are subject to licensing requirements, and to do so for the years 1995, 2000 and 2010. This process consists primarily of analyzing and characterising the relevant emitter structures, and the pertinent emission factors, for the year 1995, and then of updating the data for the years 2000 and 2010. This procedure systematically determines emission factors for the substances SO_2, NO_X, CO, NMVOC, dust and N_2O. The process 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 is also compiled; these other substances include PAH, PCDD/F, As and Cd for combustion plants subject to licensing requirements, and CH_4 for gas turbines and combustion plants under the TA Luft that are

subject to licensing requirements. Annex 3 (Chapter 14.1.1.1) discusses the procedure used in the research project.

In Germany, N_2O is monitored only in exceptional cases; for this reason, no relevant data from regular measurements is available. On the other hand, relevant emissions behaviour in combustion of hard coal and lignite, especially in fluidised-bed combustion, has been specifically studied over the past 15 years. For this reason, enough measurement data was available to permit systematic survey of N_2O emission factors in the research project. The relevant technological emission factors for large combustion plants, as determined in the research project, are summarised in 14.1.1.1. These factors were used as a basis for calculating the source-category-specific emission factors for the CSE.

Table 17: Technological emission factors for nitrous oxide from large combustion plants

Fuel / combustion technology	**N_2O emission factor (1995 - 2010) [kg/TJ]**
Hard coal / fluidised bed	20
Hard coal / other combustion methods	4
Lignite / fluidised bed	8
Lignite / dry-dust combustion, in the new Länder	3,2
Lignite / other combustion methods	3,5
Liquid fuels	1
Gaseous fuels	0,5

The data presented in the following table, taken from from the research project RENTZ et al (2002), served as the basis for systems < 50 MW furnace thermal output. The relevant median figures are shown in brackets.

Table 18: Technological emission factors for nitrous oxide from systems < 50 MW furnace thermal output

Fuel		Technology	Output	German Länder	N_2O-E factor / median [kg/TJ]	
Hard coal		Grate combustion	< 5 MW	/	2,5-5,2	[3,9]
			≥ 5 MW	ABL	2,5-5,2	[3,9]
			≥ 5 MW	NBL	2,5-5,2	[3,9]
		Furnace-shell combustion	< 5 MW	ABL	2,5-5,2	[3,9]
			< 5 MW	NBL	2,5-5,2	[3,9]
			≥ 5 MW	/	2,5-5,2	[3,9]
		Fluidised-bed combustion	< 5 MW	/	25-40	[36]
			≥ 5 MW	/	2-170	[47]
Lignite	- Dust	Dust combustion	≥ 5 MW	NBL		[3,2]
	- Bri-quette	n.i.	< 5 MW	NBL	0,4-3,7	[2,1]
	Raw	n.i.	< 5 MW	NBL	0,4-3,7	[2,1]
			≥ 5 MW	ABL	0,4-3,7	[2,1]
			≥ 5 MW	NBL	0,4-3,7	[2,1]
		Fluidised-bed combustion	≥ 5 MW	/	40-50	[45]
Heavy heating oil		n.i.	/	ABL	2-4	[3]
			/	NBL	2-4	[3]
Light heating oil		n.i.	≥ 20 MW	/	0,6-1,5	[1,1]
Natural gas		n.i.	≥ 10 MW	/	0,3-1,5	[0,9]

n.i. not included
ABL Old German Länder
NBL New German Länder

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

Research project 202 42 266 (UBA, 2004), which is aimed at implementing the IPCC-GPG requirements (2000) in inventory preparation, is systematically determining the pertinent uncertainties (cf. Chapter 1.7). This work has not yet been completed in the area of activity data for the energy sector, and thus that data will have to be provided later.

Aspects of time-series consistency with energy data are treated in Chapter 13.6.

The uncertainty of the determined emission factors has been evaluated in the framework of the DFIU research project described in Chapter 3.1.1.2 and in Annex 3, Chapter 14.1.1.1.

3.1.1.3.1 Methods for determining uncertainties of emission factors

The uncertainties in emission data result from several different factors. These include *precision*, i.e. chance and systematic errors in the framework of emission measurement and *completeness* of the database with regard to lacking measurements. Another factor is the *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 (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 error and 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' judgement should be carried out.

In general, use of *experts' judgements* is recommended in cases in which available empirical data does not suffice for quantification. A sample explanation is provided in Annex 3, in Chapter 14.1.1.2.

3.1.1.3.2 Result for N_2O

Individual evaluations of the uncertainties in N_2O emission factors, produced in the research project (RENTZ et al, 2002), are included in the Excel tables for transfer of emission factors into the Federal Environmental Agency's CSE database; for power stations, the evaluations are also described in the final report. The great majority of values for relative uncertainty lie in the range between 0.6 and 0.9. As part of an experts' judgement, carried out by the research customer, pursuant to Tier 1 IPCC-GPG (2000: Chapter 6), an upper boundary of +/- 50 % was given for the percentage uncertainty in CRF category 1.A.1a (as well as for categories 1.A.1b, 1.A.1c and 1.A.2) (remark: values for +/- ranges must be divided by 2; cf. IPCC-GPG (2000: Kapitel 6, p. 6.14); in the process, uniform distribution of uncertainties is assumed – in keeping with the calculation method selected.

3.1.1.3.3 Result for CH_4

Combustion plants in Germany are not subject to monitoring of CH_4 emissions; consequently, no systematic measurement data is available in this area. For this reason, individual items of data 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 3.1.1.2) The individual CH_4 emission factors, as determined in the research project (RENTZ et al, 2002), are summarised in Annex 14.1.1.3. Previously, the factors listed there, for hard coal fired in combustion plants < 50 MW (mean value for D: 3.35 kg/TJ), and for light heating oil and natural gas fired in gas turbines, were used in the CSE. Review and adoption of the project's remaining proposals are still pending (cf. Chapter 3.1.1.6). For these fuels, the existing country-specific emission factors in the CSE are used without change (solid fuels: 1.5 kg/TJ; liquid fuels: 3.5 kg/TJ; and gaseous fuels: 0.3 kg/TJ).

As part of an experts' judgement being carried out by the research customer, pursuant to Tier 1 of the IPCC-GPG (2000: Chapter 6), an upper limit of +/- 50 % was estimated for the percentage uncertainty in source category 1.A.1a (as well as in source categories 1.A.1b,

1.A.1c and 1.A.2); in the process, a uniform distribution of uncertainties is assumed – as was the case for N_2O.

3.1.1.3.4 Time-series consistency of emission factors

In the framework of the aforementioned research project (RENTZ et al 2002), the emission factors for N_2O were determined for 1995 (reference year) and then extrapolated, on this basis, for 2000 and 2010. With this approach, no changes result for most of these emission factors for the period from 1995 to 2003. The N_2O emission factors were forecast to decrease slightly only in the area of use of gas turbines (natural gas, light heating oil). This is a secondary effect of the higher mean gas-turbine-intake temperatures used in modern gas turbines in order to increase efficiency. These changes have no significant effect, however, on levels of total N_2O emissions in the CRF area under consideration.

A transfer error, which led to use of an erroneous, excessive value of 4.6 kg/TJ for hard-coal consumption in public power stations in 2000 (RENTZ et al, 2002: Table 2-34), was corrected, in fall 2004, following consultation with the research customer, to an accurate value of 4.3 kg/TJ; this process also involved correction of interpolated values for the years 1996 through 1999, 2001 and 2002. In addition, the values for raw-lignite power stations in eastern German mining regions were also corrected; emissions of those stations – almost all of which use solely dust combustion – are slightly lower than those of comparable stations in western Germany, as is shown in Table 17. Both corrections are helping to eliminate the stray value found, for IEF for N2O in category 1A1 / solid fuels, in the "Synthesis and Assessment Report Part II" for the 2004 report.

The time series between 1995 and 2003 were reviewed in this light and assessed as consistent overall. The time series of CH4 emission factors for 1995 to 2003 were also reviewed and assessed as internally consistent.

Source-specific review of N_2O and CH_4 emission factors with regard to consistency with the values as of 1995 remains to be carried out for the period from 1990 to 1994. This review is currently being carried out, taking account of the results of quality-assurance measures from Chapter 3.1.1.6, in the framework of a research project described in Chapter 3.1.1.4 Changed values can be included in the inventory no earlier than the 2006 report cycle.

3.1.1.4 Source-specific quality assurance / control and verification (1.A.1a)

Since the inventories, in general, are based on the energy balances for Germany prepared by the Working Group on Energy Balances (AGEB, 2003) – whose quality-assurance system is currently not available – quality assurance, quality control and verification of energy inputs are carried out by reviewing the energy balance for completeness and plausibility. This procedure leads to re-allocations of fuel-use amounts within the energy balance, as well as to addition of energy inputs not listed in the energy balance – such as firewood use in the source categories residential, commercial/institutional and commerce, trade and services (cf. Chapters 13.3, 13.5.1, 13.5.2, 13.6.1, 13.7, 3.1.12).

Measures for assuring the quality of emission factors for combustion plants, as used in the framework of a research project (RENTZ et al, 2002), are outlined in the methods description in Annex 3, Chapter 14.1.1.1 (after Figure 62). The inventory's data quality in the area of N_2O emission factors was clearly improved by adopting the N_2O emission factors from the

research project. The situation for CH_4 was less clear (cf. Chapter 3.1.1.3.3); for this reason, the following was carried out in the framework of a quality review carried out by experts of the Federal Environmental Agency, pursuant to IPCC-GPG (2000: Chapter 2.2.3): the determined country-specific emission factors for CH_4 were compared with the Tier 2 default emission factors of the IPCC Reference Manual (1996b: Table 1-15). The aim of this review was to determine whether the DFIU data or the Tier 2 default values should be included in the inventory. The review showed that, for boiler combustion plants, the existing Tier-2 default values, on average, are lower than the country-specific emission factors. For natural-gas-fired gas turbines, on the other hand, the IPCC default values are considerably higher. The finding that Table 1-15 of the IPCC Reference Manual (1996b) has a considerable number of gaps is even more significant, however; for example, the table does not list a single CH_4 value for the area of lignite-fired combustion plants, a highly significant area in Germany; in the area of gaseous fuels, the table contains only a value for natural gas – and no values for other gases, such as refinery gas (relevant especially for CRF 1.A.1b) or coking gas (relevant especially for CRF 1.A.1c). What is more, the Reference Manual (1996b) contains inconsistencies between Tables 1-15 and 1-16 (cf. Chapter 3.1.4.6.7). As a result of all of these factors, it was decided that use of the DFIU values is clearly preferable, since those values clearly provide the larger improvement in inventory quality, especially with regard to completeness and consistency. In the experts' opinion, this procedure and the relevant values should be classified within the Tier 2 approach.

3.1.1.5 Source-specific recalculations (1.A.1a)

Source-specific recalculations for energy data have been carried out to account for data updates in the energy balance and for improvements in methods. The methodological improvements were made in close connection with the methods documentation for the energy sector called for in the review report for 2003 (FCCC, 2003: p. 3, sub-point 8); the relevant methods documentation has been improved for the NIR 2004, but it has not yet been completed. Recalculations can thus be documented only on the basis of this methodological documentation – i.e. in the 2006 report.

For the period 1995 to 2003, N_2O emissions were recalculated via use of the emission factors from the research project described in Chapter 3.1.1.2, taking the corrections described in Chapter 3.1.1.3.4 into account. Source-specific review of the emission factors for CH_4 and N_2O, and recalculation of the emission factors for CH_4 and N_2O, have not yet been completed for the period between 1990 and 1994.

3.1.1.6 Planned improvements (source-specific) (1.A.1a)

As mentioned in previous chapters, a research project is currently underway that – inter alia – will review N_2O and CH_4 emission-factor time series for consistency between the period 1990 to 1994 and the period as of 1995 and that will propose changes, if necessary, in emission factors for the period 1990-1994. In addition, an effort will also be made to further improve the database for methane emission factors.

Another emphasis of the project is to review the DFIU-determined emission factors for the year 2000, as well as the projected values for the year 2010. The aim of this work is to enhance methods for describing the chronological course of modernisations of existing plants and of adaptation of plants to tighter emissions standards. Work in the follow-on

research project began in summer 2004 and is to be completed by late summer 2005; in all likelihood, therefore, the results will not be used before the NIR 2006.

Longer-term plans call for enhancing precision in determination of N_2O / CH_4 emissions behaviour of gas turbines, via measurements and/or systematic studies. The occasions for these efforts include the circumstances described in Chapters 3.1.1.3 and 3.1.1.4, the increasing importance of gas turbines in the energy sector and in other industrial sectors, such as the refinery or the mining sectors, and Federal climate-protection efforts (especially gas and steam systems, CHP systems). The time for the start of this improvement measure has not yet been specified.

3.1.2 Petroleum refining (1.A.1b)

3.1.2.1 Source-category description (1.A.1b)

CRF 1.A.1b					
Key source by level (l) / trend (t)		Gas (key source)	1990 – contribution to total emissions	2003 – contribution to total emissions	**Trend**
Liquid fuels	l / t	CO_2	1,29 %	1,78 %	rising
Solid fuels	- / t	CO_2	0,19 %	0,05 %	falling

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor[14] (EF)	CS	CS	NO	NO	NO	CS	CS	CS	CS	CS
EF uncertainties in %	< 1	+/- 50	-	-	-	+/- 50				
Distribution of uncertainties[15]	U	U	-	-	-	U				
Method of EF determination[16]	CS	Tier 2	-	-	-	Tier 2				

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

The source category "Petroleum refining" is a key source, in terms of emissions levels, trends for liquid fuels and with respect to solid fuels.

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 Environmental Agency. The numbers themselves are based on a personal communication.

The crude oil distillation capacity of German petroleum refineries totalled around 110 Mt in the year 1998. Over this period, 108 Mt of crude oil, along with intermediate products, were used for subsequent processing. Production of petroleum products totalled 117 Mt, 52 Mt of which consisted of fuels, 33 Mt of heating oils, 10 Mt of naphtha and 22 Mt of other products.

The refineries operate power stations with an electrical output of approximately 0.8 GW and a furnace thermal output of 4 GW. These power stations generated 5 TWh of electrical output, along with process heat for production purposes; their furnace thermal output was over 7 GW.

Under source category 1.A.1b, Petroleum refining, the CSE lists the sub-categories refinery process combustion, and heat and power production of refinery power stations.

14 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
15 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
16 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model

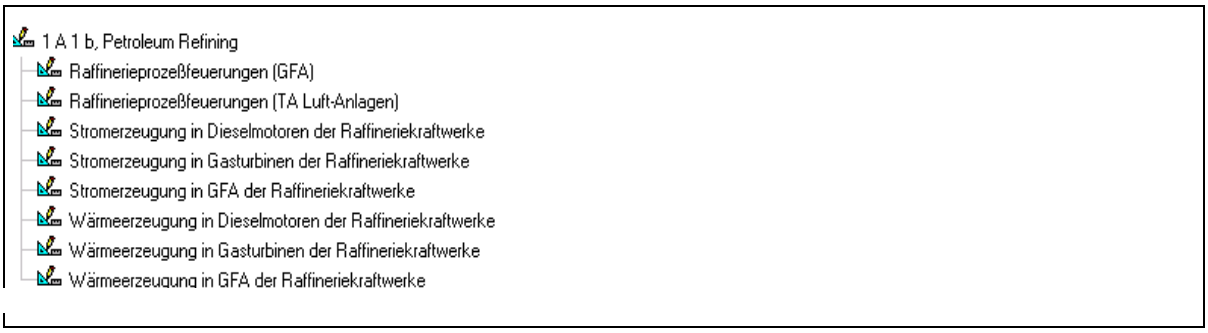


Figure 18: Structural allocation, 1.A.1b Petroleum refining

3.1.2.2 Methodological issues (1.A.1b)

For the *Balance of Emission Causes* (BEU), fuel use by refinery power stations was calculated out from the Energy Balance figures (AGEB, 2003: line 12), and the fuel inputs for power stations for heat generation and for process combustion, which are listed jointly in line 38, were separated. Table 13 (refineries) shows the plant structure used in the BEU model.

The emission factors for refinery power stations have been taken from the research project RENTZ et al. (2002). A detailed description of the procedure is presented in Chapter 3.1.1.2 and Chapter 14.1.1.1 in Annex 3. The cited project does not provide any emission factors for the bottom-heating systems that provide process heat. To compensate for this gap, for bottom-heating systems the same values for N_2O and CH_4 were chosen that are also used for refinery power stations.

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

The procedure for determining uncertainties is described in Chapters 3.1.1.3 and 3.1.1.3.1.

3.1.2.3.1 Result for N_2O

The values for the relative uncertainty are on the order of about 0.6. The pertinent comments made in Chapter 3.1.1.3.2 also apply mutatis mutandis.

3.1.2.3.2 Result for CH_4

The results of uncertainties determination are described in Chapter 3.1.1.3.3.

3.1.2.3.3 Time-series consistency of emission factors

In the framework of the aforementioned research project, the emission factors for N_2O were determined for 1995 (reference year) and then extrapolated, on this basis, for 2000 and 2010. With this approach, no changes result for most of these emission factors for the period from 1995 to 2003. The N_2O emission factors were forecast to decrease slightly only in the area of use of gas turbines (natural gas, light heating oil). This is a secondary effect of the higher mean gas-turbine-intake temperatures used in modern gas turbines in order to increase efficiency. These changes have no significant effect, however, on levels of total N_2O emissions in the CRF area under consideration.

The N_2O and CH_4 time series between 1995 and 2003 were reviewed in this light and assessed as consistent overall.

Source-specific review of N_2O and CH_4 emission factors with regard to consistency with the values as of 1995 remains to be carried out for the period from 1990 to 1994. This review is currently being carried out, in the framework of the research project described in Chapter 3.1.1.6, taking account of the results of quality-assurance measures from Chapter 3.1.1.4. Changed values are to be included in the inventory for the 2006 report cycle.

3.1.2.4 Source-specific quality assurance / control and verification (1.A.1b)

The results of source-specific quality assurance / control and verification are described in Chapter 3.1.1.4.

3.1.2.5 Source-specific recalculations (1.A.1b)

No source-specific recalculations were carried out with regard to emission factors for N_2O and CH_4.

3.1.2.6 Planned improvements (source-specific) (1.A.1b)

The planning described in Chapter 3.1.1.6 will also adequately improve the data situation for petroleum refineries. The already commenced research project described in the same chapter will also determine the emissions behaviour of refinery bottom-heating systems that provide process heat.

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

3.1.3.1 Source-category description (1.A.1c)

CRF 1.A.1c					
Key source by level (l) / trend (t)		Gas (key source)	1990 – contribution to total emissions	2003 – contribution to total emissions	**Trend**
Solid fuels	l / t	CO_2	4,53 %	1,85 %	falling

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor[17] (EF)	CS	CS	NO	NO	NO	CS	CS	CS	CS	CS
EF uncertainties in %	< 5	+/-50	-	-	-	+/- 50				
Distribution of uncertainties[18]	U	U	-	-	-	U				
Method of EF determination[19]	CS	Tier 2	-	-	-	Tier 2				

In light of its CO_2-emissions levels and trend, source category 1.A.1c is a key source.

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

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 Environmental Agency. The numbers themselves are based on a personal communication.

This category includes hard-coal and lignite mining, coking and briquetting plants and extraction of crude oil and natural gas. In 2003, the German hard-coal mining sector

extracted 25.9 Mt of usable hard coal. During the same period, coke production amounted to about 7.8 Mt (STATISTIK DER KOHLENWIRTSCHAFT, 2004)[20]. Together, production of hard-coal briquettes and other coal products totalled less than 1 Mt. An electrical power plant output of less than 3 GW, with a furnace thermal output of 7 GW, is attributable to hard-coal mining. Heat generation via combined heat and power generation is minimal.

In 2003, 179.1 Mt of crude lignite was produced in Germany. Production of lignite briquettes and other lignite products amounted to about 5 Mt (STATISTIK DER KOHLENWIRTSCHAFT, 2004). For production of such products in particular, the lignite-mining sector operates power stations with an electrical output of 0.4 GW and a furnace thermal output of 2 GW. From these plants, steam is drawn off for drying crude lignite for production of lignite products.

In 1998, German production of petroleum totalled just under 3 Mt, whilst production of natural gas totalled nearly 20,000 Mm³ (H_u = 31 736 kJ/m³). The fuel input needed for operation of the plants is included in the balance of emission causes (BEU).

In the CSE, source category 1.A.1c Manufacture of solid fuels and other energy industries includes electricity and heat generation in steam-turbine power stations, broken down by hard-coal mining (STEAG, other pit power stations) and lignite mining (pit power stations), combined electricity and heat generation in gas turbines, gas engines and diesel engines of all pit (*Zeche* + *Grube*) power stations, other heat generation 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 pit (*Zeche* + *Grube*) power stations.

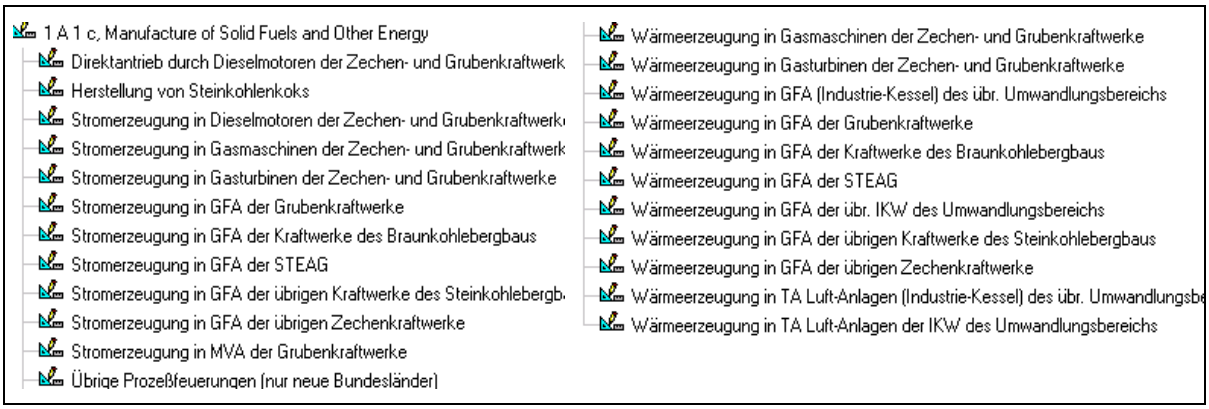


Figure 19: Structural allocation, 1.A.1c Manufacture of solid fuels and other energy industries

3.1.3.2 Methodological issues (1.A.1c)

Table 11 shows the data structure, from the *Balance of Emission Causes*, for the hard-coal and lignite-mining sectors.

Table 13 shows the BEU structure for oil extraction.

The sources used for the production data include the Energy Balance for the Federal Republic of Germany (for the years 1990-1999 AGEB, 2003: 3.1, line 21), STATISTIK DER

17 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
18 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
19 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model
[20] p. 50, overview of figures 45, line for coke production

KOHLENWIRTSCHAFT (Statistics of the coal industry, 2004) and Statistik des produzierenden Gewerbes (Statistics of the manufacturing sector; DESTATIS, Fachserie 4 Reihe 3.1, 1991-2004: Produktion im Produzierenden Gewerbe; Melde-Nr. 2310 10 330+350). Fuel-input data was taken from the Energy Balance for the Federal Republic of Germany (3.2 (Joule), AGEB, 2003: line 33).

Fichtner Beratende Ingenieure (FICHTNER, 1982) was also consulted.

The procedure described below currently applies for production of activity-rate time series oriented to the area of Germany as of 1995. It will also be the methodological starting point for the time-series recalculations that remain to be carried out for the 1990-1994 period for the old and new Länder.

Data on energy consumption in hard-coal coking cannot be taken directly from the Energy Balance (AGEB, 2003: line 33, Own consumption of coking plants), since such consumption is only a sub-set of the data shown in the relevant Energy-Balance line. An approach using specific energy consumption was thus chosen for determining activity rates. From the aforementioned study (Fichtner, 1982), bottom heating of coking furnaces of mines' coking plants was found to have an average consumption of 2950 MJ coking-plant gas per tonne of coke. For metallurgical coking plants, this value is 5 % higher, or 3100 MJ per t coke, as a result of those plants' use of blast-furnace gas. Since no figures are available for local gas works, the specific consumption of mine coking plants is assumed for this category of bottom heating of coking furnaces.

The binding basic figure for determination of relevant energy inputs is the conversion output of coking plants pursuant to the Energy Balance (AGEB, 2003: line 21) in 1000 t of hard-coal coke. The Federal Statistical Office's relevant figures are used, as a recourse, only for those years for which no Energy Balance is available. The production of by-product coke is calculated from the difference between total hard-coal-coke production and metallurgical coke production, pursuant to the coal industry's statistics. The energy input, in TJ, for bottom heating of coking furnaces is obtained by multiplying the figures for mine and metallurgical coke production with the relevant specific energy consumptions. Consumption of blast-furnace gas pursuant to the Energy Balance (AGEB, 2003: line 33) has been allocated completely to bottom heating of coking furnaces, and the difference between this and total input is the figure for coke-furnace / city gas.

Table 19 shows the activity rates determined; lignite coking plants are not included, since no energy inputs are available for them.

Table 19: Determination of activity rates (AR) of emissions-relevant energy consumption (EMEV) of process combustion in hard-coal coking

Hard-coal coke production	**Units**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Total 1)	[1000 t]	11100	10662	10774	10325	8569	9141	7265	7226
By-product (metallurgical) coke 2)	[1000 t]	6306	5833	5859	5591	5195	5296	5274	5225
Mine coke 3)	[1000 t]	4794	4829	4915	4734	3374	3845	1991	2001
Mean energy input									
Metallurgical coke	[TJ/kt]	3,1	3,1	3,1	3,1	3,1	3,1	3,1	3,1
Mine coke	[TJ/kt]	2,95	2,95	2,95	2,95	2,95	2,95	2,95	2,95
Energy input for hard-coal coking									
Metallurgical coke	[TJ]	19548,6	18082,3	18162,9	17332,1	16104,5	16417,6	16349,4	16197,5
Mine coke	[TJ]	14142,3	14245,5	14499,2	13965,3	9953,3	11342,8	5873,45	5902,95
Total	[TJ]	33691	32328	32662	31297	26058	27760	22223	22100
EMEV hard-coal coking									
AR blast-furnace gas 4)	[TJ]	19156	18172	19193	16861	12163	15662	16189	16397
AR coke-furnace gas, city gas 5)	[TJ]	14535	14156	13469	14436	13895	12098	6034	5703

1) Energy Balance (AGEB 2003), line 21; 2000/2001: DESTATIS Fachserie 4 Reihe 3.1, 1991-2004: Melde-Nr. 2310 10 330+350; 2002: Melde-Nr. 2310 10 300 as an additional aid

2) Statistik der Kohlenwirtschaft e.V. (2004): Der Kohlenbergbau in der Energiewirtschaft der Bundesrepublik Deutschland im Jahre 2002, Zahlenübersicht 45; für die Jahre 2001/2002 DESTATIS Fachserie 4 Reihe 8.1, 1991-2004: Table 3.1, Erzeugung der Hüttenkokereien (production of metallurgical works' coking plants), as an additional aid

3) Total hard-coal-coke production except for by-product (metallurgical) coke

4) Total value from Energy Balance (AGEB 2003), line 33, for blast-furnace gas and converter gas

5) Total energy input, except for AR blast-furnace gas

The emission factors for power stations and other boiler combustion for production of steam and hot/warm water, in source category 1.A.1c, have been taken from RENTZ et al (2002). A detailed description of the procedure is presented in Chapter 3.1.1.2 and in Chapter 14.1.1.1 in Annex 3.

Within the sector, the research project differentiates 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.

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

The procedure for determining uncertainties is described in Chapters 3.1.1.3 and 3.1.1.3.1.

3.1.3.3.1 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.1c. Such systems are known to have relatively higher N_2O emissions than systems using other types of coal-combustion technologies. On the other hand, emissions behaviour in combustion of hard coal and lignite, especially in fluidised-bed combustion, has been specifically studied over the past 15 years. For this reason, enough measurement data was available to permit systematic survey of N_2O emission factors in the research project. The values for the relative uncertainty of the emission factors are on the order of about 0.6. The pertinent comments made in Chapter 3.1.1.3.2 also apply mutatis mutandis.

3.1.3.3.2 Result for CH_4

The results of uncertainties determination are described in Chapter 3.1.1.3.3.

3.1.3.3.3 Time-series consistency of emission factors

The results of determination of time-series consistency are described in Chapter 3.1.2.3.3.

3.1.3.4 Source-specific quality assurance / control and verification (1.A.1c)

The results of source-specific quality assurance / control and verification are described in Chapter 3.1.1.4.

3.1.3.5 Source-specific recalculations (1.A.1c)

No source-specific recalculations were carried out with regard to emission factors for N_2O and CH_4.

3.1.3.6 Planned improvements (source-specific) (1.A.1c)

The planning described in Chapter 3.1.1.6 will also adequately improve the data situation for power stations and other combustion plants within the mining sector.

Review of existing emission factors in the area of coking plants, and of the consistency of pertinent time series, is planned for next year. In the interest of broadening the database, plans also call for development, with the help of relevant associations, operators and monitoring authorities, of a strategy for future data deliveries and uncertainties estimates. One lignite coking plant is still in operation in Germany. This coking plant's relevance for emissions reporting remains to be studied.

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

This source category consists of several sub- source categories.

CRF 1.A.2					
Key source by level (l) / trend (t)		Gas (key source)	1990 – contribution to total emissions	2003 – contribution to total emissions	**Trend**
Solid fuels	l / t	CO_2	9,66 %	5,83 %	falling
Gaseous fuels	l / t	CO_2	3,67 %	4,93 %	rising
Liquid fuels	l / t	CO_2	2,28 %	1,87 %	falling
Other Fuels	- / t	CO_2	0,15 %	0,04 %	falling

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor[21] (EF)										
EF uncertainties in %										
Distribution of uncertainties[22]										
Method of EF determination[23]										

In light of its emissions levels and trend, the source category "Manufacturing industries and construction" is a key source for solid, gaseous and liquid fuels; for other fuels, it is is a key source in light of its trend.

All of the amounts of conventional fuels used are included in the Energy Balance of the Federal Republic of Germany; in addition, the Energy Balance of the Federal Republic of Germany, in the form expanded by the Federal Environmental Agency (Balance of Emissions Causes, BEU, cf. Chapter 13), also provides figures for the secondary fuels used in industrial thermal power stations.

Where the fuels used are included in the BEU and contain fossil carbon, the resulting emissions of climate-relevant gases are included in the national emissions inventory. These emissions cannot be allocated to the various source categories under 1.A.2 and listed here, however, since the BEU is not differentiated according to these sub- source categories – it uses the structure shown in Figure 20. To these structural elements, the CSE assigns fuel-specific emission factors for the various climate gases.

For emissions calculation, Energy Balance data, dissaggregated in keeping with the BEU structure, is multiplied by the relevant emission factors. Following calculation on the structural-element level, the results are aggregated to produce the sum values reported under source category 1.A.2.

Under source category 1.A.2 Manufacturing industries and construction, the CSE includes power generation in Deutsche Bahn (German Railways) power stations, heat production in the manufacturing sector and other mining sector, process combustion for manufacture of various products, and power generation of other industrial power stations.

21 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
22 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
23 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model

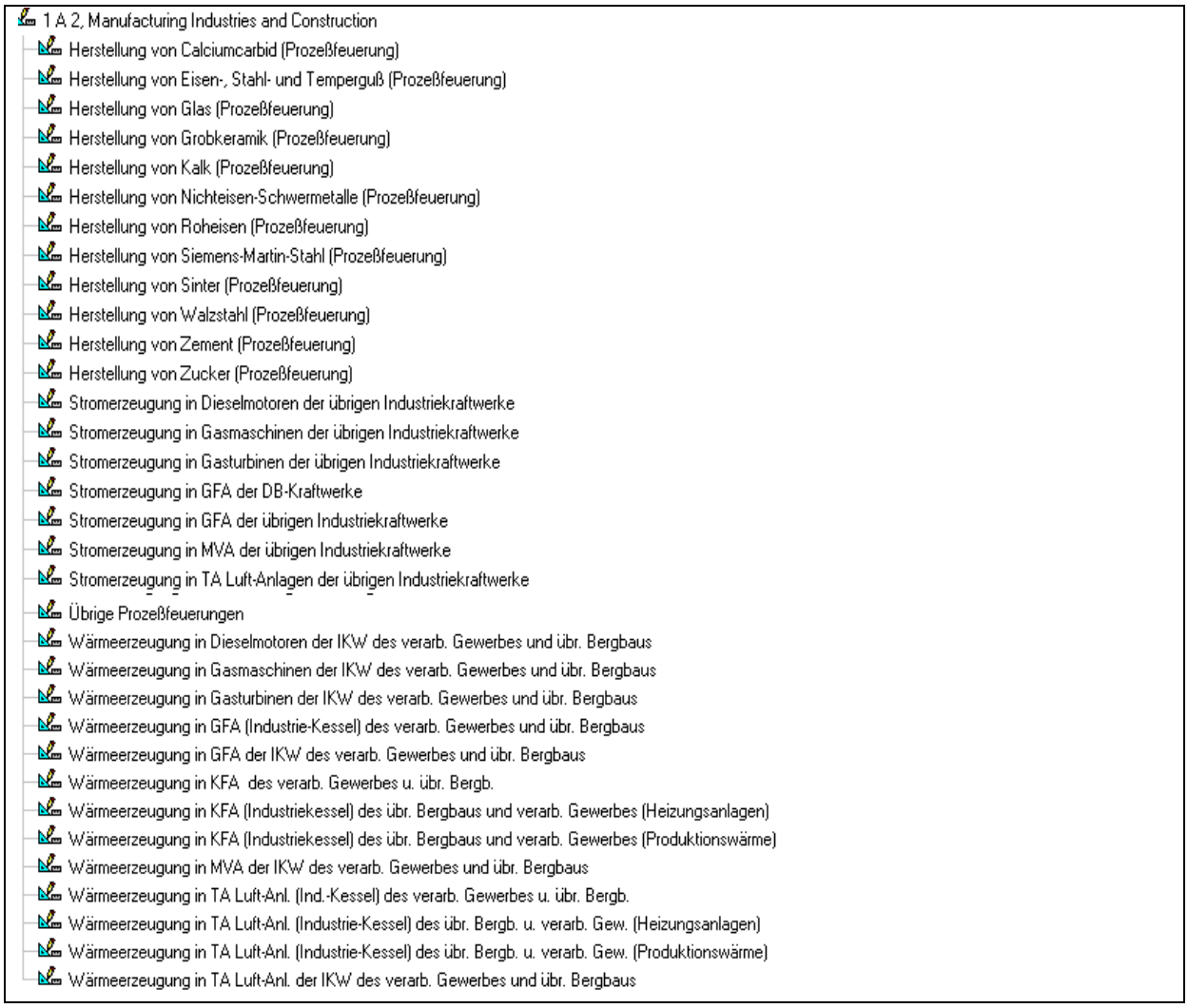


Figure 20: Structural allocation, 1.A.2 Manufacturing industries and construction

3.1.4.1 Manufacturing industries and construction – Iron and steel (1.A.2a)

Emissions of this source category are reported, in combined form, under 3.1.4.

3.1.4.2 Manufacturing industries and construction – Non-ferrous metals (1.A.2b)

Emissions of this source category are reported, in combined form, under 3.1.4.

3.1.4.3 Manufacturing industries and construction – Chemicals (1.A.2c)

Emissions of this source category are reported, in combined form, under 3.1.4.

3.1.4.4 Manufacturing industries and construction – Pulp, paper and print (1.A.2d)

Emissions of this source category are reported, in combined form, under 3.1.4.

3.1.4.5 Manufacturing industries and construction – Food processing, beverages and tobacco (1.A.2e)

Emissions of this source category are reported, in combined form, under 3.1.4.

3.1.4.6 Manufacturing industries and construction – Other (1.A.2f)

Emissions of this source category are reported, in combined form, under 3.1.4.

3.1.5 Transport

3.1.5.1 Transport – Civil aviation (1.A.3a)

3.1.5.1.1 Source-category description (1.A.3a)

CRF 1.A.3					
Key source by level (l) / trend (t)		**Gas (key source)**	**1990 – contribution to total emissions**	**2003 – contribution to total emissions**	**Trend**
Aviation gasoline	l / t	CO_2	0,23 %	0,42 %	rising

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor[24] (EF)	CS	CS	--	--	--	CS	CS	CS	CS	CS
EF uncertainties in %										
Distribution of uncertainties[25]										
Method of EF determination[26]	T1	T1	--	--	--	T1				

In terms of its emissions levels and trend, civil aviation is a key source.

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 altitude.

In addition to considering carbon dioxide, the debate on the climate effects and emissions-related environmental impacts of air transports focuses mainly on water vapour and nitrogen oxides and, secondarily, on hydrocarbons, particulates, CO 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 sulphur dioxide (SO_2), nitrogen oxides (NO_X, i.e. NO and NO_2), non-methane volatile organic compounds (NMVOC), methane (CH_4), carbon dioxide (CO_2) and nitrous oxide (N_2O – laughing gas).

CO_2 emissions have been increasingly continually as a result of increasing fuel consumption from increasing air transports. The highest level of CO_2 emissions occurred in 2000. In recent years, the fuel efficiency of aircraft engines has been markedly improved. Since 1999, this trend has resulted in changes – some of them considerable – in emission factors. As of 2000, NMVOC, NO_2 and CO emissions levels have been lower, and N_2O levels higher, than the corresponding levels in 1999.

The CSE has no sub-categories under source category 1.A.3a Civil aviation.

24 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
25 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
26 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model

Figure 21: Structural allocation, 1.A.3a Civil aviation

3.1.5.1.2 Methodological issues (1.A.3a)

With regard to the flight movements, broken down for various flight phases, of aircraft operating in Germany, no data is available. For this reason, the requirements for the Tier 2 method, calling for differentiation of emission factors for the LTO cycle and cruising flight, cannot be met. Air transport emissions are calculated via the Tier 1 method, pursuant to equation 2.7 of IPCC-GPG (2000, p. 2.57):

Emissions = fuel consumption * emission factor

The basis for the relevant activity data consists of the Energy Balance of the Federal Republic of Germany, which is oriented to the aircraft fuel sold in Germany. Since the emission factor for carbon dioxide depends on the fuel C content, this factor was determined, for reasons of consistency, by the Federal Environmental Agency's energy specialists who provide all combustion-related emission factors for specific fuels.

Emissions of sulphur dioxide depend solely on the sulphur content of the fuel in question (cf. the Annex, Chapter 14.1.3.1.1).

On the other hand, the sulphur content is subject to regional fluctuations. For reasons of consistency, this content is determined by the Federal Environmental Agency transport section that provides all fuel-relevant indexes (these were last provided in September 2003). Pursuant to measurements carried out in 1998, the sulphur concentration in fuel is about 210 ppm, i.e. 0.021 mass-percent (DÖPELHEUER, 2002). According to Shell AG (Germany) and the Association of the German Petroleum Industry (deutscher Mineralölwirtschafts-verband; MWV), the sulphur content of kerosine is on the order of that of low-sulphur diesel fuel – no precise, generally valid relevant data was provided, however. Taking the available, substantiated figures into account, the content is likely to be significantly greater than the average content in diesel fuel, about 50 ppm. For this reason, the value given in (DÖPELHEUER, 2002) is used as a basis. Assuming complete combustion, this would result in an emission factor of 0.4 g/kg SO_2. For the reader's information, it should be added that a small part of emitted sulphur dioxide is further oxidised into SO_3 which, in turn, reacts with water to form sulphuric acid. The values listed in the IPCC guidelines, 1.0 g/kg for cruising flight and 2.4 g/kg for the LTO cycle, are not considered up to date.

To date, emission factors for other pollutants have been determined on the basis of the research project "Determination of exhaust emissions from air traffic over the Federal Republic of Germany" ("Ermittlung der Abgasemissionen aus dem Flugverkehr über der Bundesrepublik Deutschland", Federal Environmental Agency, 1989) via recalculation from emissions.

In 2003, the existing emission factors were reviewed. These factors are shown in Table 20 (cf. p. 3-36). In the CSE, these factors are used for the years until 1999, since for that period not enough data is available for any recalculation. The first emission-factor column in the table uses the units [g/kg] fuel, which are customarily used in the air-transport sector, while

the second emission-factor column uses the units [kg/TJ], which are commonly used in the framework of reporting.

Table 20: Emission factors used to date

Name	Emission factor [g/kg]	Emission factor [kg/TJ]
Sulphur dioxide	0,4	9,3
Nitrogen dioxide	17,4	390
Non-methane volatile organic compounds	2,6	59
Methane	0,04	1
Carbon monoxide	17,4	390
Carbon dioxide	3.299,7	74000
Nitrous oxide (laughing gas)	0,1	1,5

For purposes of emissions reporting, the determined emission factors must be converted into the corresponding energy equivalents, taking the calorific value of kerosine into account. To date, the value 44,589 kJ/kg has been used for this purpose. In future, this value is to be changed, on the basis of figures from the Association of the German Petroleum Industry (Verband der Mineralölwirtschaft; MWV), to 43,000 kJ/kg. A value of 43,280 kJ/kg is provided in (DÖPELHEUER, 2002). In general, the factor factor 43,000 may be used for conversion of EI into the units [kg/TJ]. The energy balance "Calorific values of fuels, and factors for conversion of specific amounts units into thermal units for the Energy Balance" ("Heizwerte der Energieträger und Faktoren für die Umrechnung von spezifischen Mengeneinheiten in Wärmeeinheiten zur Energiebilanz" (AGEB, 2003: Table 1.5.2), uses the calorific value 43,000 kJ/kg as of 1993.

The emission-factor review led to adjustment of nearly all factors. The factors used as of 2000 (recalculation for the years 2000, 2001 and 2002) are shown in Table 2. The new calorific value, 43,000 kJ/kg, was used in conversion. For purposes of comparison, the previously used emission factors have been included, in the third column.

From the study "Federal Environmental Agency texts 17/01" (UBA-Texte 17/01 (Federal Environmental Agency, 2001a), the ratio between national and international air transports was determined as 20 % to 80 %. The smaller percentage is based on the number of passengers, as a percentage of all passengers, who must be assigned to intra-German air transports (including transfers, base year 1995). In keeping with this relationship, 20 % of the total emissions determined are assigned to national civil air transports.

Table 21: New emission factors as of 2003 (recalculation for 2000 through 2002, with calorific value = 43,000 kJ/kg)

Name	New emission factor [g/kg]	New emission factor [kg/TJ]	Old emission factor [kg/TJ]
Sulphur dioxide	0,4	9,3	9,3
Nitrogen as nitrogen dioxide	14,00	325,58	390
Non-methane volatile organic compounds	1,61	37,44	59
Methane	0,04	0,93	1
Carbon monoxide	9,20	213,95	390
Carbon dioxide	3.150,00	73.265	74.000
Nitrous oxide (laughing gas)	0,15	3,49	1,5

For detailed explanations of the assumption on which the methods are based, and of the development of the EF, cf. the Annex, Chapter 14.1.3.1.2. For detailed information regarding the development of the EF, cf. the Annex, Chapter (QC/QA and verification).

3.1.5.1.3 Uncertainties and time-series consistency (1.A.3a)

The uncertainties cannot be stated scientifically correctly with the emission factors used, since the available database is statistically inadequate. On the other hand, the chapter on "verification" does discuss the applicable ranges for the various factors.

3.1.5.1.4 Source-specific quality assurance / control and verification (1.A.3a)

The current calculation procedures have been verified on the basis of more current data and findings. This applies to the various emission factors used and the energy content for conversion into energy-related emission factors. No data is available to quantify a more accurate breakdown between national and international air transports. The emission factors proposed by the IPCC Reference Manual (IPCC, 1997: p.1.96ff) have been taken into account in the following considerations, however. On the other hand, it must be noted that the proposed emission factors were generated with an average fleet that is not completely representative of German air transports The data that would be needed to achieve greater precision in specifying national differences is not available, however. The results of the verification are the starting point for use of the above-described, new emission factors, which reflect the aircraft fleet's current emissions much more closely.

The emission factors used to date for determination of air-transport emissions have been revised and adjusted in keeping with new information that has become available and with technological progress in aircraft engines. As described above, combustion takes place at a range of different altitudes, and thus generation of emission factors can be problematic; emission factors for higher altitudes must be correlated with the emission factors determined for the LTO cycle (landing/take-off cycle, i.e. flight movements to an altitude of 3,000 feet, or about 915 m). For example, formation of nitrogen oxides depends strongly on external conditions and on the conditions in the combustion chamber, which change with altitude.

For detailed explanations of the assumption on which the methods are based, and of the development of the EF, cf. the Annex, Chapter 14.1.3.1.2.

Measures for standardisation of QC/QA are currently being established.

3.1.5.1.5 Source-specific recalculations (1.A.3a)

The emission factors were revised in 2003, and thus the need for a new calculation had to be reviewed. The above-cited new emission factors are sufficiently reliable for years as of 2000. For this reason, new calculations were carried out for the years 2000, 2001 and 2002.

The reason for the recalculation of emission factors for the years from 2000 to 2002 is that the relevant data has been improved. In the process, the impacts of aircraft-engine development on emissions were taken into account. As a result of recalculation, the emissions levels for 2000 to 2002 are lower (than before) for NMVOC, NO_2 and CO, and higher for nitrous oxide.

In order to review the emissions' consistency, dual calculations were carried out for the year 2000 – one calculation with the old emission factors and one with the new factors.

These two calculations differ significantly in the areas in which emission factors were adjusted to large degrees. For example, emissions levels for volatile organic compounds decreased markedly. Methane levels also decreased, although their relative changes were smaller. The primary reason for these changes is that the previously used emission factors did not reflect the considerable fuel-efficiency improvements that have occurred in recent years. Increases in fuel efficiency go hand-in-hand with reductions in hydrocarbon emissions. This relationship is apparent in the corrected values.

The value for carbon-monoxide also has to be reduced considerably, for correction. Specific CO emissions have been reduced considerably via engine modifications. For the year 2000, the adjusted emission factor cuts the originally calculated amount about in half.

Finally, the new emission factor for nitrogen oxides was also applied to the year 2000. This has shown that NO_2 emissions were overestimated with the old factor. A comparison of the old and new emission factors is presented inTable 21 (cf. p. 3-37)

The new emission factors are not the only reason that the results differ from the old values for the year 2000 – a second reason is that a new calorific value, 43,000 kJ/kg, was used.

Table 22: Emissions [Gg] comparison following recalculation

		Emissions [Gg]		
		2000	**2001**	**2002**
CH_4	**New**	0,24	0,23	0,23
	Old	0,06	0,06	0,06
CO	**New**	12,71	12,41	12,28
	Old	23,17	22,62	22,39
N_2O	**New**	0,21	0,20	0,20
	Old	0,09	0,09	0,09
NMVOC	**New**	2,22	2,17	2,15
	Old	3,50	3,42	3,39
NO_X	**New**	19,34	18,88	18,69
	Old	23,17	22,62	22,39
SO_2	**New**	0,55	0,54	0,53
	Old	2,21	2,16	2,14

3.1.5.1.6 Planned improvements (source-specific) (1.A.3a)

Plans call for improvement of the database, to permit use of a more precise method. This effort is oriented to the following aims:

- Improving information regarding what data is generated at airports,
- Improving the flow of information from airports to the Federal Statistical Office and from that office to the Federal Environmental Agency,
- Precisely defining requirements relative to data provision,
- Developing a model system that converts generated data records into values that can be used with a precise method of emissions reporting.

Plans call for reviewing the need for recalculation (extrapolation) of emission factors for the years 1996 to 2000.

3.1.5.2 Transport – Road transportation (1.A.3b)

3.1.5.2.1 Source-category description (1.A.3b)

CRF 1.A.3b					
Key source by level (l) / trend (t)		**Gas (key source)**	**1990 – contribution to total emissions**	**2003 – contribution to total emissions**	**Trend**
Gasoline	l / t	CO_2	7,69 %	7,84 %	rising
Gasoline	- / t	N_2O	0,18 %	0,30 %	rising
Diesel oil	l / t	CO_2	4,37 %	7,85 %	rising

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor[27] (EF)	CS	CS/M	-	-	-	CS/M	CS/M	CS/M	CS/M	CS/M
EF uncertainties in %	-	-	-	-	-	-				
Distribution of uncertainties[28]	-	-	-	-	-	-				
Method of EF determination[29]	T 3	T 3	T 3	T 3	T 3	T 3				

Road transportation is a key source for CO_2 – in terms of emissions levels and trend – with regard to gasoline and diesel; for N_2O, it is a key source in terms of trend with regard to gasoline.

Emissions from motorised road traffic in Germany are reported under this category. It includes traffic on public roads within Germany, excluding agriculture and forestry and excluding the military. Calculations are made for the vehicle categories of passenger cars, motorcycles, light duty vehicles, heavy duty vehicles and buses. For calculation purposes, the vehicle categories are broken down into so-called *vehicle layers* with the same emissions behaviour. To this end, the vehicle categories are divided by type of fuel used, vehicle size (utility vehicles / buses: weight class; passenger car / motorcycles: engine displacement) and installed pollution control equipment pursuant to EU directives on emissions legislation ("EURO norms") and traffic-location region (outside of municipalities, within municipalities, and autobahn).

Since 1990, emissions of CH_4, NO_X, CO, NMVOC and SO_2 from road transportation have decreased sharply, due to catalytic-converter use and engine improvements resulting from continual tightening of emissions laws, and due to improved fuel quality (cf. Table 23, p. 3-41).

The sharp reduction in the methane emission factor for gasoline and, thus, the sharp reduction in methane emissions between 1990 and 1993, is due especially to a drastic reduction in the numbers of vehicles with two-stroke engines in the new German Länder. Further reductions, until 2003, resulted from the aforementioned tightening of emissions standards.

For busses and heavy trucks (over 3.5 t total permissible vehicle weight), maximum permissible levels of hydrocarbon (HC) emissions were lowered especially sharply (- 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 fuel – and the relevant emissions themselves – decreased considerably after 2000. A similar

27 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
28 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
29 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model

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. For this reason, the decreasing trend in N_2O emissions that has been observed since 2000 can be expected to continue. Recent studies have shown, in general, that the N_2O-emission factors used to date have been too high and need to be modified for future calculations. (cf. 3.1.5.2.6).

CO_2 emissions depend directly on fuel consumption and are also not limited by law. From 1990-2000, these emissions increased, since growth in miles travelled outweighed improvements in vehicle fuel consumption. Only since 2000 has a slight reduction in CO_2 emissions occurred, due primarily to reductions in total miles travelled in passenger transports.

In addition, CO_2-emissions reductions are a result of increases in the market share of diesel-powered automobiles, which have lower fuel consumption than gasoline-powered automobiles and, thus, also have lower CO_2 emissions. The main reasons why the market share for diesel-powered cars has been increasing are the cars' better fuel consumption ("mileage advantage") and Germany's lower taxation levels for diesel fuel, compared with those for gasoline.

Table 23: Road-transporation emissions, in Gg

	CO_2	CH_4	N_2O	NO_X	CO	NMVOC	SO_2
1990	150.261,54	62,73	9,46	1284,78	6684,18	1463,85	90,20
2000	171.160,70	16,32	16,19	781,29	2380,13	283,36	19,66
2002	166.002,00	12,82	14,45	664,63	1910,61	213,69	2,81

In source category 1.A.3b Road transportation, the CSE includes mopeds, motorcycles, diesel-powered automobiles, gasoline-powered automobiles, buses, light duty vehicles with diesel and petrol engines and heavy duty vehicles, broken down by emissions-reduction equipment.

Figure 22: Structural allocation, 1.A.3b Road transportation

3.1.5.2.2 Methodological issues (1.A.3b)

Calculation of CO_2 emissions from motorised road transports in Germany is based on a top-down approach (Tier 1 procedure) based on the amount of fuel sold in Germany. The data in this respect is available in the form of *energy balances*. In order to determine the CO_2 emissions, the individual fuel consumption figures (petrol, diesel (not including biodiesel), LP gas) are multiplied by specific regional CO_2 emission factors.

Non-CO_2 emissions are calculated with the aid of the TREMOD model ("Transport Emission Estimation Model"; IFEU, 2003b)[30]. TREMOD adopts a "*bottom-up*" (Tier 3) approach whereby mileage of the individual vehicle layers is multiplied by region-specific emission factors. For passenger cars and light duty vehicles, in addition, a "*cold start surplus*" is added. The total consumption calculated on the basis of fuel type is compared with the consumption according to the energy balance. The emissions are corrected with the aid of factors obtained from this comparison process. For petrol-powered vehicles, the evaporation emissions of VOC are calculated in keeping with the reduction technology used.

From the emissions and fuel consumption for the various vehicle layers, aggregated, fuel-based emission factors are derived (kg of emissions per fuel consumption, in TJ) and then forwarded to CSE via a relevant interface (cf. Chapter 17.3.2). In keeping with the CORINAIR report structure, these factors are differentiated only by type of fuel, type of road (autobahn, rural road, city road) and, within the vehicle categories, by "without/with pollution-control equipment". The following differentiation is used in the area of pollution-control equipment:

	Without pollution-control equipment	**With pollution-control equipment**
Passenger cars / light duty vehicles with gasoline engines	without 3-way catalytic converters	with 3-way catalytic converters
Passenger cars / light duty vehicles with diesel engines, buses, heavy duty vehicles, motorcycles	prior to Euro 1	after Euro 1

For calculation with TREMOD, extensive basic data from generally accessible statistics and special surveys was used, co-ordinated, and supplemented. An overview of the principal sources and key assumptions is given below. Detailed descriptions of the databases, including information on the sources used, and the calculation methods used in TREMOD, are provided in the aforementioned IFEU report.

Real data for the years 1990-2000

Motor-vehicle ownership:

For West Germany from 1990 to 1993, and for Germany as a whole from 1994, car ownership was calculated on the basis of the ownership and new registration statistics of the Federal Motor Vehicle Agency (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.

Emission factors:

All emission factors are listed in the "Manual of road-traffic emissions 1.2" ("Handbuch für Emissionsfaktoren des Straßenverkehrs 1.2") (INFRAS, 2003). This manual was prepared in the framework of co-operation between Germany, Switzerland and Austria in derivation of emission factors for road traffic. The emission factors in the manual originate predominantly from the measurement programmes of TÜV Rheinland (TÜV = Technical

30 To permit derivation and evaluation of reduction measures, TREMOD is also used to calculate the energy consumption and CO_2 emissions of the individual vehicle categories. The values are subsequently aligned with total consumption and total emissions of CO_2.

Control Association) and RWTÜV. These include fundamental surveys for the reference years 1989/1990. In these surveys, a new method was used, for both passenger cars and heavy duty vehicles, whereby emission factors were derived according to driving conduct and the traffic situation. Within the context of field monitoring data, the passenger car emission factors were updated for cars produced up to 1994. The emission factors of more recent vehicle layers (EURO II-IV) were derived jointly by experts from the automotive industry (VDA) and from scientific institutes and environmental agencies of the aforementioned Länder. Experts from the Netherlands also participated in these co-operative efforts, in the framework of preparation of a new version of the manual (cf. Chapter 3.1.5.2.6).

- Mileage:
  The principal source is the time series of mileage of individual vehicle categories which is published continuously in "*Verkehr in Zahlen*" ("Traffic in Figures") (DIW, 2002). In differentiated mileage surveys conducted on behalf of the Federal Ministry of Transport for the years 1990 and 1993, special TREMOD requirements were taken into account: For example, the breakdown of mileage according to vehicle types and road characteristics corresponds to the differentiations used as a basis in emissions measurement programmes. The mileage data for the reference years cited was therefore transferred directly into TREMOD.

Data for the years 2001 to 2003

This real data refers to:

- Development of road-transporation fleet:

  The total fleet figures for 2001 to 2003 were derived with the help of a relayering model implemented within TREMOD. On the basis of the development of the past years, numbers of new registrations, and the various vehicle layers' shares of the new registrations, were estimated. On the basis of the total fleet size for 2000, and using survival probabilities derived from historical data and from assumptions regarding vehicle lifetimes, the vehicle fleet was broken down by type of engine, vehicle size and type of pollution-control equipment.

- Emission factors:

  The emission factors are derived from the development in the numbers of vehicles within the individual vehicle layers. The emissions reduction achieved via the introduction of sulphur-free fuels was estimated by the Federal Environmental Agency.

- Mileage travelled:

  Mileage was updated based on the medium-term forecast made by Prognos AG in the summer of 2002.

3.1.5.2.3 Uncertainties and time-series consistency (1.A.3b)

No studies of the relevant data uncertainties have yet been carried out.

3.1.5.2.4 Source-specific quality assurance / control and verification (1.A.3b)

Quality checking of the data is achieved by comparing energy consumption based on the top-down approach (Energy Balance) and bottom-up approach (uncorrected TREMOD results). For petrol, deviations of between 3.5 % and 7.0 % were calculated in the period 1994-2002. The deviations for diesel-fuel consumption ranged between 3.4 % and 10.3 %.

3.1.5.2.5 Source-specific recalculations (1.A.3b)

The presented emissions data was calculated with TREMOD version 3.1 (IFEU, 2002). With this version, the following changes, with respect to the 2004 report year, have been made in the database:

- Comparison of data on consumption of gasoline, diesel fuel, petroleum and LP gas in the year 2000-2003 with the relevant data in the preliminary 2003 Energy Balance (so-called "evaluation table")

The TREMOD model is designed to recalculate the entire relevant time series when basic data changes.

3.1.5.2.6 Planned improvements (source-specific) (1.A.3b)

Both activity data and emission factors are subject to a constant revision process. The next report is expected to include new mileage data from studies of the Federal Highway Research Institute (Bundesanstalt für Straßenwesen). With regard to emission factors, extensive changes are planned in connection with the expected completion of version 2.0 of the "Manual of road-traffic emission factors" ("Handbuchs für Emissionsfaktoren des Straßenverkehrs“; INFRAS, i.B.). As part of the changes, the results of new emissions and engine-index measurements (heavy duty vehicles and passenger cars up to Euro 3; light duty vehicles with petrol engines up to Euro 2 / with diesel engines up to Euro 1; motorcycles up to registration year 2001), and new procedures for deriving emission factors, will be taken into account. The new method for heavy duty vehicles is described in (HAUSBERGER, 2003). A description of the methods to be applied to other vehicle categories will be presented in the documentation for the "Manual of emission factors 2.0" ("Handbuch Emissionsfaktoren 2.0").

3.1.5.3 Transport – Railways (1.A.3c)

3.1.5.3.1 Source-category description (1.A.3c)

CRF 1.A.3					
Key source by level (l) / trend (t)		Gas (key source)	1990 – contribution to total emissions	2003 – contribution to total emissions	**Trend**
1.A.3.c Transport Railways					
	- / -				

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor[31] (EF)	CS	CS	--	--	--	CS				
EF uncertainties in %	--	--	--	--	--	--				
Distribution of uncertainties[32]	--	--	--	--	--	--				
Method of EF determination[33]	T1	T1	--	--	--	T1				

Railways transports are not a key source.

Nonetheless, modern, environmentally friendly railway transports play a significant role in Germany's mix of modes of transport. Germany's railway sector is undergoing a modernisation process, and electricity now accounts for the bulk of energy use in rail transports. Use of electric traction has continually been increased, and now electric traction accounts for 80 % of all traction energy (with diesel traction accounting for the rest)[34]. Power stations for generation of traction current are allocated to the stationary component of the energy sector (1.A.1.a) and are not included in further description below.

In energy input for trains of German Railways (Deutsche Bahn AG), diesel fuel is the only energy source that plays a significant role apart from electric power. Solid fuels are used for historical rail vehicles – in the main, steam locomotives are operated for demonstration and exhibition purposes. The amounts of hard-coal and lignite used in historical railway vehicles vary from year to year. As a result, the CO_2 emission factors for railway use of solid fuels also differ from year to year. Such fuels are of little significance, accounting for only 1.5 % of total energy inputs in the railway sector. 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.

Source category 1.A.3c Railways is included as a separate category in the CSE.

Figure 23: Structural allocation, 1.A.3c Railways

3.1.5.3.2 Methodological issues (1.A.3c)

No specific information relative to this source category is found in IPCC Good Practice Guidance (2000: Chapter 2). The relevant emissions are thus calculated as the product of fuel consumption and the relevant country-specific emission factors. This procedure

31 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
32 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
33 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model
34 from Energiewirtschaftliche Tagesfragen, 54th year (2004), issue 3, p. 185

conforms to the general Tier 1 method and the basic calculation rule pursuant to equation 2.6 of the IPCC Good Practice Guidance (2000: p. 2.46).

The energy consumption data is taken from the *Energy Balance* (AGEB, 2003). In particular, the fuel data has been taken from the following Energy Balance lines, for the following periods:

Table 24: Sources for AR in 1A3c

Fuel type	Energy Balance line	Relevant years
Diesel fuel	74	until 1994
	61	as of 1995
Lignite briquettes	61	as of 1996
Crude lignite	61	as of 1996
Hard coal	74	until 1994
	61	as of 1995
Hard-coal coke	61	as of 1995

The emission factors are based, for each specific gas, on the results of various Federal Environmental Agency research projects and expert opinions:

- For CO_2, the reader's attention is called to the documentation in Annex 2, Chapter CO_2 emission factors.
- The CH_4 EF are based on the Federal Environmental Agency study "Luftreinhaltung '88" ("Air Quality Control '88", UBA, 1989b). These country-specific factors can be compared with the IPCC default values: Germany's emission factor for diesel fuel is the same as the default value in the IPCC Reference Manual (1996b, Table 1-7), while Germany's EFs for coal are higher than the corresponding lignite values in IPCC Reference Manual (1996b, Table 1-7).
- As to the emission factor for N_2O, the Federal Environmental Agency's experts agree with the Federal Environmental Agency study "Luftreinhaltung '88" (UBA, 1989b). The country-specific EF are considerably higher than the correspondding values in the IPCC Reference Manual (1996b, Table 1-8).

Table 25: Comparison of current EF for railway transports with the corresponding default emission factors

Gas	Emission factor [kg/TJ]	Default emission factor [kg/TJ]
CH_4	Diesel fuel: 5.0 Hard coal: 15.0 Lignite briquettes: 15.0 Crude lignite: 15,0 Hard-coal coke: 0.5	Oil: 5 Coal: 10
N_2O	Diesel fuel: 3.4 Hard coal: 4.0 Lignite briquettes: 3.5 Crude lignite: 3.5 Hard-coal coke: 4,0	Oil: 0.6 Coal: 1.4

Source: Luftreinhaltung '88 (UBA, 1989)

3.1.5.3.3 Uncertainties and time-series consistency (1.A.3c)

No studies have yet been carried out of the data uncertainties for this source category. The AR 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.

3.1.5.3.4 Source-specific quality assurance / control and verification (1.A.3c)

Measures for standardisation of QC/QA are currently being established.

3.1.5.3.5 Source-specific recalculations (1.A.3c)

Recalculations are expected to be necessary when the planned methods transition has been carried out.

3.1.5.3.6 Planned improvements (source-specific) (1.A.3c)

In future, specific emission factors will be derived for all diesel locomotives used in Germany's railway sector. The emission calculations are being converted to a technique which links these type-specific emission factors to the corresponding operational outputs (kilometres travelled).

3.1.5.4 Transport – Navigation (1.A.3d)

3.1.5.4.1 Source-category description (1.A.3d)

CRF 1.A.3					
Key source by level (l) / trend (t)		**Gas (key source)**	**1990 – contribution to total emissions**	**2003 – contribution to total emissions**	**Trend**
Transport navigation 1.A.3.d					
	- / -				

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor[35] (EF)	CS	CS	--	--	--	CS				
EF uncertainties in %	--	--	--	--	--	--				
Distribution of uncertainties[36]	--	--	--	--	--	--				
Method of EF determination[37]	T1	T1	--	--	--	T1				

Navigation is not a key source.

Navigation is broken down primarily into the categories "coastal and inland navigation" and "marine transport". All domestic navigation is diesel-powered, while heavy fuel oil is also used in the international shipping sector. Emissions from international navigation are listed in the emissions inventories, as a memo item, but they are not included in total emissions.

The importance of Germany's navigation sector derives from Germany's network of waterways. The German Federal Water and Maritime Administration (WSV) notes in this

35 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
36 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
37 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model

connection[38]: "The waterway network, although much less dense than the country's railway and road networks, is still a contiguous network that links the country's major seaports with the high seas and with inland areas and that interconnects the country's most important industrial centres. Most of Germany's large cities are connected to the waterway network. The Federal waterway network has a total of about 7,300 km of inland waterways and includes some 17,800 km² of maritime areas. Of the former, some 6,500 km are navigable inland waterways and about 750 km are maritime routes, not including the outer areas of seaward access routes.

Under source category 1.A.3d Navigation, the CSE includes coastal and inland fishing and coastal and inland shipping.

Figure 24: Structural allocation, 1.A.3d Navigation

3.1.5.4.2 Methodological issues (1.A.3d)

The IPCC Good Practice Guidance (IPCC, 2000: page 2.52) specifies that, where data availability is good, the Tier 2 method is to be used, in connection with country-specific CO_2 emission factors and engine-specific EF for CH_4 and N_2O. If no engine-specific energy consumption data is available, then the IPCC default emission factors for CH_4 and N_2O may be used. Where country-specific emission factors for CO_2 are lacking, calculations may be carried out on the basis of the IPCC default emission factors, as long as the source in question is not a key source.

The IPCC Guidelines do not specify any methods for calculating emissions from military navigation. Good practice for the determination of such emissions calls for consulting military experts.

For Germany, emissions from this source category as calculated as the product of consumed fuels and country-specific emission factors for CO_2, CH_4 and N_2O. This procedure is in keeping with the general Tier 1 method and the basic calculation rule using the equation "emission factor times fuel consumption" pursuant to IPCC Guidance (2000: Chapter 2.4.1.1, p. 2.51).

The emission factors are based, for each specific gas, on the results of various Federal Environmental Agency research projects and expert opinions:

- With regard to the CO_2 emission factor for diesel fuel, 74,000 kg/TJ, and to that for heavy fuel oil, 78,000 kg/TJ, the reader's attention is called to the documentation in Annex 2 – the chapter on "CO_2 emission factors".
- The CH_4 emission factor for diesel fuel and heavy fuel oil, 3.0 kg/TJ, is based on the Federal Environmental Agency study "Luftreinhaltung '88 (UBA, 1989b). The country-specific EF for diesel fuel is lower than the IPCC default value for diesel fuel, 5 kg/TJ (in the Reference Manual; IPCC et al, 1997, p. 1.35, Table 1-7), and lower than the Reference Manual value for heavy fuel oil in marine transport, 7 kg/TJ (IPCC et al, 1997, p. 1.90, Table -48).

[38] http://www.wsv.de/Wasserstrassen/Wasserstrassen.html, last revision, 7 June 2002

- The EF for N_2O are in keeping with the position of the Federal Environmental Agency's experts, in the Federal Environmental Agency study "Luftreinhaltung '88". The country-specific EF for diesel fuel, at 3.4 kg/TJ, is considerably higher than the value of 0.6 kg N_2O/TJ provided by the Reference Manual (IPCC, 1997: Table 1-8); the EF for heavy heating oil, 3.5 kg/TJ, is nearly twice as high as the corresponding recommended value in the Reference Manual (IPCC et al, 1997: p. 1.90, Table 1-48).

The energy consumption data is taken from the *Energy Balance* (AGEB, 2003). In particular, the fuel data has been taken from the following Energy Balance lines, for the following periods:

Table 26: Sources for AR in 1A3d

Fuel type	Energy Balance line	Area	Relevant years
Diesel fuel	6 77 64	international domestic domestic	all until 1994 as of 1995
Heavy fuel oil	6	international	all

The following section breaks down the activity rates into the areas of domestic and international, taking account of sales – as listed in different Energy Balance lines – of different ship fuels subject to different taxation rates. The resulting amounts of fuel, in combination with the various relevant EF, make it possible to calculate and list domestic and international emissions separately. Since no data is available on ship movements, the IPCC-GPG criteria for separating domestic and international emissions (2000: Table 2.8) cannot be used.

The majority of the fuel in question is sold for marine transport. Sales have been relatively constant. An increase has occurred in the years since 1999, although sales have not returned to their levels in 1990. Consumption in coastal and inland navigation has been decreasing, although the abrupt decrease in 1994/1995 was due solely to a conversion within the Energy Balance.

3.1.5.4.3 Uncertainties and time-series consistency (1.A.3d)

No studies have yet been carried out of the data uncertainties for these source categories. The emission factors for CO_2 , CH_4 and N_2O are constant throughout the entire time series and, thus, are consistent.

The activity-data time series for coastal and inland shipping exhibit inconsistencies resulting from statistical conversion as of 1994/1995; these inconsistencies cannot be eliminated at present.

3.1.5.4.4 Source-specific quality assurance / control and verification (1.A.3d)

Source-specific verification is currently being carried out via comparison of the emission factors used, newly obtained country-specific emission factors and existing default emission factors. The old emission factors will be replaced as appropriate upon the completion of this work.

3.1.5.4.5 Source-specific recalculations (1.A.3d)

At present, no information can be provided regarding future recalculations.

3.1.5.4.6 Planned improvements (source-specific) (1.A.3d)

No improvements are planned at present.

3.1.5.5 Transport – Other transportation (1.A.3e)

3.1.5.5.1 Source-category description (1.A.3e)

CRF 1.A.3e					
Key source by level (l) / trend (t)		**Gas (key source)**	**1990 – contribution to total emissions**	**2003 – contribution to total emissions**	**Trend**
Transport Other Transportation 1.A.3.e					
Flüssige Brennstoffe	l / -	CO_2	0,29	0,28	stagniert

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor39 (EF)	CS	CS	--	--	--	CS	--	--	--	--
EF uncertainties in %	--	--	--	--	--	--				
Distribution of uncertainties40	--	--	--	--	--	--				
Method of EF determination41	T1	T1	--	--	--	T1				

The source category "Other transportation" is a key source.

Emissions from construction-related transports and from gas turbines in natural-gas-compressor stations are reported under this source category. Construction-related transports are a category within the Energy Balance. Gas turbines in natural-gas-compressor stations, on the other hand, are a clearly defined plant type.

In the CSE, construction-related transports and gas turbines in natural-gas-compressor stations are allocated to source category 1.A.3e Other transportation.

Figure 25: Structural allocation, 1.A.3e Other transportation

3.1.5.5.2 Methodological issues (1.A.3e)

The emissions for the aforementioned areas are calculated as the product of fuel consumption and the relevant country-specific emission factors. The IPCC Good Practice Guidance (2000) provides no specific provisions for "good practice" in connection with Other transportation. The selected procedure is in keeping with the general Tier 1 method as set forth, for example, in equation 2.3 of the IPCC Good Practice Guidance (2000: p. 2.37).

The area *construction transports (Bauwirtschaftlicher Verkehr)* accounts for the greater share of energy inputs. The relevant energy-consumption data, for diesel fuel and petrol, are taken from Energy Balance lines 79 and 67, respectively (until 1994 and as of 1995). Since construction transports are significant to this category's status as a key source, the calculation procedure used for this category should be as detailed as possible. At present,

39 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
40 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
41 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model

due to a lack of detailed data, only the above-described Tier 1 method can be used, however.

The emission factors are based, for each specific gas, on the results of various Federal Environmental Agency research projects and expert opinions:

- For CO_2, the reader's attention is called to the documentation in Annex 2, Chapter CO_2 emission factors.
- The country-specific CH_4 and N_2O EF are based on the Federal Environmental Agency study "Luftreinhaltung '88" (UBA 1989b), since no IPCC default values are available.

The area *natural-gas-compressor stations* accounts for the smaller share of energy inputs. The relevant energy-consumption data for natural gas is taken from Energy Balance lines 8 and 40, respectively (until 1994 and as of 1995). Since this area is an insignificant sub-emissions area of the source category in question, the above-described Tier 1 method was used.

The emission factors are based, for each specific gas, on the results of various Federal Environmental Agency research projects and expert opinions:

- For CO_2, the reader's attention is called to the documentation in Annex 2, Chapter CO2 emission factors.
- The CH_4 and N_2O EF have been taken from Chapter 4.9.5 and Annex E, Table 5 of the Federal Environmental Agency study on stationary combustion plants (RENTZ et al, 2002). IPCC default values are available for such systems. Comparisons are presented in the Chapter on the Public electricity and heat supply.

3.1.5.5.3 Uncertainties and time-series consistency (1.A.3e)

As a result of statistical conversions in 1994/1995, the EF time series for CH_4 (for all fuels) and the EF time series for N_2O (for gasoline, construction industry) contain inconsistencies that cannot be eliminated. Since 1995, relevant activities in the new German Länder have not been listed separately. As a result, emissions cannot be calculated using new-Länder EF that diverge from those for the old German Länder. Since it cannot be assumed that specific emissions – and, thus, EF – were comparable in the old and new German Länder until 1994, the different EF for those years have been retained. As a result, the time series contains a methodological change, manifested as a jump in the overall EF (IEF).

3.1.5.5.4 Source-specific quality assurance / control and verification (1.A.3e)

At present, it is not possible to carry out more detailed source-specific quality assurance / control and verification.

3.1.5.5.5 Source-specific recalculations (1.A.3e)

No recalculations are required.

3.1.5.5.6 Planned improvements (source-specific) (1.A.3e)

No improvements are planned.

3.1.6 Other: Residential, commercial/institutional, agriculture, forestry and fishing (1.A.4)

3.1.6.1 Source-category description (1.A.4)

CRF 1.A.4a (Commercial/Institutional)					
Key source by level (l) / trend (t)		**Gas (key source)**	**1990 – contribution to total emissions**	**2003 – contribution to total emissions**	**Trend**
CRF 1.A.4a Commercial/institutional					
Gaseous fuels	l / t	CO_2	1,10 %	2,67 %	rising
Liquid fuels	l / t	CO_2	2,19 %	1,99 %	falling
Solid fuels	- / t	CO_2	1,68 %	0,12 %	falling
CRF 1.A.4b (Residential)					
Gaseous fuels	l / t	CO_2	2,55 %	5,94 %	rising
Liquid fuels	l / t	CO_2	4,51 %	5,79 %	rising
Solid fuels	- / t	CO_2	3,33 %	0,29 %	falling
CRF 1.A.4c (Agriculture/Forestry/Fisheries)					
Liquid fuels	l / -	CO_2	0,65 %	0,56 %	falling
Solid fuels	- / t	CO_2	0,38 %	0,01 %	falling

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor[42] (EF)	CS	CS	NO	NO	NO	CS	CS	CS	CS	CS
EF uncertainties in % - liquid fuels		-25/ +50	-	-	-	± 35				
EF uncertainties in % - gaseous fuels		-50 / +100	-	-	-	± 35				
EF uncertainties in % - solid fuels		-50/ +100	-	-	-	± 50				
Distribution of uncertainties [43]		L	-	-	-	N				
Method for EF determination[44]		Tier 2	-	-	-	Tier 2				

Source category 1.A.4 "Other sectors" is a key source for CO_2, in all of its sub- source categories, for nearly all fuel categories and in terms of emissions levels or trend or both.

Source category 1.A.4 comprises combustion systems in the areas Residential, Commercial and Institutional and Agriculture, along with various mobile sources.

Heat-generation systems in small combustion systems of small commercial and institutional users (commerce and services) are reported under source category 1.A.4.a.

1.A.4.b comprises energy inputs in the Residential area. This refers primarily to combustion systems. In addition, source category 1.A.4.b includes residential mobile sources (not including road transportation).

Sub- source category 1.A.4.c comprises the areas of agriculture, forestry and fisheries. Reporting under this category includes emissions from heat generation in small and medium-sized combustion systems and emissions from agricultural transports. Pursuant to the IPCC structure, 1.A.4.c also includes emissions from mobile sources in fisheries and in forestry. Such emissions cannot be reported in 1.A.4, due to differences, in this area, in the

42 D = IPCC default, C = Corinair, CS = country-specific, PS = Plant-specific, M = Model
43 N = Normal, L = Log normal, T = Triangular, U = Uniform (even distribution)
44 D = IPCC default, RA = Reference approach, T1= IPPC tier 1, T1a/ T1b/ T1c = IPPC tier 1a/ 1b/ 1c, T2 = IPPC tier 2, T3 = IPPC tier 3, C = CORINAIR, CS = country-specific, M = Model

breakdown of basic energy statistics. Such emissions are included instead in transport emissions (1.A.3).

While emissions from agricultural transports and from mobile residential sources are reported within source category 1.A.4, the relevant emissions data is obtained together with data for the transport sector. This section does not include a description of the method in which these emissions are calculated.

The following Figure 26 shows relevant allocations within the Central System of Emissions

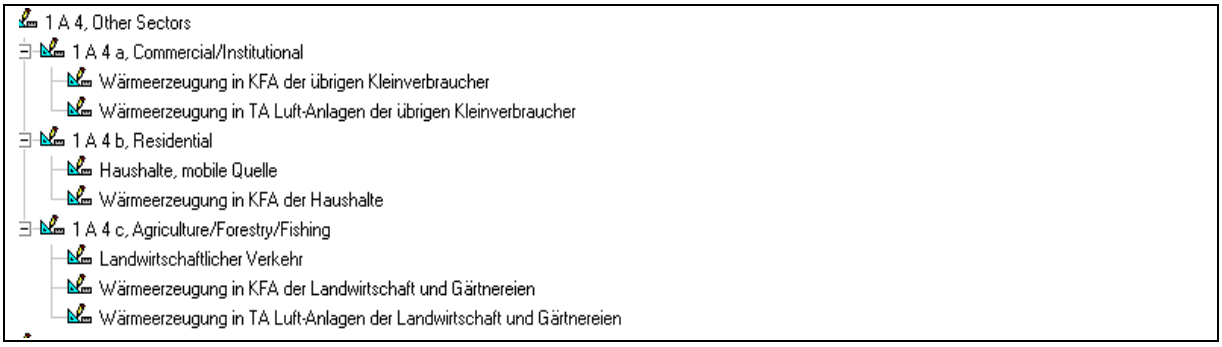


Figure 26: Structural allocation, 1.A.4 Other sectors

The group of combustion systems in the residential and commercial/institutional segment 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 to generate room heat and hot water (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 2000, more than 36 million combustion systems were installed in Germany in the residential and commercial/institutional sectors (UBA, 2003d: p. 10). Combustion systems for solid fuels accounted for a majority of these systems, or some 14.6 million, while the group of gas-fired furnaces accounted for some 13.5 million systems and that of oil-fired furnaces accounted for some 7.9 million. The great majority of these systems (over 95%) is in place in private households (UBA, 2000a and UBA, 2003d).

3.1.6.2 Methodological issues (1.A.4)

The **activity rates** in source category 1.A.4 are based on the Energy Balance for the Federal Republic of Germany, as prepared by the Working Group on Energy Balances. Lines 66 (residential) and 67 (commerce, trade, services and other consumers) (AGEB, 2003) are of primary importance.

Since the figures in Energy Balance line 67 (commerce, trade, services and other consumers) also include consumption by military agences, such consumption must be deducted from the relevant positions in line 67 (stationary sources within the military sector are described in source category 1.A.5.a, Chapter 3.1.7). For energy inputs in agricultural combustion systems, which are also included in line 67 of the Energy Balance, relevant data is available in an existing study (UBA, 2000a) for 1995. This study provides an estimate of

agricultural combustion systems' share of total energy inputs in line 67. This share was assumed to be constant for years until 2003.

The database for the **emission factors** used consists of UBA, 2000a. Within the context of this project, device-related and source-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 year 1995.

Determination of emission factors is based on a source-category-specific "bottom-up" approach that, in addition, to differentiating (sub-) source 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 source 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 corresponds to the Tier 2 method of the IPCC-GPG (2000: p. 2.92).

The emission factors are structured in accordance with the relevant fuels involved in final energy consumption in Germany:

- Fuel oil EL
- Fuel oil S/SA
- Natural gas
- Lignite (crude lignite, briquettes from the Rhine, Lausitz and central German regions, imported briquettes)
- Hard coal (coke, briquettes, anthracite) and
- Wood (natural wood, 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. In the commercial/institutional area, additionally, a distinction was made between installations not subject to licensing within the scope of validity of the 1st Ordinance on the Execution of the Federal Immission Control Act (*BImSchV*) (Ordinance on small and medium-sized combustion systems) and licensable installations that are subject to the requirements of the Technical Instructions in Air Quality Control (Clean Air Directive - *TA Luft*). The emissions behaviour of the combustion systems in question was determined via a comprehensive review of the literature, in an approach that distinguished between results from test-bench studies and field measurements. Supplementary to this, experiments were conducted on furnaces using solid fuels, both on the test bench and via measurements in the field.

The description of the plant structure for installed furnaces was prepared using statistics on residential and other buildings, statistics from the chimney-sweeping trade, and surveys by the researchers themselves in selected chimney-sweep districts of Baden-Wuerttemberg, North-Rhine Westphalia and Saxony. This data was used to estimate the energy inputs for various system types, to make it possible to determe sectoral emission factors weighted by energy inputs. Table 27 shows the sectoral emission factors determined.

Table 27: Sectoral emission factors for combustion systems in the residential, commercial and institutional areas

Residential	CH_4 [kg/TJ]	N_2O [kg/TJ]
Hard coal and hard-coal briquettes	273	11
Hard coal	259	12
Briquettes	293	10
Hard-coal coke	7,1	0,8
Lignite briquettes	105	4,4
Untreated wood	123	1,5
Heating oil EL	0,06	0,61
Natural gas	1,1	0,31
Commercial and institutional		
Hard coal and hard-coal briquettes	9,2	4,9
Hard coal	9,2	4,9
Briquettes	-	-
Hard-coal coke	20	0,81
Lignite briquettes	248	0,47
Untreated wood	96	0,99
Heating oil EL	0,02	0,56
Natural gas	0,12	0,34

On the basis of the emissions data calculated for the year 1995, the subsequent development of emissions in 5-year stages up until the year 2020 was estimated using two scenarios.

3.1.6.3 Uncertainties and time-series consistency (1.A.4)

Calculating reliable emission factors in this plant sector is possible only via a complex procedure. Apart from emission figures, it is also necessary to obtain other information e.g. in order to make allowance for the relevant mode of operation (loads), plant 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 plants 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 plant types, moreover, only inadequate data or no data at all was available on emissions behaviour when using certain fuels. In this respect, it is important to bear in mind that for furnaces belonging to residential and commercial/institutional users, there is no statutory obligation to measure the greenhouse gas emissions under consideration here. When calculating the emission factors, therefore, in most cases (with the exception of CO_2, which is largely independent from the furnace design) the researchers only had recourse to a few results from individual measurements on selected installations. In some of these cases, the data gaps were closed by adopting emission factors from comparable furnace designs or by using emission data from other studies.

The uncertainties listed for the emission factors for CH_4 and N_2O were determined via experts' judgement pursuant to IPCC-GPG (2000: Chapter 6). This assessment, which is based on the emissions data obtained for the aforementioned research project, was carried out by experts from the Federal Environmental Agency, in co-operation with the University of Stuttgart's Institute of Process Engineering and Power Plant Technology (Institut für Verfahrenstechnik und Dampfkesselwesen).

The following sources of error entered into the estimate 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 plant data used (overall group structure in terms of type, age and performance and fuel consumption)

For all of these influencing factors, it proved useful to differentiate between systems burning liquid and gaseous fuels and systems burning solid fuels. All uncertainties, with the exception of the measuring error in N_2O measurement, must be considered greater for systems burning solid fuels than for systems burning liquid or gaseous fuels. One reason for this is that the group of solid fuels comprises many different fuels, with different emissions behaviours (e.g. various types of lignite, hard coal and wood, from various different origins and with various different characteristics); in systems burning gaseous or liquid fuels, on the other hand, almost all emissions result from use of natural gas or light heating oil.

In gas-fired systems in particular, another error occurs in determination of start/stop emissions. During start-up/shutdown procedures, some partly unburned CH_4 is emitted from natural gas. These emissions, which occur upstream and downstream from the actual combustion process, cf. Chapter 3.2.2.2 (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, in a first approximation, a normal distribution is assumed for N_2O emission factors. Given the considerably larger uncertainties for CH_4 (up to 100%) in comparison to those for N_2O, on the other hand, it must be assumed that deviations toward larger values in this area are considerably more pronounced than those toward smaller values. For this reason, a log-normal distribution must be assumed for CH_4, for all fuels.

In the aforementioned research project, the emission factors for CH_4 and N_2O were determined in five-year steps for the period 1995 (reference year) through 2020. With this approach, no changes result for most of these emission factors for the period until 2003. The CH_4 emission factors were forecast to decrease slightly only in the area of use of some solid fuels (lignite, wood). This is due primarily to modernisation of existing systems (replacement of old systems with new systems with lower emissions) and, in part, to changes in fuel-consumption structures (sharply decreasing use of eastern German lignite since 1990). In a good approximation, constant emission factors for this period may be assumed for N_2O, which is largely fuel-dependent in small combustion systems.

For the period 1990 to 1994, source-specific recalculation of emission factors was carried out; as a rule, this process was able to draw on existing emission factors from 1995 (cf. 3.1.6.5).

3.1.6.4 Source-specific quality assurance / control and verification (1.A.4)

For the purposes of quality assurance, in the context of the aforementioned research and development project, all the input data used from literature and from the research company's own investigations was examined with a view to validity. The review included comparisons

with confirmed data and plausibility checks. As a general principle, when describing the emissions behaviour of combustion systems, emissions data was 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. Records were kept, by the research company, of all key materials used for inventory preparation (UBA, 2000a).

In a quality review carried out by Federal Environmental Agency experts, pursuant to IPCC-GPG (2000: Chapters 2.2.3 and 8), the country-specific emission factors for CH_4 and N_2O, as determined pursuant to Tier 2, were compared with the IPCC Tier 1 default factors of the IPCC Reference Manual (1996b). For most fuels, the values agreed well (discrepancies within one order of magnitude), although the default values for CH_4 tended to be higher, and those for N_2O lower, than the country-specific values. Larger discrepancies occurred only for fuel oil; they are due to the very high Tier 1 default value (10 kg/TJ CH_4 for "oil"). A comparison with the relevant Tier 2 default value (0.7 kg/TJ CH_4 for "distillate fuel oil") produces considerably smaller discrepancies from the country-specific values.

Furthermore, data was compared with that for Austria, whose plant and fuel-consumption structures are similar to those of Germany (UBA Wien, 2004, 2004). The results included good agreement of emission factors, with lower discrepancies overall than seen in the default-value comparison.

3.1.6.5 Source-specific recalculations (1.A.4)

The emission factors are consistent throughout the time series for the period 1995 to 2003.

Initially, the emission factors for the years 1990 to 1994 diverged considerably from the factors used as of 1995, and they were inadequately substantiated. UBA 2000a contains valid data, broken down by the old and new German Länder, for the year 1995. Since the emission factors for the greenhouse gases CH_4 and N_2O change only slightly over periods of several years, this data was used for the years 1990 to 1994.

The activity rates for the period 1990 to 1994 have not yet been corrected; such correction is required because the Energy Balance figures do not conform to the CRF-format structure. The resulting effort only affects the distribution of activity rates among sub- source categories in 1.A.4a and 1.A.4c, however. The recalculation is to be carried out in 2005. The procedure described above for the period 1995-2003 will provide the methodological starting point for such recalculation.

3.1.6.6 Planned improvements (source-specific) (1.A.4)

In order to create a broader database for calculating certain emission factors (particularly for CH_4 in connection with use of solid or gaseous fuels), further investigations are required. This is to be achieved within the context of research projects that have yet to be commissioned.

3.1.7 Other areas (1.A.5)

Source category 1.A.5 includes all combustion-related emissions that are not included in source categories 1.A.1 through 1.A.4. Most significantly, it includes the emissions of the

military sector. Although it is divided into the source categories 1.A.5a "*Stationary*" and 1.A.5b "*Mobile*", the data for this category is reported in combined form.

Figure 27: Source category 1.A.5

3.1.7.1 Source-category description (1.A.5)

CRF 1.A.5					
Key source by level (l) / trend (t)		**Gas (key source)**	**1990 – contribution to total emissions**	**2003 – contribution to total emissions**	**Trend**
Liquid fuels	l / t	CO_2	0,53 %	0,13 %	falling
Solid fuels	l / t	CO_2	0,37 %	0,00 %	falling

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**NMVOC**	**VOC**	**SO_2**
Emission factor[45] (EF)	NO	CS	NO	NO	NO	NO	NO	NO	NO	NO
EF uncertainties in %		25								
Distribution of uncertainties[46]		N								
Method of EF determination[47]		CS								

Source category 1.A.5 is a key source for solid and liquid fuels in terms of level and trend.

3.1.7.2 Methodological issues (1.A.5)

The Energy Balance of the Federal Republic of Germany (AGEB, 2003) provides the basis for the **activity rates** used. Since the Energy Balance does not provide separate listings of military agencies' final energy consumption as of 1995 – and includes this consumption in line 67, under "commerce, trade, services and other consumers" – additional sources of energy statistics had to be found for source category 1.A.5.

For source category 1.A.5a, use was made of data of the Federal Ministry of Defence (BMVg), which has reported the "Energy input for heat generation in the German Federal Armed Forces", by fuels and for 1995-2002, to the Federal Environmental Agency. These figures were deducted from the figures in Energy Balance line 67 (commerce, trade, services) and thus are reported in 1.A.5, rather than in 1.A.4.

For source category 1.A.5b, military fuel and aircraft-fuel consumption for 1995-1999, in TJ, was drawn from a special analysis of the Working Group on Energy Balances (AGEB). The following source was used for the years 2000-2002: Association of the German Petroleum Industry (Verband der Mineralölwirtschaft; MWV; 2003), Mineralöl-Zahlen 2002, p. 32. The consumption figures, which are given in units of 1000 t, were converted into TJ on the basis of the relevant heating statistics listed for 2001.

The database for the **emission factors** used for source category 1.A.5a consists of UBA (2000a). Within the context of this project, device-related and source-category-specific emission factors for combustion systems in military agencies were calculated, with a high

46 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
47 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model

level of detail, for all important emissions components for the reference year 1995. The method used to determine the factors conforms to the procedure described for source category 1.A.4.

The following Table 28 shows the sectoral emission factors used.

Table 28: Sectoral emission factors for combustion systems of military agencies

Military	CH_4 [kg/TJ]	N_2O [kg/TJ]
Hard coal and hard-coal briquettes	2,4	4,8
Hard-coal coke	19	0,8
Lignite briquettes	242	0,37
Crude lignite	368	
Heating oil EL	0,02	0,56
Natural gas	0,02	0,29

3.1.7.3 Uncertainties and time-series consistency (1.A.5)

Information regarding the uncertainties for the emission factors is provided in the description for source category 1.A.4.

3.1.7.4 Source-specific recalculations (1.A.5)

Information regarding the source-specific recalculations is also provided in the description for source category 1.A.4.

3.1.8 Comparison with the CO_2 reference procedure

Reporting on combustion-related CO_2 emissions is centrally important within the context of international climate protection. To this end, industrialised countries routinely adopt the source-category-specific approach, which addresses the level of individual energy consumption sectors and therefore permits differentiated statements on the structure of emitters. By way of a comparative approach, the *Intergovernmental Panel on Climate Change* (IPCC) has developed the *Reference Approach*, which is based on the level of primary energy consumption (input of energy resources in a given country). This approach places less demanding requirements on the databases than does the source-category-specific approach.

PROGNOS AG has carried out a research project for analysing this calculation procedure (PROGNOS, 2000).

3.1.8.1 Methodological issues

The basic principle of the reference approach is an aggregated carbon balance for the energy sector. The quantity of carbon emitted from the energy sector (per annum) is then calculated as the difference between the quantities of carbon input and output with the energy resources (cf. Figure 28).

The carbon inputs are linked to imports of primary energy resources (such as petroleum, natural gas) and secondary energy resources (e.g. heating oil, motor gasoline, coke) and to domestic production of primary energy resources. Carbon outputs are linked to exports of primary and secondary energy resources and bunkering (fuel consumption by marine

shipping and international air traffic). The reference approach therefore includes adjustments to the carbon balance to allow for non-emissions-relevant quantities of carbon. These take account of carbon output in combustion residues containing carbon (*fraction of carbon oxidised)* and long-term-fixed carbon in downstream products from the non-energy-related consumption of energy resources (*fraction of carbon stored*; e.g. use of naphtha in plastics production).

The purpose of the correction factors is to refine calculation of the CO_2 emissions figures obtained from the simple input/output balance of energy resources. In calculation of the correction factors "*fraction of carbon stored*", non-combustion-related emissions, particularly solvent and process emissions, are also included in the balance as "*carbon stored*", in addition to the carbon actually stored in long-lived products. The remaining portion, included in the balance as *released carbon*, then actually consists only of combustion-related CO_2 emissions (e.g. waste incineration, internal fuel consumption by steam crackers). Within the downstream product chains of non-energy-related consumption, imports and exports of intermediate and finished products are included in the balance on the basis of the "*producer principle*" – in other words, imports are disregarded, and exports are included in the CO_2 balance.

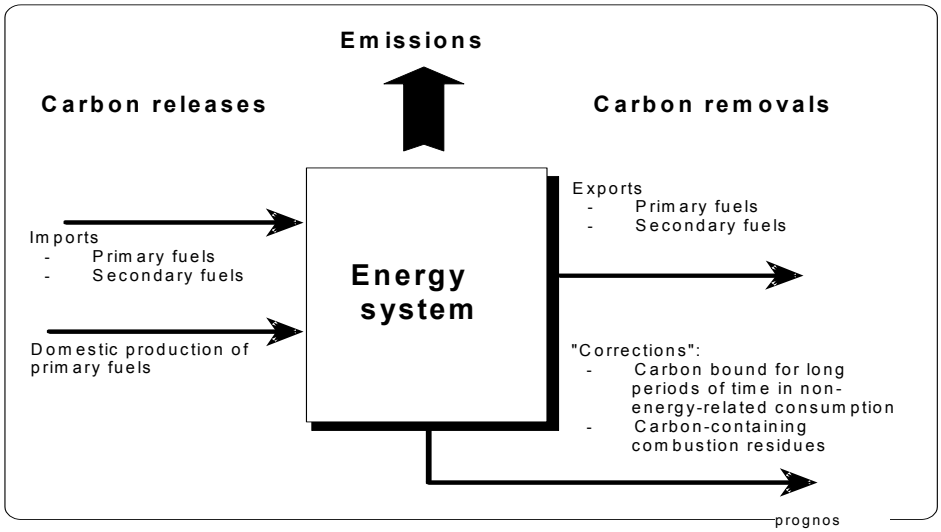


Figure 28: Basic principle of the IPCC reference procedure (Prognos, 2000)

The IPCC reference approach is designed to calculate the potential CO_2 emissions from the energy resources used in a given country. The potential emissions are not the same as the actual emissions.

In applying the IPCC reference approach in Germany, the principal methodological assertions outlined below were made.

3.1.8.1.1 Hard coal

The German Energy Balance does not differentiate according to different hard-coal types. In the German coal statistics, however, domestic production of hard coal is divided into bright-burning coal, rich coal, forge coal, lean coal and anthracite coal. The same breakdown is also used when applying the IPCC approach. However, as this system differs from the IPCC classification of hard coal ("*bituminous coal*") into anthracite, coke coal and others, only one

collective category, *bituminous coal*, is shown in the IPCC tables. Differentiated calculation for domestic production, by types of coal, is carried out as part of a special calculation (cf. the R&D project on use of the IPCC reference procedure for determining combustion-related CO_2 emissions in Germany, UFOPLAN97).

The same applies to hard coal imports: Imported coal has different characteristic values, depending on its country of origin. Based on the foreign trade statistics of the Federal Statistical Office and STATISTIK DER KOHLENWIRTSCHAFT (2004) (coal-industry statistics), differentiated reporting of hard-coal imports, according to countries of origin, is envisaged for application of the IPCC method. In this way, allowance can be made for the influence on carbon input of changes in the origin structure of imports.

3.1.8.1.2 Lignite

The IPCC procedure only envisages one category in this area, "*lignite*". In order to make allowance for the particular significance of lignite in Germany, a differentiation is implemented within the context of a special calculation (cf. the R&D project on use of the IPCC reference procedure for determining combustion-related CO_2 emissions in Germany, UFOPLAN97):

- For domestic production, a differentiation is made according to the main mining regions of Rhineland, Lausitz, central Germany, Helmstedt and others (Borken and Wölfersheim, both of which were decommissioned on 31 October 1991). The production quantities are regularly reported in coal-mining-industry statistics.
- Amongst imports, a distinction was made between lignite and hard lignite (Czech Republic), in keeping with the Energy Balance statistics. Since 2003, hard lignite from the Czech Republic is no longer used in German power stations.
- Exports and stock changes are not further differentiated and are taken from the data in the Energy Balance.

3.1.8.1.3 Natural gas

Natural gas, petroleum gas and pit gas, which are shown separately in the German Energy Balance, are combined under “*natural gas*”. Natural gas imports have different characteristic values, depending on their origin. Analogous to the procedure for hard coal, therefore, natural gas imports are considered in a differentiated way in a separate calculation according to their principal countries of origin (Russia, the Netherlands, Norway).

3.1.8.1.4 Petroleum imports

In the Federal Republic of Germany, petroleum imports account for a large proportion of the input of carbon into the energy system. Changes in the import structure, i.e. the proportions of individual countries of origin or qualities, may therefore lead to tangible fluctuations in the quantity of carbon imported via crude oil. However, allowance must be made for the fact that the carbon content in crude oil may fluctuate within a comparatively narrow band of between approximately 82 % and 87 %[48]. These limits are extreme values. The fluctuation range in the crude oil mix consumed annually is significantly lower. For this reason, changes in the composition of crude oil imports have only a limited influence on the average carbon content of crude oil imports.

48) The global average is approximately 84.5 %.

Nevertheless, in applying the IPCC Reference Approach for calculating the carbon content in crude oil imports, a special calculation was envisaged and implemented on the basis of principal importing countries and qualities as well as oil fields (analogous to the procedure for hard coal and natural gas). The quantities given (crude oil imports on the basis of production regions and types) are not published, but may be obtained from the industry association, *Association of the German Petroleum Industry* (MWV), in Hamburg. There is no data available on the carbon content of the individual crude oil types, since this does not represent a relevant factor in petroleum processing. Nevertheless, there is an empirical correlation between the specific weight of petroleum and its carbon content (MARLAND et al, 1983). The carbon content of the individual crude oil types has been estimated on the basis of this correlation and of published data on specific gravity *("API Gravity"*[49]).

3.1.8.2 Databases

The principal databases for application of the IPCC Reference Approach in Germany are summarised below:

Energy data: Energy data is based on the currently available (1990 to 1999) energy balances of the Working Group on Energy Balances (AGEB). As these balances are not yet available for the years 2000 and 2003, it was not possible to apply the Reference Approach here in a fully detailed manner. As a result of past reviews of submitted emissions inventories, the failure to use the IPCC reference procedure for the entire time series has repeatedly been highlighted as an existing deficit. For this reason, the possibility of using the existing analysis tables for the Energy Balance, which contain recent, but highly aggregated, data, was again reviewed. This led to development of a simplified procedure, based on these analysis tables and drawing on pragmatic considerations (transfer of relationships between fuel inputs and fuel-consumption data, and continued use of the structure for non-energy-related fuel consumption), that this year, for the first time, has made it possible to provide tentative reference-procedure results for the previously missing years. These results will be appropriately supplanted, however, upon publication of detailed energy balances in the framework of recalculations. For the main primary fuels of petroleum, natural gas, hard coal and lignite, in the Reference Procedure a further differentiation is made on the basis of type or geographical origin. Data obtained from the energy statistics of the respective associations is used for this purpose.

Fuel characteristics / emission factors: This information is based on the GEMIS database (Öko-Institut), supplemented with data from the Jülich Research Centre (from the IKARUS project).

Downstream product chains of non-energy-related consumption: A study by the Fraunhofer Institute for Systems and Innovation Research (ISI) provides the main database. As this did not provide a complete database for calculating carbon storage, it was supplemented with our own estimates.

49) The specific gravities are available for all varieties, with the exception of Russian oil (OIL & GAS JOURNAL DATA BOOK 1997). Average values were used for Russian petroleum.

3.1.8.3 Results

The CO_2 emissions calculated using the IPCC Reference Approach decreased by almost 17 % between 1990 and 1999. This is roughly consistent with the emissions trend in the detailed source-category-related calculations for energy-related CO_2 emissions.

On average, the results of the Reference Approach for the period under review are 3 % above the CO_2 emissions calculated in detail.

Around 2/3 of these deviations are attributable to differences in the emission factors or average carbon contents of the energy resources, which cannot be calculated as precisely with the Reference Approach as with the source-category-specific approach. The remainder of the deviations are attributable to systematic differences between the two methods at the level of underlying energy consumption – specifically, in consideration of non-energy-related consumption, waste incineration, statistical differences and losses in the transformation sector of the energy system, including energy consumption by natural-gas-pipeline compressors (cf. Figure 29).

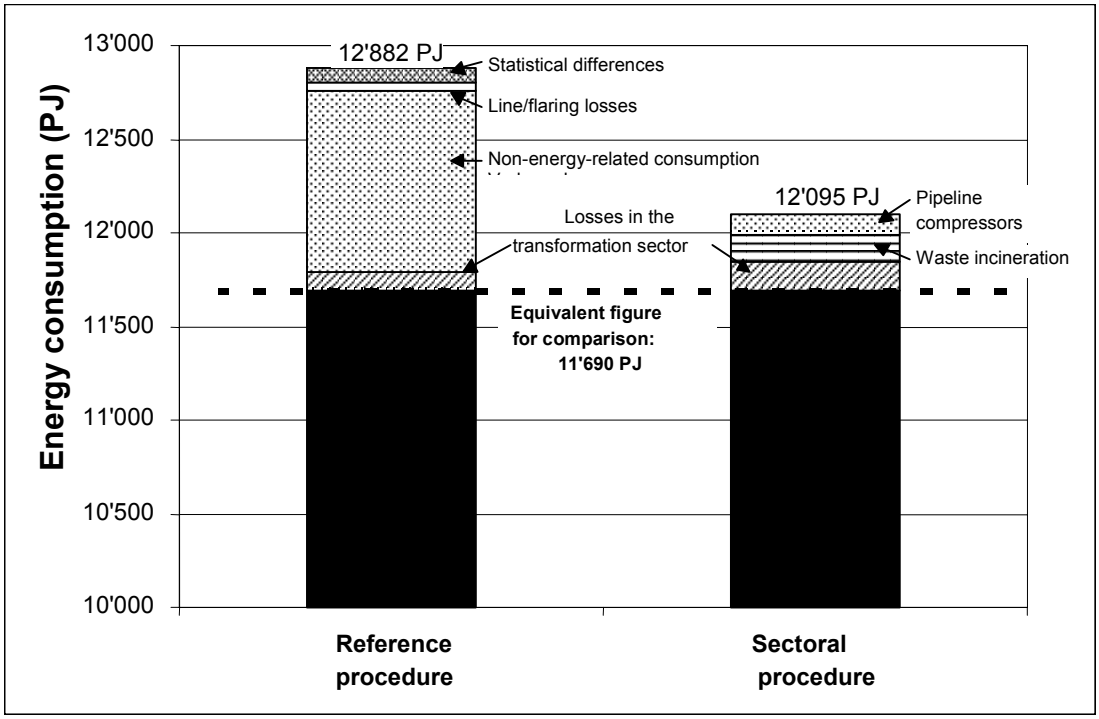


Figure 29: Systematic differences between the reference approach and the source-category-specific approach (1990)

3.1.8.4 Planned improvements

Precise summing and assessment of emissions from non-energy-related fuel consumption plays a key role in comparison of results of the reference procedure with those of detailed sectoral CO_2 calculation. In the reference procedure, these emissions are taken into account via determination of the amounts of carbon stored in products for long periods of time. In the detailed sectoral calculations that are currently carried out for Germany, such emissions are taken into account only to a limited extent (for example, in combustion of fossil fuels). The first studies in this area have shown that emissions from non-energy-related fuel consumption are of the order of about 1 to 2 % of total CO_2 emissions. This is the amount,

therefore, by which the results of the two calculation methods would differ. One of the emphases of ongoing efforts to improve inventories with respect to CO_2 emissions is to precisely analyse such methodological issues, and make any necessary modifications, with regard to both the reference procedure and detailed sectoral emissions calculation.

In applying the IPCC Reference Approach at the international level, special calculation of the "*fraction of carbon stored*", in order to correct CO_2 potentials by subtracting the carbon stored in the downstream product chains of non-energy-related consumption, would seem to be extremely time-consuming:

- On the one hand, a considerable amount of data collection is needed, and this is inconsistent with the objective of the Reference Approach to minimise data requirements – not all the necessary data is available even in Germany. This is further exacerbated by delimitation problems in determining the amount of carbon stored, problems which hinder the international comparability of results.
- On the benefits side, this contrasts with only a limited "accuracy gain" for most countries, purely by virtue of the fact that total non-energy-related consumption generally accounts for no more than 10 % of primary fuel consumption. In Germany, the accuracy gain is between 5 and 6 %. It is also doubtful whether any refinement of the results can be achieved by using the default values proposed by the IPCC, since these are general estimates which fail to make allowance for the specific situations in individual countries.

3.1.9 Emissions from international transports (1.BU.1/1.BU.2)

The area of international transports is divided into international civil air transports (1.BU.1) and international sea transports (1.BU.2), the latter of which also includes blue-water fisheries and marine navigation.

3.1.9.1 Emissions from international aviation (1.BU.1)

Emissions from fuel consumption for international aviation are included in inventory calculation; however, in agreement with IPCC Good Practice Guidance (IPCC, 2000: p. 2.57) they are not reported as part of national total inventories.

German energy statistics do not yet provide an official breakdown of fuel consumption relative to international air-traffic emissions. To make it possible to differentiate national and international consumption nevertheless, these fuel-consumption statistics are broken down into shares of 20 % for domestic air transports and 80 % for international air transports. This relationship was confirmed for 1996 in a research project (cf. Annex, Chapter 14.1.3.1.2). Overall, this estimate must be considered very conservative, since it breaks down the strong growth in air transports into consistent shares for national and international air transports. In actual practice, this strong growth, over the last 12 years, has most likely taken place very predominantly in the international air transports sector.

Currently, R&D activities are being prepared for a joint project of the European Community (European Commission, EUROSTAT, EUROCONTRL and EEA) for calculation of emissions, from national and international air transports, for the levels of the individual Member States and the entire European Union. This project is expected to be able to solve the aforementioned problems.

International civil aviation is separately listed as such in the CSE.

Figure 30: Structural allocation, 1.BU.1 civil aviation (international)

3.1.9.2 Emissions from international navigation (1.BU.2)

3.1.9.2.1 Source-category description (1.BU.2)

CRF 1.BU.2: TABLE 1.C sectoral backround data for energy					
Key source by level (l) / trend (t)		**Gas (key source)**	**1990 – contribution to total emissions**	**2003 – contribution to total emissions**	**Trend**
Transport navigation					
	- / -				

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor[50] (EF)	CS	D	--	--	--	D	D	D	D	
EF uncertainties in %	--	--	--	--	--	--				
Distribution of uncertainties[51]	--	--	--	--	--	--				
Method of EF determination[52]	T1	T1	--	--	--	T1				

International navigation includes international blue-water fisheries and marine transport, categories which are also listed as such in the CSE.

Figure 31: Structural allocation 1.BU.2 Navigation (international)

Emissions from fuel consumption for international transports of ocean-going ships are included in the inventory calculation although, in keeping with the UNFCCC guidelines, they are not reported as part of total national inventories.

In 1997, a total of 97,248 ships called at Germany's 19 ports on the North and Baltic seas. These ships spent a total of 902,057 hours in Germany's ports and took on 715,537 tonnes of fuel, comprising heavy fuel oil and marine diesel oil.

Consumption of heavy fuel oil has been increasing since 1984 as a result of high petroleum prices, global increases in transports and increasing maritime use of diesel engines that can run on heavy fuel oil.

The emissions fluctuations that occurred in the navigation sector in 1992 and 1996 were caused by trade and oil crises.

50 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
51 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
52 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model

3.1.9.2.2 Methodological issues (1.BU.2)

The "Good Practice Guidance" (2000: page 2.52) specifies that, where good data is available, the Tier 2 method is to be used, along with country-specific CO_2 EF and engine-specific EF for CH_4 and N_2O. If no engine-specific energy consumption data is available, then the IPCC default emission factors for CH_4 and N_2O may be used. Where country-specific emission factors for CO_2 are lacking, calculations may be carried out on the basis of the IPCC default emission factors, as long as the source in question is not a key source.

For Germany, emissions from this source category as calculated as the product of consumed fuels and country-specific emission factors for CO_2 and default EF for CH_4 and N_2O. This procedure conforms to the Tier 1 method.

The activity rates for bunkerung are taken directly from the Energy Balance of the Federal Republic of Germany. The reason why these rates are is listed separately is that fuel purchased in ports is taxed differently. Current data from the Energy Balance of the Federal Republic of Germany is available for the period until 1999. For the period since then, statistics from the Association of the German Petroleum Industry (MWV; www.mwv.de) have been used.

For calculation of N_2O, CH_4, CO, NO_X and NMVOC emissions, default emission factors from the Revised 1996 IPCC Guidelines (Reference Manual, 1996b: p.1.90 Table 1-48) are used.

With regard to the CO_2 emission factor for diesel fuel, 74,000 kg/TJ, and to that for heavy fuel oil, 78,000 kg/TJ, the reader's attention is called to the documentation in Annex 2, Chapter 13.8.

3.1.9.2.3 Uncertainties and time-series consistency (1.BU.2)

The responsible Federal Environmental Agency expert has estimated the uncertainties from the MARION model as amounting to 10%.

The MARION research project was carried out in 1995/1997. Its aim was to calculate the emissions balances for individual ships, in the marine transports (navigation) sector. The area covered by the project included Bremen's ports. Data for the world's merchant fleet was available. The data entered into the project programme included all shipping routes, consumption figures for individual ships and a range of ship characteristics. The resulting transport terms and emissions terms were used to determine the total emissions for the various relevant ship types, as a function of size class. Oily residues of consumed heavy fuel oil, from operation of ships' main engines, were estimated as amounting to 2%. Ships' main engines were assumed to run at 85 %, and auxiliary engines were assumed to run at 30 %. It is not possible to carry out separate calculations for heavy oil and marine diesel oil.

3.1.9.2.4 Source-specific quality assurance / control and verification (1.BU.2)

Source-specific verification of the CO, CO_2 and NO_X emission factors was carried out by comparing the country-specific emission factors, as used to that point, with the default emission factors. The verification was carried out in keeping with the MARION method.

3.1.9.2.5 Source-specific recalculations (1.BU.2)

Because the previously used values lacked transparency, the N_2O, CO, CH_4, NMVOC and NO_X emission factors for navigation were replaced with default values (cf. Table 29). The recalculation was carried out consistently for the entire time series. This did not affect the trend in the development. As a result of the recalculation, the methane and NO_X emissions increased and those of N_2O, NMVOC and CO decreased (cf. Table 30).

Table 29: Comparison of emission factors

Name	Verified emission factor (MARION method) [kg/TJ]	New emission factor [kg/TJ]	Old emission factor [kg/TJ]
N_2O		2	3,5
NMVOC		52	147
CH_4		7	3
CO	193,6	180	360
NO_X	1744,41	1800	1500

Table 30: Comparison of emissions following recalculation for heavy fuel oil

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
N_2O	New	0,2	0,1	0,10	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,2
	Old	0,3	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,3	0,3
CH_4	New	0,6	0,5	0,4	0,5	0,5	0,5	0,4	0,4	0,4	O,5	0,5	0,5	0,5
	Old	0,2	O,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2	0,2
NMVOC	New	4,2	3,5	2,8	3,6	3,3	3,3	2,9	3,3	3,3	3,4	3,6	3,8	4
	Old	11,8	10,0	7,9	10,3	9,5	9,5	8,3	9,2	9,2	9,7	10,1	10,6	11,4
CO	New	14,4	12,2	9,7	12,6	11,6	11,6	10,2	11,3	11,3	11,9	12,4	13,0	14
	Old	28,9	24,5	19,5	25,2	23,2	23,2	20,3	22,6	23,8	24,8	24,8	26,0	28
NO_X	New	144,5	122,4	97,3	126,1	115,9	115,9	101,7	112,9	113,0	118,8	124,0	130,2	140,0
	Old	120,3	102,0	81,0	105,1	96,5	96,6	84,7	94,0	94,2	99,0	103,3	108,4	116,7

3.1.9.2.6 Planned improvements (1.BU.2)

No improvements are planned at present.

3.1.10 Storage

Emissions from storage are not calculated at present. This data is only used within the context of the Reference Approach.

3.1.11 Military

Emissions from international deployments by the Federal Armed Forces, under a UN mandate, are currently not calculated as a separate activity for purposes of German emission inventories. However, this task is to be carried out soon within the framework of the National System.

This practice does not lead to any omissions in the inventories, since the fuel inputs associated with these actions are included in national military consumption figures.

The basis for activity data for military fuels consists of the official petroleum data for the Federal Republic of Germany (BAFA, 2003: Table 7j).

In the CSE, source category 1.A.5 includes, under stationary sources, heat production of military agences; under mobile sources, it includes military transports and aviation.

Figure 32: Structural allocation, 1.A.5 Other: Military

3.1.12 Quality assurance / control and verification (1.A)

Below, the results of the detailed source-category-based calculation of CO_2 emissions for Germany, carried out in accordance with the specifications of the *IPCC Good Practice Guidance* (2000), are compared with other national and international data on energy-related CO_2 emissions (data available to Germany), for verification purposes.

This is achieved by comparing the calculation results with data:

- from EUROSTAT
- from IEA (source-category-specific procedure and Reference Procedure)
- from the CO2 calculations performed at Länder level.

Table 31 presents the results of the various CO_2 calculation approaches for comparison. For visualisation purposes, the data is also presented graphically, on a comparative basis over time, in Figure 33. This approach reveals the key development trends in all calculation approaches, including the Reference Approach, albeit at differing levels. In order to illustrate these level differences, the relative deviations in the data records created by the varying calculations are also depicted in Figure 34.

Among the available results, the detailed calculations performed by the Federal Environmental Agency prove to represent a conservative approach. The IEA calculations produce higher values (maximum of 1.7 %) only in a few selected years (since 1996).

CO2-EMISSIONEN EMISSIONSVERGLEICH UNFCCC-INVENTAR MIT VERSCHIEDENEN UNABHÄNGIGEN ERGEBNISSEN

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
DIW-Ergenisse	986,8	951,1	902,9	893,0	877,2	872,4	896,4	864,5	855,7	828,7	830,7	849,1	833,6	833,6
Abweichung DIW zu UBA	-0,2	-0,3	-0,3	-0,3	-0,4	-0,4	-0,4	-0,4	-0,5	-0,4	-0,5	-0,1	-0,9	-1,0
EUROSTAT	943,0	918,5	877,1	870,2	857,6	863,3	870,1	827,8	824,2	802,3	NE	NE	NE	NE
Abweichung EUROSTAT zu UBA	-4,9	-3,8	-3,2	-3,0	-2,7	-1,5	-3,4	-4,9	-4,3	-3,7	NE	NE	NE	NE
IEA Statistics Sectoral Approach	964,1	941,5	892,6	884,9	871,8	870,0	908,4	879,7	867,6	837,7	835,0	850,1	837,5	NE
Abweichung IEA zu UBA	-2,6	-1,3	-1,5	-1,3	-1,0	-0,7	0,9	1,3	0,9	0,7	0,0	0,0	-0,4	NE
IEA Statistics Reference Approach	968,7	937,5	897,5	883,7	870,7	870,4	895,5	870,4	869,9	833,9	839,9	867,8	847,8	NE
Abweichung IEA RA zu UBA	-2,1	-1,7	-0,9	-1,4	-1,1	-0,7	-0,5	0,3	1,2	0,3	0,6	2,0	0,8	NE
Abweichung IEA RA zu UBA RA	-5,2	-4,7	-4,1	-4,6	-4,2	-2,9	-3,1	-2,5	-1,3	-1,5	-1,3	-0,1	-0,4	NE
Ergebnisse der Bundesländer	980,6	957,6	919,1	906,3	880,3	874,6	889,3	881,2	879,7	852,6	838,9	876,7	NE	NE
Abweichung Bundesländer zu UBA	-0,84	0,4	1,5	1,1	0,0	-0,17	-1,19	1,51	2,3	2,5	0,51	3,10	NE	NE
Reference Approach UBA	1.018,6	981,2	934,7	924,4	907,0	895,7	923,0	892,4	881,1	846,6	851,10	868,80	850,80	853,30
Abweichung RA zu UBA	2,9	2,8	3,1	3,1	2,9	2,2	2,5	2,7	2,4	1,8	1,94	2,12	1,14	1,36

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2002
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	(Gg)													
1. Energy	**988.859,23**	**953.634,43**	**905.592,80**	**896.073,92**	**880.359,19**	**876.060,42**	**900.004,15**	**868.079,23**	**859.646,72**	**831.640,55**	**834.598,88**	**850.356,66**	**841.106,09**	**841.691,65**
A. Fuel Combustion (Sectoral Approach)	988.859,23	953.634,43	905.592,80	896.073,92	880.359,19	876.060,42	900.004,15	868.079,23	859.646,72	831.640,55	834.598,88	850.356,66	841.106,09	841.691,65
1. Energy Industries	413.944,87	401.073,68	378.992,23	368.922,83	365.659,88	355.210,92	360.732,57	342.797,08	345.038,67	330.878,55	343.845,62	349.203,86	356.602,74	362.581,56
2. Manufacturing Industries and Construction	196.314,98	172.612,31	159.331,37	147.573,17	149.298,32	149.910,96	144.173,25	144.165,58	138.562,00	135.440,88	135.613,12	132.890,43	132.053,89	129.056,20
3. Transport	162.359,56	165.953,47	171.660,95	176.532,60	172.898,84	176.563,36	176.661,18	177.158,90	180.426,56	186.066,63	182.268,72	178.136,57	176.233,78	170.209,47
4. Other Sectors	204.413,84	205.529,60	189.183,17	197.903,75	187.747,91	190.346,45	215.266,60	200.905,46	192.555,88	176.633,66	170.527,40	188.200,96	174.252,71	177.791,86
5. Other	11.825,99	8.465,37	6.425,08	5.141,57	4.754,25	4.028,74	3.170,55	3.052,22	3.063,61	2.620,84	2.344,02	1.924,84	1.962,97	2.052,57
B. Fugitive Emissions from Fuels	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
1. Solid Fuels	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2. Oil and Natural Gas	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
2. Industrial Processes	**26.172,26**	**23.303,03**	**23.858,44**	**23.972,06**	**25.266,64**	**26.152,41**	**24.903,91**	**25.449,79**	**25.554,03**	**25.778,19**	**25.492,57**	**23.505,43**	**22.770,75**	**23.675,63**
A. Mineral Products	22.970,14	20.799,69	21.498,68	21.733,04	23.056,69	23.551,26	22.325,19	22.889,51	22.932,49	23.189,72	22.777,01	20.803,45	20.032,73	20.758,48
B. Chemical Industry	2.190,55	1.560,12	1.535,46	1.484,43	1.522,35	1.815,12	1.791,33	1.778,36	1.784,94	1.721,80	1.835,21	1.810,69	1.845,36	2.013,56
C. Metal Production	1.011,58	943,23	824,30	754,58	687,60	786,03	787,39	781,92	836,60	866,68	880,35	891,28	892,65	903,59
D. Other Production	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
G. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
3. Solvent and Other Product Use	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
4. Agriculture	**IE**	**IE**	**IE**	**IE**	**IE**	**IE**	**IE**	**IE**	**IE**	**IE**	**IE**	**IE**	**IE**	**IE**
5. Land-Use Change and Forestry (3)	**-28.944,0**	**-29.649,6**	**-30.187,1**	**-30.810,0**	**-31.423,2**	**-31.672,6**	**-32.093,6**	**-32.483,9**	**-32.731,7**	**-33.182,4**	**-34.421,7**	**-35.195,2**	**-35.216,8**	**-35.690,3**
6. Waste	**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**
7. Other *(please specify)*	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Total Emissions/Removals with LUCF (4)	**986.087,5**	**947.287,9**	**899.264,1**	**889.236,0**	**874.202,6**	**870.540,2**	**892.814,4**	**861.045,1**	**852.469,1**	**824.236,4**	**825.669,7**	**838.666,9**	**828.660,0**	**829.677,0**
Total Emissions without LUCF(4)	**1.015.031,5**	**976.937,5**	**929.451,2**	**920.046,0**	**905.625,8**	**902.212,8**	**924.908,1**	**893.529,0**	**885.200,8**	**857.418,7**	**860.091,4**	**873.862,1**	**863.876,8**	**865.367,3**
Memo Items:														
International Bunkers	**19.569,2**	**18.101,4**	**17.818,2**	**19.917,2**	**19.874,7**	**20.420,4**	**21.008,8**	**22.018,2**	**22.088,4**	**23.341,7**	**24.373,8**	**24.094,7**	**24.414,2**	**25.525,7**
Aviation	11.589,4	11.366,7	12.200,2	12.891,8	13.398,4	13.887,1	14.536,9	15.096,7	15.523,1	16.656,2	17.407,8	16.997,5	16.821,6	17.150,8
Marine	7.979,8	6.734,7	5.618,1	7.025,5	6.476,3	6.533,3	6.471,8	6.921,6	6.565,3	6.685,5	6.966,0	7.097,2	7.592,6	8.375,0
Multilateral Operations	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**

1) IEA OECD Statistics "CO2 Emissions from fuel combustion 1971-2000" Edition 2002, Paris
2) AG Länderenergiebilanzen, UBA Analyse; also includes emissions from energy consumption for international transports
3) Take the net emissions as reported in Summary 1.A of this common reporting format. Please note that for the purposes of reporting, the sign for storage is always (-) and the sign for emissions is always (+).
4) The information in these rows is requested to facilitate data comparison, since Parties differ in the way they report CO2 emissions and removals from land-use changes and forestry.
5) Due to a lack of detailed figures (Energy Balance), UBA was unable to use the CO2 reference procedure for 2000 and 2001.

Translation: (from top): Title: CO2 Emissions Comparison: UNFCCC Inventory and Various Independent Results ; Column 1: DIW results; Deviation of DIW Results from UBA; EUROSTAT; Deviation of EUROSTAT results from UBA; IEA Statistics, Sectoral Approach; Deviation of IEA results from UBA; IEA Statistics, Reference Approach; Deviation of IEA RA results from UBA; Deviation of IEA RA results from UBA RA; Results of German Länder; Deviation of German Länder results from UBA; Reference Approach, UBA; Deviation of RA results from UBA

Table 31: Comparison of CO_2 inventories with other independent national and international results for CO_2 emissions

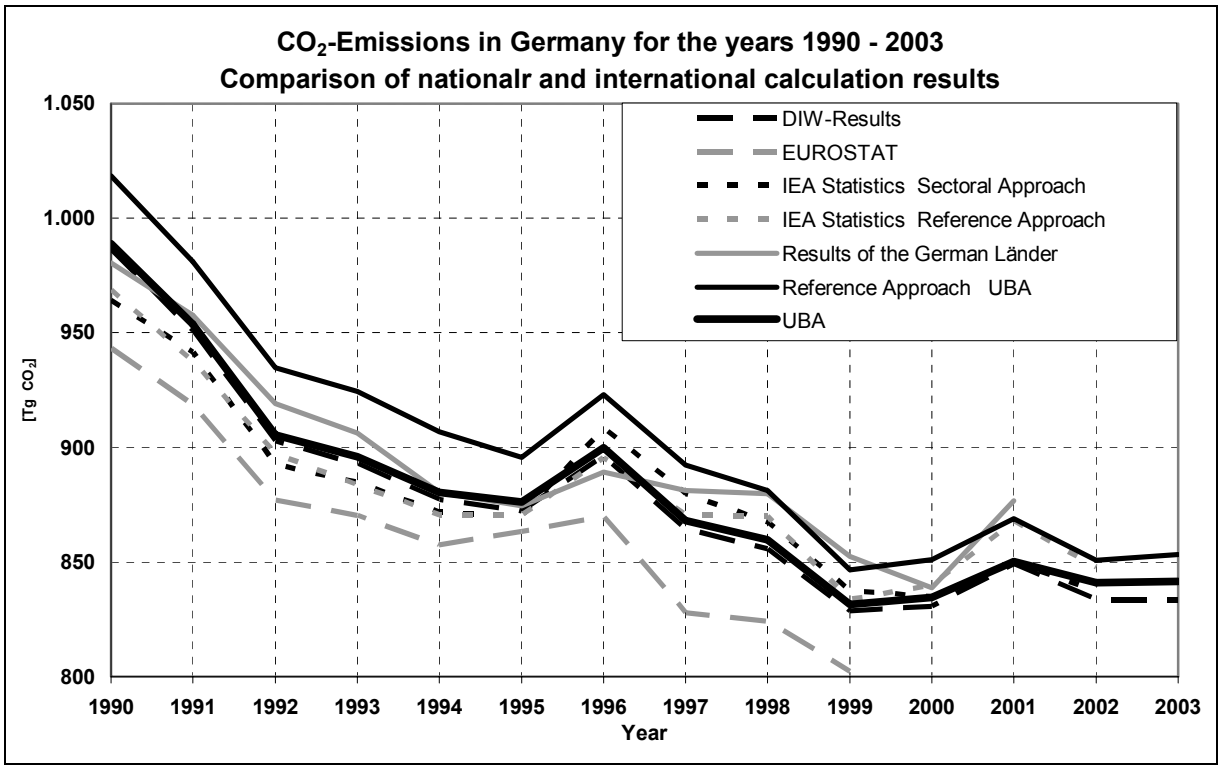


Figure 33: CO_2 emissions in Germany for the years 1990 to 2003 – Comparison of national and international calculation results

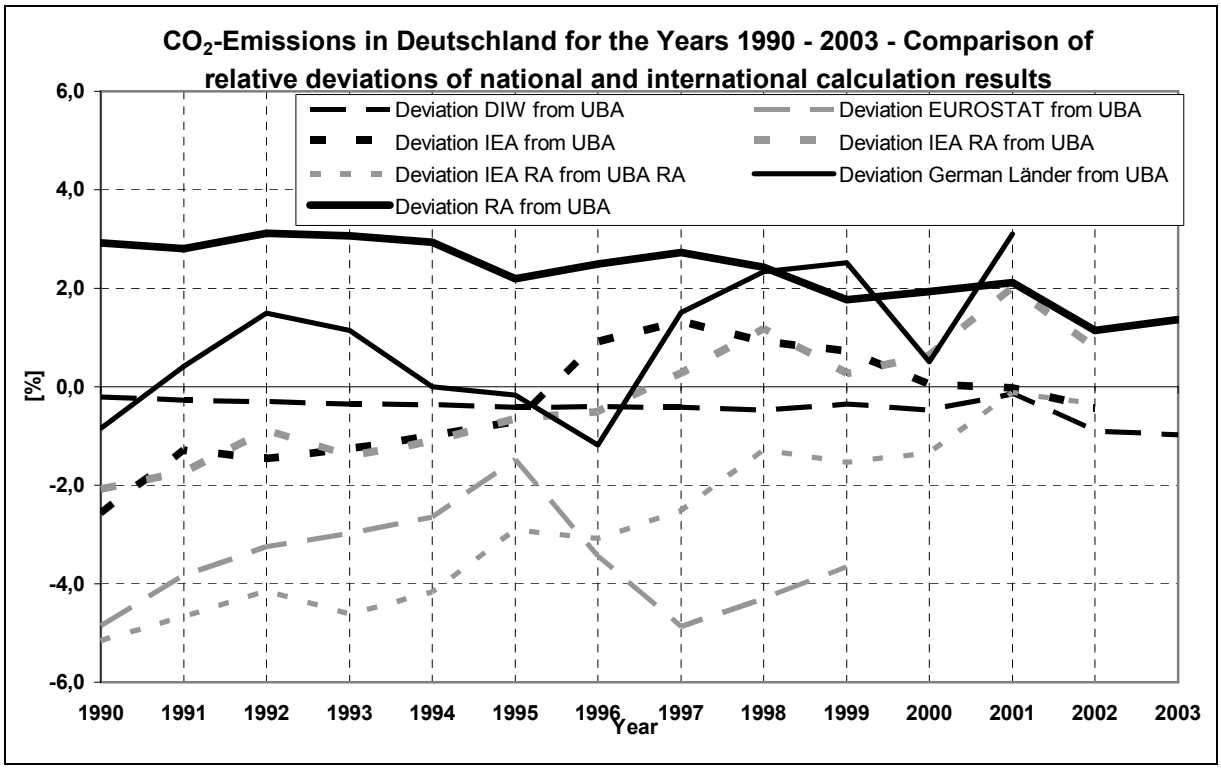


Figure 34: CO_2 emissions in Germany for the years 1990 to 2003 – Comparison of relative deviations of national and international calculation results

3.1.12.1 Comparison with the EUROSTAT results

The sectoral calculations performed by EUROSTAT deviate inconsistently, in terms of their trend, from the detailed national data of the Energy Balance (cf. Table 32). On average, the results are about 3.5 % below the UBA data. The fluctuation in these deviations ranges from – 4.9 % (= 45 million tonnes in 1990) to – 1.5 % (= 13 million tonnes in 1995).

In order to determine the causes for these differences, in 2001 the Federal Environmental Agency commissioned the German Institute for Economic Research (DIW; in Berlin) and the Ökoinstitut, to carry out a relevant research project to be co-funded by EUROSTAT itself. The initial results from this project (DIW 2002), which is not yet complete, are compiled below.

EUROSTAT, like the International Energy Agency (IEA), prepares energy balances for individual Member States and for the European Union as a whole. These energy balances are essentially based on aggregation of a total of five standardised questionnaires (Annual Questionnaires) which must be completed by individual Member States and which contain information on production, foreign trade (imports and exports classified according to countries), stock changes and consumption of energy resources in the individual transformation and final consumption sectors, as well as on non-energy-related consumption in the preceding year. These questionnaires are sent to Member States towards the middle of the year, with the request that they be returned to EUROSTAT/IEA by the end of November together with an initial draft energy balance.

Specifically, the following five questionnaires are sent out:

- Annual Questionnaire on Oil: Data on petroleum is recorded in thousands of metric tonnes. In Germany, data is collected and compiled by the Federal Office of Economics and Export Control (BAFA) in Eschborn, which compiles data in collaboration with the Association of the Germany Petroleum Industry (MWV) and then forwards it to both the Federal Ministry of Economics and Employment (BMWA) and EUROSTAT/IEA.
- Annual Questionnaire on Gas: The production of, and foreign trade in, natural gas, as well as changes in gas stocks, are reported in millions of cubic metres at standard conditions and in terajoules (TJ), which relate to gross calorific value. Consumption quantities are only recorded in terajoules. The questionnaire is supplemented with data on gas pipelines and underground stocks. Up to and including 1995, the questionnaire was completed by the Electricity and Gas Industry Department of the Federal Ministry of Economics (BMWi); since then, this task has been undertaken by the BAFA in collaboration with the corresponding department of the BMWi (now the Federal Ministry of Economics and Employment, BMWA). BMWA).
- Annual Questionnaire on Solid Fuels: This questionnaire is used to record production and consumption data for coal (hard coal, comprising coking coal and other hard coal as well as lignite), peat, briquettes and coke. Data is reported in thousands of tonnes, and a table with respective net calorific values is included with the questionnaire. The data is compiled from statistics provided by the coal industry association Kohlenwirtschaft e.V., whereby the data on hard coal is prepared in collaboration with the General Association of the German Hard Coal Industry (GVSt), Essen, the data for lignite is prepared in collaboration with the Federal Lignite Association (DEBRIV), Cologne, and the overall process is co-ordinated with the responsible Department at

the BMWi (now the Federal Ministry of Economics and Employment, BMWA). BMWA).

- Annual Questionnaire on Renewables and Wastes: This questionnaire, which is structured similarly to the others, covers use of renewable energies and of waste. It includes separate categories for the various energy sources and waste types involved. Apart from charcoal and liquid biofuels, both of which are recorded in thousands of tonnes, data is reported in terajoules (TJ). To date, processing has been carried out by the Federal Ministry of Economics and Employment (BMWA) in close collaboration with the Federal Statistical Office (Destatis) in Wiesbaden.
- Annual Questionnaire on Electricity and Heat: This questionnaire seeks information on the generation and consumption of electricity and heat, distinguishing between public and industrial supply. Information is reported in GWh for electricity and in terajoules for heat, for both gross and net generation, and by energy sources. In addition, in the case of electricity generation, fuel consumption quantities are also to be provided in natural units and in terajoules (TJ). The final consumption quantities are reported on the basis of source category and industrial branch. This questionnaire is of central importance insofar as it is used by EUROSTAT/IEA to examine information on fuel consumption for electricity and heat generation in the other questionnaires. The Electricity and Gas Industry Department at the BMWA compiles the required data and forwards it to EUROSTAT/IEA.

3.1.12.1.1 Reasons for discrepancies in the energy data used

The discrepancies observed vary in nature. One reason why they occur is that the questionnaires have not always been co-ordinated between the institutions that supply the data prior to reporting to EUROSTAT/IEA. Another important factor concerns the timing of data reporting; that is, whether estimates are involved, or provisional figures that can later be revised. The data that flows into annual EUROSTAT/IEA questionnaires is therefore of varied validity.

In particular, divergences between data reported in the annual questionnaires and that shown in the national energy balance are attributable to differences in the timing of data compilation, since there is currently a gap of two years between submission of the questionnaires and presentation of the final energy balances. For this reason, a corresponding delay always ensues before provisional figures reported to EUROSTAT/IEA can be replaced with final data. The national inventories, on the other hand, are always based on the most current energy data available at the time in question.

Initial consequences have been drawn from problems arising in the past (cf. also Chapter 3.1.12.1.2): For example, close collaboration and co-operation has since been agreed between all the parties involved, as a result of which data from the individual questionnaires will now be compiled at the BMWA in an initial provisional energy balance, prepared in close collaboration with the institutions supplying the data, the Federal Statistical Office and the Working Group on Energy Balances (AGEB), and then forwarded to EUROSTAT/IEA. This balance is essentially based on the “evaluation tables” prepared by the AGEB in which, depending on the availability of data, largely detailed information for the preceding year is compiled, in the early summer, on primary energy consumption, non-energy-related consumption and final energy consumption, by source category and energy source.

In addition to the causes mentioned, there are obviously other causes of discrepancies that are more of a systematic nature. Analysis concentrates primarily on the following two groups of potential reasons for differences in data used for the calculation of CO_2 emissions:

As far as natural quantities are concerned, it is necessary to investigate whether there are any differences between the quantities reported under both systems and, if so, how large they are, in percentage terms; it is also necessary to explore the causes for such discrepancies, to determine the time of relevant reporting (if applicable), and to learn whether and to what extent earlier reports have been revised, or whether the discrepancies are of a systematic nature.

The conversion coefficients used for the net calorific values may lead to considerable differences in results, particularly where the CO_2 factors relate to energy units and not to natural units. As a general principle, energy balances are based on net calorific value, but exceptions can occur, particularly with gases, since their gross calorific value is often used to calculate energy quantity – for example in official statistics or price statistics. Irrespective of this, however, differences in net calorific values are possible simply because, in the case of aggregated groups of energy sources, the net calorific values of the assigned energy sources are often disregarded (for example, even hard coal or crude lignite can vary widely according to type and origin). Consequently, it is necessary to examine the type of data concerned and its respective sources.

The aforementioned causes, in varying combinations, may lead to highly disparate results during subsequent calculations e.g. of CO_2 emissions.

A comparison of the amounts listed in the two energy balances revealed a number of discrepancies, some of them considerable. By way of example, Table 32 below shows the discrepancies for 1998.

Table 32: Differences between the energy balance data of EUROSTAT and of the Working Group on Energy Balances (AGEB), for the balance year 1998[53]

Alle Angaben in 1000 t	Steinkohlen			Braunkohlen		Mineralöle							
	Kohle	Briketts	Koks	Roh-braun-kohle, Hart-braun-kohle	Briketts und andere Braun-kohlen-produkte	Erdöl (roh)	Otto-kraft-stoffe	Roh-benzin	Flug-turbinen-kraft-stoff	Diesel-kraft-stoff einschl. HEL	Heizöl schwer	Flüssig-gas	Raffine-riegas
Gewinnung im Inland	6248	0	0	-149	0	53	0	0	0	0	0	0	0
Einfuhr	0	0	0	-126	107	345	385	-448	104	202	-102	-23	-26
Bestandsentnahmen	818	0	3	-72	-17	0	186	41	102	564	155	76	0
Ausfuhr	0	-66	17	-140	26	0	0	0	32	-1	0	0	0
Hochseebunkerungen	0	0	0	0	0	-	-	-	-	-	0	-	-
Bestandsaufstockungen	-	0	-	-	0	206	0	0	0	0	0	0	5
PRIMÄRENERGIEVERBRAUCH IM INLAND	7066	66	-14	-207	69	192	571	-407	174	328	180	53	31
Umwandlungseinsatz insgesamt	2498	0	224	-3041	-7	193	-3995	-4884	0	-749	-2457	-381	-324
Umwandlungsausstoß insgesamt	0	0	139	0	0	0	-3266	-170	39	-50	-714	-267	-225
E.-Verbrauch im Umwandl.-Bereich insgesamt	2	0	0	-108	-2	0	0	0	0	46	642	77	148
Fackel- u. Leitungsverluste	-	-	-	-	-	-	0	0	0	-	0	0	0
NICHTENERGETISCHER VERBRAUCH	-	0	102	-1	-142	-	0	1145	11	-1	-581	-218	-123
Statistische Differenzen	-360	66	405	3035	223	-1	187	106	90	67	133	79	-5
ENDENERGIEVERBRAUCH	526	0	8	-92	-3	-	1	0	17	-173	-493	0	32
Bergbau, Gew. Steine u. Erden, verarbeitendes Gewerbe insgesamt	530	0	8	-59	30	-	0	0	0	330	-546	-80	32
Verkehr insgesamt	0	0	0	0	-28	-	191	0	376	43	0	61	0
Haushalte	149	0	20	73	0	-	55	0	1	0	0	-36	0
Haushalte, Gewerbe, Handel und Dienstleistungen	-4	0	0	-106	-5	-	-190	0	-359	-546	53	19	0

Substantial differences can be seen between the two balances for *hard coal*, primarily with regard to production, stock depletion and transformation input. According to statistics supplied by the coal industry (*Statistik der Kohlewirtschaft)*, in the case of production these differences can be explained by the fact that EUROSTAT data is compiled on the basis of tonnes of gross production (i.e. the total quantity of mined hard coal of varying qualities and ballast contents), whereas the Working Group on Energy Balances (AGEB) uses quantitative data on the basis of tonnes of ballast-free, marketable production. Nonetheless, the EUROSTAT figures are approximately 1.869 million tonnes higher than the figures for tonnes of gross production from *Statistik der Kohlenwirtschaft,* and thus the deviations cannot be attributed solely to the differences in units. In the transformation sector, the difference arises from the fact that EUROSTAT records consumption by public supply power plants in tonnes, whereas the Working Group on Energy Balances (AGEB) uses standardised tonnes of hard coal equivalents. However, this difference diminishes considerably if values are compared in terajoules or crude oil equivalents.

Energy sources such as tar and benzene, which are listed by the Working Group on Energy Balances (AGEB) under "*Coal derivatives*", are not considered separately by EUROSTAT. Unlike EUROSTAT, German energy balances include these energy sources in the

[53] Translation:
X-Axis: All figures in thousands of tonnes; Hard coal, Lignite, Petroleum; Coal; Briquettes; Coke; Crude lignite, Hard lignite; Briquettes and other lignite products; Petroleum (crude), Gasoline; Raw gasoline; Jet kerosine; Diesel fuel, including light heating oil; Heavy heating oil; Natural gas liquids; Refinery gas;
Y-Axis: Domestic production; Imports; Removals from stocks; Exports; International bunkers; Additions to stocks; Domestic primary energy consumption; Total transformation input; Total transformation production; Total energy consumption in the transformation sector; Flaring and line losses; Non-energy-related consumption; Statistical differences; Final energy consumption; Mining, extraction of non-metallic minerals; Total transports; Households; Households, commerce, trade and services]

calculation of primary energy consumption, and assign them solely to non-energy-related consumption.

In the category of *Lignite* (crude lignite, including hard lignite), there are only slight differences in the areas of production, imports and exports. These can be attributed to the fact that the Working Group on Energy Balances lists amounts of peat with hard lignite, while EUROSTAT does not report them at all. The quantity of 3.014 million tonnes in the transformation sector by which the EUROSTAT figures exceed those of the Working Group on Energy Balances (AGEB) is roughly equivalent to the statistical difference, amounting to 3.035 million tonnes, that is reported in EUROSTAT balances but not in the AGEB balances.

In the case of *petroleum*, differences arise primarily in the transformation sector, and they are attributable to the different treatment of petrochemicals in the area of Other Energy Producers. Here, quantitative flows (replacement of products, transfer of products, and backflows from the petrochemicals industry) are presented in detail by EUROSTAT, but are summarised by the AGEB. Both sets of statistics also differ in their presentation of petroleum products, whereby EUROSTAT includes diesel fuel and light heating oil under a single item, whereas the AGEB records both petroleum products separately. Similar problems also arise in the case of Heavy Heating Oil and Residual Fuel Oil, as well as Other Petroleum Products and Feedstocks. The differing entries have yet to be clarified with the Association of the German Petroleum Industry (*Mineralölwirtschaftsverband*).

As well as publishing a balance in the respective units (tonnes, kWh and terajoules [TJ]), EUROSTAT also produces another balance in tonnes of crude oil equivalents – but not in terajoules – and a table of conversion coefficients. However, in the table with conversion coefficients only figures with very broad ranges are provided for major energy sources such as hard coal, lignite and crude oil. For this reason, the conversion coefficients actually used by EUROSTAT for Germany had to be derived from data in tonnes and in tonnes of crude oil equivalents. These coefficients were compared with the net calorific values used by the AGEB for its calculations.

It was found that significant differences also exist in the net calorific values that are used: For hard coal produced in Germany, EUROSTAT assumes a conversion coefficient of 27,168 kJ/kg, which corresponds neither to tonnes of marketable production (29,638 kJ/kg), as used by the AGEB, nor to tonnes of gross production (27,223 kJ/kg), as used in the statistics provided by the coal industry (*Statistik der Kohlenwirtschaft*).

The same applies to lignite; in this case, the EUROSTAT coefficients for crude lignite, 8,840 kJ/kg, and for imports of hard lignite, 13,461 kJ/kg, both lie below the respective coefficients used by the AGEB, 8,931 kJ/kg and 14,962 kJ/kg. As a general trend, it can be asserted that the conversion coefficients used by EUROSTAT tend to be below those used by the AGEB.

3.1.12.1.2 Analysis of the emission factors used

One reason for the data discrepancies between EUROSTAT emission inventories and the national emission inventories may lie in the choice of emission factors used. To begin with, in the framework of the project, we analysed the emission factors used by EUROSTAT for the area of energy-related CO_2 emissions. However, as these emission factors were not explicitly available, they had to be identified by way of recalculation from jointly published energy balances and CO_2 inventories.

The emission factors were calculated for the source categories and sub-source-categories of the energy balance as the quotient of emission value and energy input. Since energy balance data was available in the dimensional unit of kilotonnes of crude oil equivalents, whilst emissions were available in the unit of kilotonnes of CO_2, the emission factors were calculated (in t CO2/TJ) via the following equation[54]:

$$EF_{i;j} = \frac{E_{i;j}}{Q_{i;j} \cdot 41{,}868} \cdot 1000$$

mit

$EF_{i;j}$ *Emissionsfaktor für den Brennstoff i im Energiebilanzsektor j*
$E_{i;j}$ *CO_2-Emission für den Brennstoff i im Energiebilanzsektor j*
$Q_{i;j}$ *Energieeinsatz für den Brennstoff i im Energiebilanzsektor j*

Bei dem numerischen Wert handelt es sich um den Heizwert 41,868 kJ je kg Rohöläquivalent.

The first thing apparent from the recalculations in 2002 is that EUROSTAT has not differentiated any of the emission factors for the various source categories / sectors.

[54] Translation:
with;
Emission factor for fuel i in energy balance sector j
CO2 emissions for fuel i in energy balance sector j
energy input for fuel i in energy balance sector j
The numerical value consists of the net caloric value of 41.868 kJ per kg of crude-oil equivalents.

Table 33: Results of the recalculation of emission factors, 1991-1998

	EUROSTAT [T CO_2/TJ]	Remarks
Hard coal	94	UBA uses values from 92 to 94, depending on source category – 92 for power stations and district heat stations – 93 for industrial combustion plants – 94 for households and small consumers
Hard-coal coke	106	UBA uses values from 100 to 105, depending on source category
Hard-coal briquettes	93	UBA uses the value 93 throughout
Crude lignite	99	UBA uses values from 110 to 113, depending on source category and origin – 110 for industry, small consumers and military – 111 for power stations and district heat stations and other transformation – 112 for other industrial power stations Where separate energy input data is available for the new German Länder: 113, the value for central German crude lignite, is likely to be about 100
Hard lignite	No emission factor, in crude lignite	UBA uses the value 97 throughout
Lignite briquettes	93	UBA uses values from 97 to 99, depending on source category and origin – 99 for power stations and district heat stations – 97 for other source categories Where separate energy input data is available for the new German Länder:
Lignite coke	No emission factor, allocation still unknown	UBA uses values from 96 to 111, depending on source category – 96 for power stations and district heat stations – 107 for industrial combustion plants – 111 for other transformation and small consumers
Coal dust and dry coal	No emission factor, allocation still unknown	UBA uses the value 96 throughout
Peat	No emission factor, allocation still unknown	UBA uses the value 98 throughout
Crude petroleum	No emission factor, allocation still unknown	UBA uses the value 80 throughout
Raw gasoline	73	UBA uses the value 80 throughout
Gasoline	69	UBA uses the value 72 throughout
Diesel fuel	73	UBA uses the value 72 throughout as of 1991
Petroleum and jet kerosine	71	UBA uses the value 74 throughout as of 1991
Light heating oil	73	UBA uses the value 74 throughout
Heavy heating oil	77	UBA uses the value 78 throughout
Natural gas liquids	62	UBA uses values of 64 to 65, depending on source category
Refinery gas	66	UBA uses the value 60 throughout
Petroleum coke	No emission factor, allocation still unknown	UBA uses the value 101 throughout
Other petroleum products	73	UBA uses values from 78 to 80, depending on source category Where separate energy input data is available for the new German Länder:
Coke-oven and city gas	Only in aggregated form in the EUROSTAT energy balance	UBA uses the value 44 throughout
Blast-furnace gas		UBA uses the value 105 throughout; to prevent double-counting with regard to blast-furnace processes and blast-furnace-gas combustion, blast-furnace gas is treated the same as hard-coal coke
Natural gas	56	For natural gas, UBA uses values from 55 to 56, depending on origin; for petroleum gas, it uses 58; for pit gas, it uses 55 Where separate energy input data is available for natural gas in the new German Länder: 55
Industrial wase	Only organic industrial waste is recorded	Apart from values for special sectors, UBA uses the value 20 throughout
Household waste	Household waste is completely recorded, but no emission factor can be determined	UBA uses the value 15 throughout

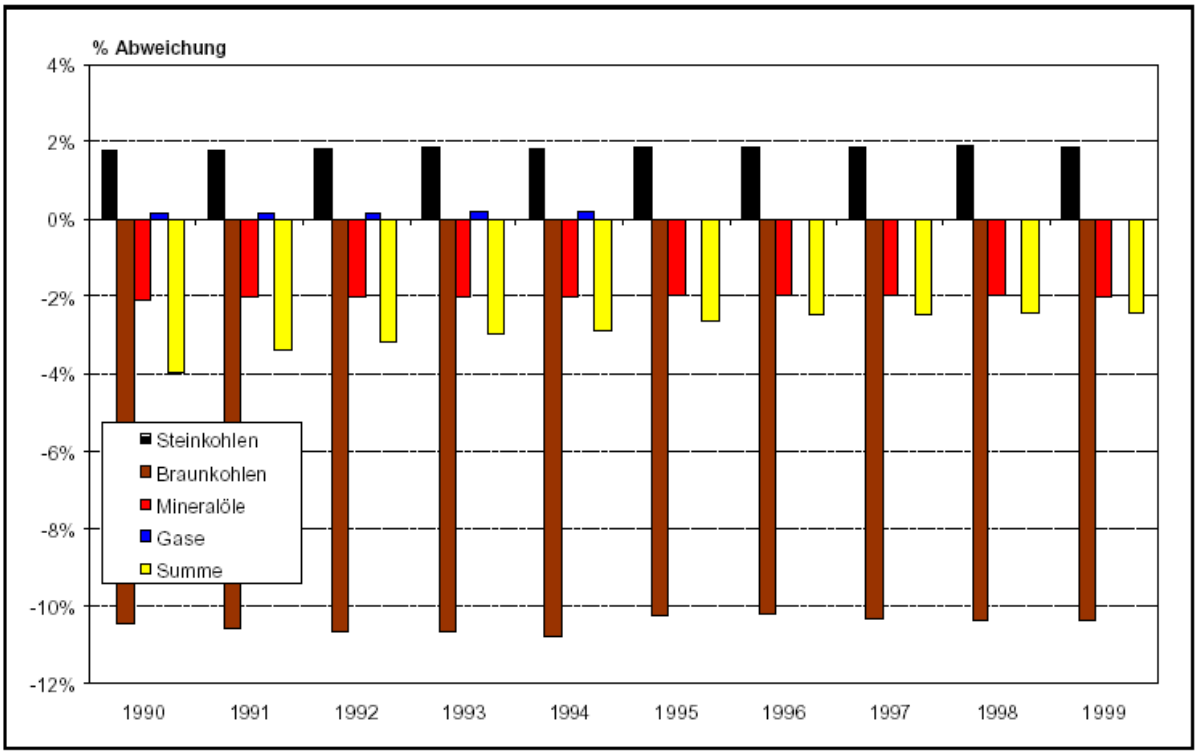
Sources; EUROSTAT, UBA, calculations of the Öko-Institut

Table 33 lists the results, both in the form of an overview and in comparison to the emission factors used in the Federal Environmental Agency's inventory system for reporting in 2003. In the framework of reporting in 2004, the national emission factors were updated, with the result that they diverge, in some cases, from the values in the table.

For the area of *hard coal*, it is evident that the emission factors used by EUROSTAT are always at the top end of the range of values used by the UBA; the spread of fuel consumption (high for power generation, low for commercial/institutional) suggests that, in this case, emissions are exceeded on average by approximately 2 t CO_2/TJ; that is, by about 2 %. In the case of hard-coal coke, the value is even substantially exceeded.

With *lignite*, on the other hand, emissions were clearly underestimated, and the deviations in emission factors amounted to more than 10 % in some cases. The same is true of almost all *petroleum products*; only in the case of refinery gas was the emission factor used by EUROSTAT clearly above the values on which the UBA inventories are based. In this respect, the difference for motor gasoline is of particular significance; in this case, emissions are assumed to be underestimated by about 7 %. The values employed for *natural gases* were very similar. Due to the predominant role of natural gas H in the current natural gas supply mix in Germany, the concurrence is good.

Since combustion of coal and mineral oil products plays a substantial role in CO_2 emissions in Germany, the large discrepancies between the emission factors for these fuels lead, in particular, to a significant emissions underestimation by EUROSTAT. The same also applies with respect to the uncertainties that arise in the area of CO_2 emissions from those fuels which could not be included in this analysis due to the lack of adequate databases.



Quellen: EUROSTAT, UBA, Berechnungen des Öko-Instituts

Figure 35: Discrepancies via differences between UBA and EUROSTAT emission factors, by fuel category, 1990-1999[55]

Divergences arising from differences in emission factors in the period 1990 to 1999 amount to between -39.5 million tonnes of CO_2 (1990) and 21.0 million tonnes of CO_2 (1999), based on an identical framework of input quantities (according to the German Energy Balance and previous UBA supplementation for crude lignite and natural gas). In EUROSTAT calculations, CO_2 emissions in Germany were therefore underestimated by between 4.0 (1990) and 2.5 percent (1999). As illustrated by Figure 35 the deviations in the individual fuel categories are considerably greater than the net balance.

The decisive conclusion to be drawn at this point is that harmonisation of data between EUROSTAT and German institutions should not be confined solely to basic energy data – it should be expanded to include the emission factors.

3.1.12.1.3 Planned improvements

With regard to the avoidance of differences in the energy statistics database, the following recommendations were made in the project:

1. As a general principle, the energy balances published by the Working Group on Energy Balances (AGEB) should always be used as the statistical basis for calculating CO_2 emissions. This applies not only to the national emissions inventory to be drawn up by the Federal Environmental Agency, but also to relevant efforts of international institutions such as EUROSTAT and IEA, insofar as they make their own calculations of emissions.

[55] Translation: Abweichung = deviation; Steinkohlen = hard coal; Braunkohlen = lignite; Mineralöle = petroleum; Gase = gases; Summe = total]

2. The Working Group on Energy Balances (AGEB) is urged to document its methodological steps and procedures in preparation of energy balances, as well as the data sources used for the various balance areas, with the aim of achieving transparency for those outside the AGEB. The Federal Government should provide the necessary material resources for this task.
3. At present, finalised energy balances for Germany are available only for the years from 1990 to 2000. The AGEB, and the institute employed by it (DIW Berlin), are therefore urgently advised to substantially reduce the time lag, within a reasonable period of time. The aim should be to present energy balances no later than 12 months after the end of the year under review.
4. Completion and submission of annual questionnaires should be better co-ordinated, also with regard to timing and content. Measures should be taken to ensure that the arrangements made by all parties for this purpose are consistently implemented. Accordingly, data from individual questionnaires should be compiled, in an initial, provisional energy balance, by the Federal Ministry of Economics and Labour (BMWA), working in close collaboration with the institutions that supply the data (the Federal Statistical Office and the AGEB), and then the data should be forwarded to EUROSTAT/IEA. The “evaluation tables” prepared by the Working Group on Energy Balances (AGEB) constitute a key element of this provisional energy balance. Data which is not yet available at this point in time should be supplemented with appropriate estimates.
5. Where EUROSTAT, in deriving energy balances, uses data that diverges from figures supplied in questionnaires or from the final German energy balances, it should report such divergences, along with the pertinent reasons, to the Federal Ministry of Economics and Labour (BMWA). The BMWA, for its part, should report such divergences to the Federal Environmental Agency and the Working Group on Energy Balances.
6. Corrections made by the Federal Environmental Agency (UBA) to the energy balance with respect to emission-relevant quantities of fuel (lignite drying, waste and others, where applicable), should be included as a memo item in the provisional energy balance referred to in no. 3 once finalised methodological clarification has been achieved.

Emission-related recommendations comprise the following points:

7. In calculating CO_2 emissions, as a general principle, EUROSTAT should use the emission factors employed by the Federal Environmental Agency (UBA). To this end, aggregated emission factors should be supplied annually by the UBA – firstly, for the energy resource and sector structure of the provisional energy balance referred to under point 3., and, secondly, for the energy resource and sector structure of the published energy balance. Logically, the emission factors should be aggregated in keeping with the fuel differentiation used by EUROSTAT.
8. An analysis of the EUROSTAT data suggests that in drawing up and updating energy balances, on the one hand, and in determining CO_2 emissions, on the other, consistent databases or databases of the same currentness status have not always been used. Any co-ordination that may be needed with EUROSTAT should be carried out as soon as possible in collaboration with the Federal Environmental Agency (and, where necessary, with the AGEB).
9. Within the scope of revision and verification of German inventories of atmospheric pollutants, the Federal Environmental Agency (UBA) should develop, as soon as possible,

a methodology for differentiation of bunker fuels for international aviation, by intra-European and extra-European transports, in order to facilitate correct determination of the appropriate memo item at EU level.

As a general principle, agreement should also be reached with EUROSTAT to the effect that energy data and emission factors may be corrected retroactively to take account of changes that are irrefutably confirmed in retrospect (due to new findings). Germany, for its part, must find a harmonisation procedure for communication of energy data and emission factors, so that a high degree of consistency can always be maintained between both sets of data. For this purpose, procedures must be precisely defined for interaction between the AGEB and the UBA, on the one hand, and between the BMU and the BMWA, on the other.

3.1.12.2 Comparison with the IEA results

Comparison with the IEA results was included here for reasons of completeness. Annually updated, internationally published data (most recently: OECD/IEA, 2004) is available. The method of determining, processing and applying the basic data used for this purpose is not precisely comparable with the national procedure in Germany at present, due to a lack of the necessary further methodological information – particularly on the detailed data used.

However, results of the comparison confirm the data obtained via the national, detailed method (average deviation over 13 years: -0.4 %, fluctuation range from -2.6 % in 1990 to +1.3 % in 1997).

In preparing the energy balances, the IEA also has recourse to information from EUROSTAT. Consequently, discrepancies in emissions data, between the two data sets, are noteworthy. The same applies to consistency of results between the two calculation methods used (*sectoral approach* and *reference approach*). Whereas only marginal deviations in the case of the results from OECD/IEA (approximately 4 million tonnes of CO_2) indicate consistency for the most part, application of these methods to the national emission calculations produces significant deviations; in such cases, the results of the reference approach, more or less consistently, are approximately 3 % above the results of the detailed, source-category-specific calculation method.

3.1.12.3 Comparison with the data obtained for the individual German *Länder*

Over the past ten years, a Working Group of the German Länder on Energy Balances has been formed in Germany, via collaboration between the competent authorities and institutions in the German Länder. This includes representatives of the Ministries of the *Länder* responsible for the energy industry – these are generally the industry or environment ministries – as well as the energy officers of the Statistical Offices of the *Länder* where these are appointed to prepare the energy balance for the respective *Land*. The Working Group also includes representatives of economic institutions which prepare the energy balance, on a by-commission basis, in selected German *Länder*.

The principal task of this Länder Working Group is to co-ordinate the preparation of energy balances for the individual German *Länder*. Since the balance year 1995, these balances have been prepared according to a uniform agreed and binding method[56].

56 Information about the methods developed and used in the working group can be found on the Internet at http://www.lak-energiebilanzen.de. The data available from that site in March 2003 was used for the purposes of this comparison.

In 1998, the Working Group of the German Länder on Energy Balances also adopted the preparation of CO_2 balances for the *Länder* as one of its duties. Since then, it has published CO_2 balances for a growing number of *Länder*; these balances are likewise prepared on the basis of the national energy balances, according to standardised rules. Two different approaches are adopted:

Source balance – this refers to an account of emissions based on the primary energy consumption of a *Land*, subdivided according to emission sources, transformation sector and final energy consumption. The source balance allows statements to be made regarding the total volume of carbon dioxide emitted in a *Land* as a result of the consumption of fossil fuels.

Consumption balance – this refers to an account of emissions based on the final energy consumption in a given *Land*. This approach also includes the use of electricity and district heating as well as their "foreign trade balance" (from the viewpoint of the German *Länder*) in the CO_2 balance. The reason for this parallel calculation method is that up to 70 % of energy consumption in individual *Länder* is based on the import of electricity and district heat from other German Länder. Only with this holistic approach is it possible to balance and evaluate the effects of prepared or implemented climate protection measures in the German *Länder*.

Since 2002, the German Länder have also been recalculating CO_2 emissions for the years since 1990. In the following, the Länder results published to date (based on the source balance) are compared with the calculated Federal-level inventories for energy-related CO_2 emissions. The comparison, which refers to data for the years 1990 to 2001, is hampered by the following constraints:

- Not all German Länder participate in the working group, which means that for a few *Länder* no comparable energy balance data can be used. Of those *Länder* who do participate in the working group, not all prepare CO_2 source balances.
- The available information is not always given in the form of consistent time series, so that not all the required data is available for all years. It thus became necessary to use appropriate techniques to close the gaps. For the German Länder for which data has been published, such techniques are based on interpolation or extrapolation. For Länder for which no information has been published, the procedures are normally based on evaluation of statistics on primary and final energy consumption (taking account of percentage changes, and correlating the results with the relevant population figures) and in application of keys for correlating these coefficients throughout the German Länder.

The data used and the relevant results – which, in keeping with the data-determination methods described – should be considered only as orientational in nature, are presented in the following table for the years 1990 to 2001.

Table 34: Comparison of the results of the CO_2 calculations of the individual German *Länder* with the national inventories for the years 1990 to 2001[57]

German Land (state)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Baden-Württemberg	74,4	78,6	78,0	78,7	74,5	78,1	81,8	78,6	80,1	77,4	74,9	80,0
Bavaria	84,1	88,4	86,5	89,7	87,3	87,5	92,0	89,8	91,9	89,7	87,7	89,4
Berlin	***25,6***	***23,5***	***24,5***	***22,8***	***22,8***	***23,0***	***23,2***	***22,6***	22,7	***22,3***	***22,3***	***22,3***
Brandenburg	81,9	66,8	58,9	57,1	54,0	50,8	50,3	50,8	59,3	58,8	60,4	60,9
Bremen	13,4	13,6	12,9	12,5	13,3	13,2	14,2	14,1	13,9	12,8	14,1	14,2
Hamburg	***21,8***	***22,1***	***21,9***	***21,3***	***21,1***	***16,9***	***17,7***	***18,6***	***19,0***	***19,4***	***19,7***	***20,3***
Hesse	***45,6***	***46,5***	***47,3***	***50,0***	***46,6***	***47,4***	***49,8***	***50,8***	***52,5***	***50,3***	***48,6***	***51,5***
Mecklenburg – West Pomerania	***10,9***	***9,3***	***10,1***	***9,7***	***10,0***	10,2	11,7	10,7	10,4	10,6	10,3	10,7
Lower Saxony	78,7	83,9	***82,6***	***81,3***	80,0	***79,9***	79,8	***80,8***	81,8	***78,6***	75,5	***75,5***
North Rhin – Westphalia	298,9	309,7	306,1	299,9	295,4	303,1	311,0	305,7	304,7	291,5	293,9	298,4
Rhineland-Palatinate	***40,7***	***42,5***	***41,0***	***38,3***	***37,5***	***30,9***	***28,6***	***36,8***	***35,4***	***34,9***	***34,4***	***34,0***
Saarland	***11,5***	***12,7***	***12,0***	***11,3***	***11,1***	***11,8***	***11,2***	***11,1***	***11,5***	***10,9***	***10,7***	***10,9***
Saxony	91,5	77,1	64,1	66,0	63,0	61,3	56,2	51,0	37,2	35,1	41,6	48,8
Saxony-Anhalt	50,9	38,3	31,6	27,9	26,3	25,2	25,7	25,3	25,3	26,9	26,3	26,8
Schleswig-Holstein	22,8	22,5	22,8	23,4	23,4	22,0	22,5	21,7	21,4	20,9	20,4	***20,4***
Thuringia	28,1	22,1	18,7	16,3	14,0	13,3	13,7	12,8	12,7	12,4	12,1	12,4
Total for all German Länder	**980,6**	**957,6**	**919,1**	**906,3**	**880,3**	**874,6**	**889,3**	**881,2**	**879,7**	**852,6**	**853,0**	**876,7**
National result (CRF 1A)	**988,9**	**953,6**	**905,6**	**896,1**	**880,4**	**876,1**	**900,0**	**868,1**	**859,6**	**831,6**	**834,6**	**850,4**
Discrepancy [millions of tonnes of CO_2]	**-8,3**	**3,9**	**13,5**	**10,2**	**-0,1**	**-1,5**	**-10,7**	**13,1**	**20,1**	**20,9**	**18,4**	**26,4**
Discrepancy [%]	**-0,8**	**0,4**	**1,5**	**1,1**	**0,0**	**-0,2**	**-1,2**	**1,5**	**2,3**	**2,5**	**0,5**	**3,1**

In the comparison, excellent agreement was found between the combined *Länder* results and the national inventory. On the average for the 12 years in question, the CO_2 emissions of the German *Länder* were a total of about 1% higher than the national result. The largest discrepancies were –1.2% in 1996 and +3.1% in 2001. In all likelihood, the large deviation for 2001 results in that for that year the most extensive gap-closing procedures had to be applied (results were available for only 9 of the 16 German Länder). Overall, these comparisons confirm the CO_2 emissions calculated for Germany as a whole.

3.1.12.3.1 Planned improvements

The calculation method chosen was revised this year. Following the reporting process, the results will discussed, regularly and intensively, with the representatives of the Working Group of the German Länder on Energy Balances. On this basis, the method for comparison between the Länder result and the national result will be improved this year. This improvement will be oriented in particular to the methods chosen for closing the existing data gaps (decisions on analogies between the various Länder). Moreover, research will be undertaken to investigate the extent to which such comparisons can then be refined with respect to consumption of individual energy resources or fuel categories. Yet another option for improvement is to enhance provision of original Länder data to the Federal Environmental Agency, to reduce future needs for using the gap-closing procedure when data is lacking or when data is not provided on time.

[57] The numbers printed in italics or boldface are not part of consistent time series; they were generation via gap-closing procedures (cf. text).

3.2 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 is the most important emission within the source category "solid fuels", fugitive emissions of oil and natural gas also include substantial amounts of carbon dioxide and nitrous oxide.

3.2.1 Solid fuels (1.B.1)

In the "solid fuels" source category, fugitive emissions occur in production, storage and processing.

In the Central System of Emissions (CSE), the areas listed in the NIR are specified in detail, with activity data and specific emission factors. In the CRF tables, these areas are listed in aggregated form, with aggregation of individual aspects carried out in keeping with the following Table 35.

Table 35: Allocation of methane emissions to areas of the CRF

CRF areas	Included emissions
1.B.1.a. Coal mining and handling	
i. Underground Mines	
Mining activities	Emissions from active underground hard-coal mining. The total emissions from pit gas flows and pit-gas removal are reduced by the amount of pit gas used.
Post-mining activities	Emissions from processing, storage and transport of hard coal
ii. Surface mines	
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.
Post-mining activities	No separate listing – the emissions are already included in "mining activities"
1.B.1.b. Solid fuel transformation	
	Emissions from coal processing. This area takes account of specific emissions that occur in hard-coal processing (hard-coal coke, hard-coal briquettes). Emissions from lignite processing (lignite coke, coal dust, dry coal, fluidised-bed coal, lignite briquettes, lignite granulate) are already included in 1.B.1.a.ii "Mining activities". The assumed activity rate covers the total for all processed products from hard coal and lignite.
1.B.1.c. Others	
Abandoned mines	Methane emissions for decommissioned hard-coal mines are listed here. No methane emissions from decommissioned lignite mines are recorded. Specification of an activity rate is not required.

In keeping with allocation of emissions to the various areas of the CRF table for "1.B.1 – Fugitive emissions from solid fuels", the following table presents calculated values for 2003 activity data, along with information regarding the origin of the data.

Table 36: Calculation of methane emissions from coal mining for 2003, pursuant to CRF

VRF areas	Activity data [Mt]	CH_4 emissions [Gg]
1.B.1.a. Coal mining and handling	**205,04** (= 1.B.1.a.i + 1.B.1.a.ii)	(= 1.B.1.a.i + 1.B.1.a.ii) = 327,76+1,97 **= 329,73**
i. Underground mines	**25,96** Hard-coal mining 1)	= mining + post-mining = 312,81 + 14,95 = 327,76
Mining activities		= AR * EF = 25,96 *12,05 **= 312,81**
Post-mining activities		= 14,95
ii. Surface mines	**179,08** Lignite mining 1)	= Mining activities **= 1,97**
Mining activities		= AR * EF = 179,08 * 0,011 = 1,97
Post-mining activities		IE (included in 1.B.1.a.ii)
1.B.1.b. Solid fuel transformation	**11,08** Total for processed products 2) 1)	$AR_{H\text{-coal production}}$ *$EF_{H\text{-coal production}}$ + $AR_{lignite\ production}$ *$EF_{lignite\ production}$ = 6,24 * 0,15 + 4,84 * 0 **= 0,94**
1.B.1.c. Others		= Abandoned mines **= 87,00**
Abandoned mines	**NO**	Experts' estimate **= 87,00**

1) pursuant to STATISTIK DER KOHLENWIRTSCHAFT (2003b)

2) Hard-coal coke, hard-coal briquettes, lignite coke, coal dust, dry coal, fluidised-bed coal, lignite briquettes, lignite granulate

3.2.1.1 Coal mining (1.B.1a)

3.2.1.1.1 Source-category description (1.B.1a)

CRF 1.B.1a					
Key source by level (l) / trend (t)		Gas (key source)	1990 – contribution to total emissions	2003 – contribution to total emissions	**Trend**
Solid fuels	l / t	CH_4	2,06 %	0,67 %	falling

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor[58] (EF)	NO	CS	NO	NO	NO	NO	NO	NO	NO	NO
EF uncertainties in %		-								
Distribution of uncertainties[59]		-								
Method of EF determination[60]		T2								

In Germany, fugitive methane emissions from coal mines are a key source, in terms of both emissions levels and emissions trend.

During coal production, transport and storage, methane can escape from coal and the rock surrounding it. The amount of methane released depends primarily on the amount of

59 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)

60 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model

methane stored in the coal. All of the emissions that result from this relationship – but not the greenhouse gases caused by coal combustion – are to be recorded in this source category.

In the mining sector, a distinction is made between open-pit mines, in which raw materials are extracted from pits open to the surface, and closed-pit mines, in which seams are mined underground. In Germany, hard coal is mined in 10 mines (all closed-pit), and lignite is mined in 6 coal fields, solely using the open-pit method (13 pits). In underground hard-coal mining, ventilation systems are used to keep mine methane concentrations within safe limits for mining. Such systems can emit significant amounts of methane into the atmosphere as they ventilate the air and gas mixtures prevailing in underground mines. Within the framework of this source category, hard-coal mining is thus the largest source of fugitive emissions of CH_4. Some methane is suctioned off directly from seams and ancillary rocks and used, primarily as pit gas.

In 2003, hard-coal production totalled 25.9 million tonnes of usable production, whilst lignite production totalled 179.1 million tonnes (STATISTIK DER KOHLENWIRTSCHAFT, 2004). As a result, hard-coal and lignite production decreased by about 1.5 % over the previous year.

In recent years, methane emissions from hard-coal mining have decreased as a result of decreases in production. Emissions from open-pit lignite mining also decreased, as a result of production decreases in comparison to the previous year. On 10 November 2003, the Federal Government approved a financial framework for further support of the hard-coal sector, thereby providing support for further adaption of production, from 26 million tonnes in 2005 to 16 million tonnes in 2012 (BMWA 2003). As a result, further decreases in methane emissions from hard-coal mining can be expected.

3.2.1.1.2 Methodological issues (1.B.1a)

For calculation of CH_4 emissions from coal mining, emissions are determined for the areas of underground hard-coal mining, pit-gas use, hard-coal storage and open-pit lignite mining.

Emissions from ***underground hard-coal mining*** have been calculated, in keeping with the Tier 2 approach, pursuant to the relevant equation in the IPCC Reference Manual (1996b: Chapter 1.7.2.2, p. 104):

Emissions (Gg CH_4) = EF (m^3 CH_4 /t) * hard-coal production * conversion factor ($Gg/10^6m^3$)

The activity rate (hard-coal mining: entire production) has been taken from the Statistik der Kohlenwirtschaft (coal-industry statistics; 2004: p.14).

The data basis for the CH_4 emission factor used for hard-coal mining, 18.5 kg/t (ca. 27.61 m^3/t, cf. Chapter 3.2.1.1.4), is the report on the FHG ISI (1993) research project. This emission factor lies within the emission-factor ranges given by the IPCC Reference Manual, and is close to the relevant values listed (IPCC et al 1997: Table 1-54, p. 105). Determination of emission factors is based on a source-category-specific "bottom-up" approach that, in addition, to differentiating (sub-) source categories and fuels, also differentiates system technologies in detail. This procedure corresponds to the Tier 2 method of the IPCC Good Practice Guidance (2000).

Emissions are calculated by multiplying the emission factors by the activity rates, taking **pit-gas use** into account. Since in pit-gas use CH_4 is used for energy generation, the emissions calculated for pit-gas use must be deducted from the CH_4 emissions from hard-coal mining.

The amount of pit gas in question is also taken from the Energy Balance for the Federal Republic of Germany (AGEB 2003: line 1) and, due to the lack of an alternate data source, is used consistently as of 1999. Such use will continue until the new Energy Balance is published. The emission factor of 320 kg/10^3 m^3 is used consistently for the entire time series.

For calculation of CH_4 emissions from **storage of hard coal**, the same activity data is used as was used for hard coal mining. The emission factor of 0.576 kg/t has also been taken from the FHG ISI study (1993).

Emissions from ***open-pit lignite mining*** have been calculated, in keeping with the Tier 2 approach, pursuant to the above equation from the IPCC Reference Manual:

The activity rate (crude lignite) has been taken from the STATISTIK DER KOHLENWIRTSCHAFT (2004: p.26). A pertinent memorandum of the DEBRIV (Deutscher Braunkohlen-Industrie-Verein e.V (German lignite-industry association; DEBRIV 2004) provides an average emission factor of 0.015 m³ CH_4/t (corresponds to 0.011 kg CH_4/t). This value is considerably lower than the emission factor used to date, 0.11 m³ CH_4/t, which was derived from the EF for American hard lignite. Such American EF cannot be applied to German soft lignite, since the latter's temperature did not exceed 50°C during coalification. Significant methane releases occur only at temperatures above 80°C, however.

The DEBRIV EF is based on a study carried out by RWE Rheinbraun AG in 1989 (source: DEBRIV, 2004), and it has been upheld by publications of the Öko-Institut and of the German Society for Petroleum and Coal Science and Technology (DGMK; research report 448-2).

No ***storage of lignite*** takes place.

3.2.1.1.3 Uncertainties and time-series consistency (1.B.1a)

The emission factors remain at the same level in the time series and are thus consistent within the meaning of comparability throughout the time series.

According to information provided by the German lignite mining industry association (Deutscher Braunkohlen-Industrie-Verein e. V.), the uncertainties in determination of lignite production amounts (in tonnes) are ± 2-3 % (DEBRIV, 2005). The uncertainties in calculation of calorific values (pursuant to DIN 51900 Teil 1-3) are given as ± 3.5% (DEBRIV, 2005).

No additional information regarding uncertainties has yet been obtained.

3.2.1.1.4 Source-specific quality assurance / control and verification (1.B.1a)

For underground hard-coal mining, the IPCC Reference Manual recommends emission factors on the order of 10 to 25 m³/t. Conversion of the German emission factors, using a conversion factor of 0.67 Gg/$10^6$$m^3$ (pursuant to IPCC Reference Manual, 1996b: at 20° C, 1 atmosphere) yields the individual values listed in Table 37. When production, storage and deductable pit-gas use are combined in one emission factor, a value of 18.85 m^3 CH_4/t coal (marketable production) results, which is within the recommended range.

Table 37: Emission factors for CH_4, from hard coal mining

Emission factors	Hard coal		Lignite	
	EF [m^3 CH_4/t]	EF [kg/t]	EF [m^3 CH_4/t}	EF [kg/t]
CH_4 from extraction	27,61	18,50	0,015	0,011
CH_4 from extraction, minus pit gas	17,98	12,05	-	-
CH_4 from storage	0,86	0,58	-	-
CH_4 from mining (extraction and storage, minus pit-gas use)	18,85	12,63	0,015	0,011

The IPCC Reference Manual (1996b) does not recommend any specific emission-factor levels for open-pit lignite mining.

Measures for standardisation of QC/QA are currently being established.

In the framework of verification, various data sources for activity rates in coal mining, and the relevant EF used, were compared with the corresponding sources and EF of other countries. For further information, see Chapter 14.1.4.1.

A by-country comparison of specific emission factors for underground coal mining shows a broad range, with Germany in the lower part of the range, in a position comparable to that of the Czech Republic. France's EF lies considerably higher within the range, while Poland's is considerably lower. Both of these countries' EF lie outside of the UNFCCC's recommended range.

A by-country comparison of specific emission factors for open-pit coal mining shows that Poland, France and Germany have relatively low emission factors that are below the UNFCCC default values. The reason for this is that the relevant coal in these countries has very low methane content, as a result of its degree of coalification and its geological history. Consequently, suitably low emission factors have to be applied to it. The comparison value for the Czech Republic is considerably higher, since its coal is not the "lignite" found in Germany, which has a low degree of coalification; instead, its coal is largely "sub-bituminous coal", which has a higher degree of coalification and higher methane content.

3.2.1.1.5 Source-specific recalculations (1.B.1a)

No source-specific recalculations have been carried out. Efforts will be made to carry out recalculations on the basis of the planned improvements.

3.2.1.1.6 Planned improvements (source-specific) (1.B.1a)

Current key-source analysis for methane emissions from coal mining, with regard to emissions levels, has just barely led to the sector's classification as a key source. Consequently, the next step is to consider whether reductions in coal production will soon reduce the sector's emissions to a level that no longer corresponds to that of a key source.

Since methane emissions from coal mining are currently a key source, the IPCC methods require the emissions to be calculated pursuant to Tier ⅔, on the basis of measurements of methane in mine-air/gas mixtures and ventilated pit-gas from individual mines/locations. In this area, the ongoing research project "Methane emissions from coal mining" (FKZ 203 41 253 / 05) will develop the necessary data sources, derive national emission factors, carry out calculations and determine uncertainties. The available relevant data will be compiled from operators, associations and the licensing and monitoring authorities of the Länder.

Furthermore, the project is studying estimation ranges and reference formation for use of a combined method, pursuant to Tier ⅔, for the source category. This effort will also include review of currently used emission factors for hard coal, which are relatively high when compared internationally. In addition, the project will consider the issue of what available data can be used as a basis for determining CO_2 and N_2O emissions (and, where data is available, also as a basis for determining emissions of CO, SO_2, and higher hydrocarbons). All improvements will include consideration of the uncertainties in emission factors.

Since to date German inventories do not list any emissions for lignite transport and storage, and since the available data on hard coal storage is out of date, data/information sources for determination of these emissions will be developed, and the sources' suitability for inventory preparation will be considered.

The relevance of methane emissions from lignite production is to be reviewed.

Within the framework of the project, and with the help of other players in the National System of Emissions, possibilities will be reviewed for improving the inventory calculation of pit-gas use and for taking account of cold and hot gas flaring.

A central review of German emissions reporting for 2003, carried out by independent experts under commission to the Climate Secretariat, critically noted that no data on CO_2 and N_2O emissions was provided in this category. Germany plans to take action on this point.

The results of the planned NaSE workshop will be noted and applied within the framework of the research project.

3.2.1.2 Solid fuel transformation (1.B.1b)

3.2.1.2.1 Source-category description (1.B.1b)

CRF 1.B.1b					
Key source by level (l) / trend (t)		Gas (key source)	1990 – contribution to total emissions	2003 – contribution to total emissions	**Trend**
	- / -				

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor[61] (EF)	NO	CS	NO	NO	NO	NO	NO	CS	CS	CS
EF uncertainties in %										
Distribution of uncertainties[62]										
Method of EF determination[63]		CS								

The source category "solid fuel transformation" (1.B.1b) is not a key source.

In 2003, hard-coal production amounted to 7.8 million tonnes, of which 2.0 million tonnes were by-product coke and 5.8 million tonnes were metallurgical coke. The metallurgical-coke production figure includes the production of the Schwelgern coking plant, which has been in operation since 04/2003. That plant's production is placed at about 1.7 million tonnes. Hard-coal-coke production increased by 8.3 % over the previous year (STATISTIK DER KOHLENWIRTSCHAFT, 2004).

62 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
63 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model

3.2.1.2.2 Methodological issues (1.B.1b)

The IPCC Reference Manual does not describe any methods for this source category (IPCC et al, 1997, Reference Manual, p.1.110f). The country-specific method that is used is based on activity rates from the STATISTIK DER KOHLENWIRTSCHAFT (2004) and on corresponding emission factors.

Production of low-temperature lignite coke took place solely in the new German Länder and, for purposes of the inventory, is of relevance only to the base year. Production was discontinued after 1992.

The activity rate for hard-coal-coke production has been taken from the STATISTIK DER KOHLENWIRTSCHAFT (2004: p. 6).

Emissions from hard-coal-coke production have been calculated pursuant to the Tier 2 approach, in a manner similar to that of the IPCC Reference Manual's equation for CH_4 emissions from coal mining (1996b: 1.7.2.2, p. 104):

Emissions (Gg CH_4) = EF (m^3 CH_4 /t) * hard-coal-coke production * conversion factor (Gg/$10^6 m^3$)

The emission factor used for calculation of CH_4 emissions from hard-coal-coke production (coking plants) is 0.150 kg CH_4 per tonne of hard-coal-coke production (LANGE 1988, BATZ 1995), and this value has been used consistently since 1995.

In the CSE, the source category "solid fuel transformation" is covered by the time series for hard-coal coke production (coking plants).

No emissions are to be expected from processed lignite products, since the EF used for 1.B.1a corresponds to the gas content of the lignite occurring in Germany.

3.2.1.2.3 Uncertainties and time-series consistency (1.B.1b)

No information about this is available at present.

3.2.1.2.4 Source-specific quality assurance / control and verification (1.B.1b)

Measures for standardisation of QC/QA are currently being established.

3.2.1.2.5 Source-specific recalculations (1.B.1b)

No source-specific recalculations have been carried out.

3.2.1.2.6 Planned improvements (source-specific) (1.B.1b)

The activity rates and emission factors used to date for coal treatment (coal processing) are to be reviewed and updated, and the proper defining limits for the source category (including those for hard-coal coke production) are to be determined. Current sources of data and information for identifying emissions are to be developed, and the sources' suitability for inventory preparation is to be reviewed.

In light of the requirements from the Guidelines, the data available in Germany for the time series beginning in 1990 is to be reviewed, and a consistent CH_4-emissions-calculation procedure is to be developed that permits adequate extrapolation of activity rates and emission factors.

If suitable national emission factors are available, calculations in the area of coal treatment (coal processing) are to be in keeping with the Tier 2 approach.

Results from the planned NaSE workshop are to be noted and applied.

3.2.1.3 Other (1.B.1c)

3.2.1.3.1 Source-category description (1.B.1c)

CRF 1.B.1c					
Key source by level (l) / trend (t)		Gas (key source)	1990 – contribution to total emissions	2003 – contribution to total emissions	**Trend**
	- / -				

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor[64] (EF)	NO	CS	NO	NO	NO	NO	NO	CS	CS	CS
EF uncertainties in %										
Distribution of uncertainties[65]										
Method of EF determination[66]		CS								

Only rough estimates are available on degassing from decommissioned hard-coal mines. A figure of 87 kt has been used consistently since 1990 (FHG ISI 1993: p. 39). Presumably, this value is considerably lower than the actual emissions, since decreases of coal production in Germany have gone hand-in-hand with decommissioning of hard-coal mines. As a result, this value is no longer used in current reporting, and priority will have to be given to revising the time series.

3.2.1.3.2 Methodological issues (1.B.1c)

The IPCC Reference Manual does not describe any methods for the source category "Other" (IPCC et al, 1997: p.1.110f).

As well as active mines and coal processing, decommissioned hard-coal mines (degassing) represent another relevant source of fugitive CH_4 emissions. A figure of 87 kt has been used consistently since 1990 (cf. the previous chapter).

No emissions are to be expected from decommissioned open-pit lignite mines, since the EF used for 1.B.1a corresponds the the gas content of the lignite occurring in Germany.

3.2.1.3.3 Uncertainties and time-series consistency (1.B.1c)

No information about this is available at present.

3.2.1.3.4 Source-specific quality assurance / control and verification (1.B.1c)

Measures for standardisation of QC/QA are currently being established.

3.2.1.3.5 Source-specific recalculations (1.B.1c)

No source-specific recalculations have been carried out.

65 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)

66 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model

3.2.1.3.6 Planned improvements (source-specific) (1.B.1c)

Currently, the expert-judgement procedure is being used to collect opinions regarding the total amount of methane released.

According to Landesinitiative Zukunftsenergien NRW (MUNVEL o.J.), a total of 180 million m³ CH_4 are released annually. The emissions prevented via pit-gas collection are deducted from this amount. Pursuant to FHG UMSICHT (2003), a total of 45,527 million m³ was used in 2003. This represents an increase of 70.7 % over the previous year.

3.2.2 Oil and natural gas (1.B.2)

In the CSE, data on fugitive emissions from oil and natural gas is included with data on sub-source categories. Disaggregations relative to the line network are carried out, inter alia, in the CSE. Aggregated information and data are included in the CRF tables (Table 1(s2), 2. Oil and Natural Gas, and Table 1.B.2 Fugitive Emissions from Oil, Natural Gas and other Sources).

CRF 1.B.2					
Key source by level (l) / trend (t)		**Gas (key source)**	**1990 – contribution to total emissions**	**2003 – contribution to total emissions**	**Trend**
Natural gas	l / t	CH_4	0,51 %	0,71 %	rising

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**NMVOC**	**VOC**	**SO_2**
Emission factor[67] (EF)	NO	CS	NO	NO	NO	NO	NO	NO	NO	NO
EF uncertainties in %		25								
Distribution of uncertainties[68]		N								
Method of EF determination[69]		CS								

The source category "Fugitive emissions from oil and natural gas" (1.B.2) is a key source with respect to emissions from natural gas, in light of its emissions levels and trend.

Distribution of natural gas constitutes the principal source of fugitive emissions of CH_4. CH_4 emissions from natural gas extraction and processing, as well as from transfer stations, play a subordinate role in this respect. CH_4 emissions from petroleum extraction and from storage of petroleum products only account for approximately 3 % of emissions from natural gas.

3.2.2.1 Oil (1.B.2.a)

CH_4 emissions from petroleum originate primarily from fugitive emissions from extraction, from the refinery process and from storage of petroleum products. Specific emissions from petroleum extraction (sum of 1.B.2.a i, 1.B.2.a ii and 1.B.2.a iii and 1.B.2.c) have decreased only slightly – by 10 % - since 1990. On the other hand, specific fugitive CH_4 emissions from the refinery sector and in-refinery storage of petroleum products (particularly gasoline), including venting losses and flaring emissions, were reduced by 65 % - from 0.06 to 0.02 kg/t – over the same period (1.B.2.a iv). This is due primarily to introduction of vapour-tight machinery (pumps, compressors), sealing systems (connectors) and vapour-recovery equipment. Overall, CH_4 emissions for source category 1.B.2.a were reduced from 10.79 Gg

68 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
69 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model

in 1990 to 6.74 Gg in 2002. The relevant emission factors have not changed from their values in 2003. Due to a lack of activity rates for 2003, the 2002 emissions data was used.

To date, it has not been possible to determine the CO_2 emissions for this source category.

3.2.2.1.1 Source-category description: Oil (1.B.2.a)

Crude oil (1.B.2.a iii) is transported almost exclusively via pipelines. In 2003, the pipeline network for crude oil and petroleum products had a total length of 6,247 km and a total throughput of 154.4 million t.

The IPCC Synthesis and Assessment Report Part I (IPCC, 2004a) noted that the IEF of the source category Refining / storage is lower than those of other Annex I countries. The low IEF for this source category is due to implementation of technical requirements from national legal provisions relative to equipping of systems for storage, transfer and transport of volatile petroleum products. The Technical Instructions on Air Quality Control (TA LUFT, 2002) require the use of structurally tight valves, flanged joints and connections, pumps and compressors, as well as storage of petroleum products in fixed-roof tanks with connections to gas-collection lines.

Only about 0.1 % of all amounts of crude oil used is transported by tanker ships on inland waterways (111,800 t in 2000, cf. DESTATIS Fachserie 8, Reihe 4, 1991-2004). For this reason, this transport pathway has not been included in the present context.

In 2003, a total of 14 crude-oil refineries, and 7 lubricating-oil and used-oil refineries, were in operation in Germany. One refinery for used oil is currently undergoing trial operation. The total crude-oil input was 118.1 million t in 2003 (MWV, 2004).

No CH_4 emissions have been determined to date for source category 1.B.2.a v "Distribution of oil products". Distribution of gasoline and straight-run gasoline (naphtha) is emissions-relevant in Germany.

3.2.2.1.2 Methodological issues (1.B.2.a)

The CH_4 emissions were determined from the relevant specific emission factors and activity rates.

The CH_4 emission factor for the area of exploration, production and transport of crude oil, 1.1 kg/t crude oil, includes the resulting flaring emissions and vapour losses. It origininates in a research report of the German Society for Petroleum and Coal Science and Technology (DGMK 1992: p. II-98). The CH_4 emission factors for the area of refining and storage were derived from a VOC emission factor (the CH_4 emission factor corresponds to 10 % of the VOC emission factor), and they have continued to be used, due to progress made in emissions-reduction technology. The original VOC emission factor, unfortunately, is not sufficiently substantiated.

The activity rates have been taken either from the annual Energy Balance of the Working Group for Energy Balances (Arbeitsgemeinschaft für Energiebilanzen) or from the "Oil industry statistics" ("Mineralöl-Zahlen", an annual special publication of the Association of the Germany Petroleum Industry, the Mineralölwirtschaftsverband e.V. (MWV, 2004).

3.2.2.1.3 Uncertainties and time-series consistency (1.B.2.a)

The uncertainties, amounting to 25 %, were determined in the framework of an expert judgement, and they are of the same order as the IPCC-GPG default value of ± 25 % to ± 50 % (IPCC, 2000: p. 2.92).

3.2.2.1.4 Source-specific quality assurance / control and verification (1.B.2.a)

For source category 1.B.2a (oil refining / storage), comparison with the IPCC Guidelines' default values (IPCC Guidelines - Reference Manual, 1996b) shows good agreement. Table 1.62 of the Guidelines lists emission factors for this area in a sum ranging from 110 to 1660 kg/PJ. Conversion of the German emission factor for 2003, 0.02 kg/t crude oil, using the lower net calorific value of crude oil (42.7 MJ/kg), produces an emission factor of 468.4 kg/PJ. This value lies within the range for the IPCC default value. Similarly, the emission factor listed by Austria for the year 2000, 0.033 kg/t crude oil, agrees well with the German emission factor determined on a country-specific basis.

Measures for standardisation of QC and QA are currently being established.

3.2.2.1.5 Source-specific recalculations (1.B.2.a)

No recalculations are required.

3.2.2.1.6 Planned improvements (source-specific) (1.B.2.a)

Plans for the NIR 2006 call for determining, for the first time, CH_4 emissions from sale of petroleum products.

Due to a lack of country-specific emission factors in the area of pipeline oil transports, in future the default values from the IPCC Good Practice Guidance (2000: p 2.87) will initially be used for the Tier 1 approach:

$$EF_{CH4} = 5.4E\text{-}06;$$
$$EF_{CO2} = 4.9E\text{-}07;$$
$$EF_{N2O} = 0$$

[Gg/(10³m³ oil transported per pipeline)]

For the most part, the country-specific activity rates in this area are available in the form of pipeline oil throughputs listed in the MWV's "Oil-industry statistics for 2003" ("Mineralölzahlen 2003") and listed by the MWV in 2000.

Further aspects of inventory completion have been included in the inventory-improvement plan.

3.2.2.2 Natural gas (1.B.2.b)

3.2.2.2.1 Source-category description: Erdgas (1.B.2.b)

This source category includes description of production and processing of natural gas (including onshore and offshore drilling, gas conditioning) as well as description of pertinent pipeline transports and distribution (including long-distance pipelines and local gas networks with their measuring and control stations and compressors) and of natural gas releases at usage sites (residential, commercial/institutional: 1.A.4). In the case of natural gas, the

principal source of fugitive CH_4 emissions is distribution of natural gas to the end consumer. Even though the distribution network was expanded, during the period covered by the report, from about 150,000 km to 432,614 km (2003), CH_4 emissions were slightly reduced. This was accomplished via a reduction of about 40 % in diffuse distribution losses. CH_4 emissions in the source category "oil and natural gas" decreased considerably between 1990 (10.8 Gg) and 2002 (4.1 Gg). One explanation for the sharp reduction in methane emissions is that fugitive emissions in refineries were reduced through technical upgrades (tightly sealing fittings, such as flange connections, valves, pumps, compressors) resulting from implementation of emissions-control provisions under relevant regulations (TA Luft 2002, VDI Richtlinie (Guideline) 2440: VDI, 2000).
The other fugitive emissions arising from extraction, processing and high-pressure distribution of natural gas showed only a slight decrease during the period under review. CH_4 emissions were reduced overall. Since the overall framework conditions have not changed, only slight changes – if any at all – in emissions for 2003 are to be expected.

Replacement of gray-cast pipelines, a process in which further progress was made in 2003, was also a factor in reduction of CH_4 emissions. The German Association of the Gas and Water Industries (DVGW) reports that accidents have been decreasing, over the years, in the area of gas supply to residential and commercial/institutional. At the same time, it notes that accidents have been concentrated in two areas. These two areas are "backhoe damage", occurring during excavation related to household gas connections, and tampering with household gas systems. During the year under consideration, a total of 23 pore reservoirs and 20 cavern reservoirs for natural gas were in operation. Within the latter group, a total of 145 individual caves were used. Following a slight decrease in 2002, the working gas volume of underground reservoirs increased slightly in 2003 – by 0.7 billion m³ (V_n), to 19.6 billion m³ (V_n). Of this volume, a maximum of 18.6 billion m³ (V_n) are currently technically usable. Current planning calls for an additional 3.5 billion m³ (V_n) of working-gas storage capacity to be installed, primarily in the form of cavern reservoirs. The major projects underway since the early 1990s have now largely been completed, and the working-gas volume has been stable for several years as a result.

The sub- source category "Other leakage" includes emissions occurring in household use of natural gas.

3.2.2.2.2 Methodological issues (1.B.2.b)

The CH_4 emissions for natural gas were determined from the relevant specific emission factors and activity rates. The activity rates are drawn predominantly from the National Energy Balance published annually by the Working Group on Energy Balances (AGEB). Activity rates for calculation of emissions from natural-gas transport / distribution are determined with the help of gas statistics of the Federal Association of the German Gas and Water Industry (Bundesverband der deutschen Gas- und Wasserwirtschaft; BGW). On the basis of these gas statistics, the activity rates are determined first, via intermediate steps, for the existing time series. These intermediate steps are needed for the National Inventory, since certain activity rates are no longer included in gas statistics.

The specific emission factors were derived by the Federal Environmental Agency, on the basis of research in the literature (SCHÖN, WALZ et al., 1993) and among relevant companies, and they have been continually used.

NMVOC emissions in the gas sector have not been determined to date.

3.2.2.2.3 Uncertainties and time-series consistency (1.B.2.b)

The uncertainties, amounting to 25 %, were determined by Federal Environmental Agency experts in the framework of an "expert judgement", and they are of the same order as the IPCC Good Practice Guidance default value.

3.2.2.2.4 Source-specific quality assurance / control and verification (1.B.2.b)

As to source category 1.B.2b (natural gas production, processing and distribution), Table 1.62 of the IPCC Guidelines (1996b) lists only a default value for the emission factor for the entire source category – 58,000 to 111,000 kg/PJ (cf. also SCHNEIDER-FRESENIUS et al., 1989). A comparison with the summed German emission factors converted using the lower net calorific value of natural gas (35.7 MJ/Nm³) shows good agreement. The country-specific determination produced an overall emission factor that lies within the lower range of the spread for the IPCC default value.

The country-specific emission factor of 27,000 kg/PJ for natural-gas extraction has not been adequately substantiated to date.

Measures for standardisation of QC and QA are currently being established.

3.2.2.2.5 Source-specific recalculations (1.B.2.b)

No recalculations are required.

3.2.2.2.6 Planned improvements (source-specific) (1.B.2.b)

The emissions-calculation procedures are being reviewed and adjusted in the interest of inventory completion.

As to lacking data on CO_2 emissions, it is hoped that relevant data can be obtained as of 2006, in the framework of transposition of the European Directive on Emissions Trading. Plans for the NIR 2006 also call for supplanting emission factors for natural-gas distribution with more current factors, obtained from another source.

Findings from a planned research project will be used to improve the data from the energy balance for the Federal Republic of Germany.

3.2.3 Venting and flaring (1.B.2.c)

CH_4 emissions from flaring and venting (vapour losses) have already been covered in the relevant previous sections of the NIR (1.B.2.a and 1.B.2.b).

CO_2 emissions for this source category have not been determined to date.

3.2.3.1.1 Source-category description: venting and flaring (1.B.2.c)

At present, emissions from venting and flaring of oil during direct further processing (refinery flaring) are reported in source category 1.B.2a II. No activity rates and emission factors for emissions during exploration are known.

3.2.3.1.2 Methodological issues (1.B.2.c)

Emissions from venting and flaring of natural gas are included in source categories 1.B.2.a and 1.B.2.b.

3.2.3.1.3 Uncertainties and time-series consistency (1.B.2.c)

The relevant statements made in chapters 1.B.2.a and 1.B.2.b also apply here to uncertainties relative to emissions from venting and flaring.

3.2.3.1.4 Source-specific quality assurance / control and verification (1.B.2.c)

Plans for the NIR 2006 call for determining, for the first time, CH_4 emissions from sale of petroleum products.

Measures for standardisation of QC and QA are currently being established.

3.2.3.1.5 Source-specific recalculations (1.B.2.c)

No recalculations are required.

3.2.3.1.6 Planned improvements (source-specific) (1.B.2.c)

Further studies relative to activity data and CH_4 and CO_2 emissions are planned. The German emissions-trading agency's (DEHSt's) database relative to the *"Directive on Greenhouse Gas Trading"* could serve as the data source for such efforts.

Further aspects of inventory completion have been included in the inventory-improvement plan.

4 INDUSTRIAL PROCESSES (CRF SEKTOR 2)

4.1 Mineral products (2.A)

Source category 2.A Mineral products is divided into the sub-categories 2.A.1 through 2.A.7. Of these, the CSE includes Cement production, divided into cement clinker production and cement production (2.A.1), Lime production (2.A.2), Soda ash production and use (2.A.4), Road paving with asphalt (2.A.6) and, under Other (2.A.7), glass production, coarse ceramics and salt and potassium salt production.

Limestone and dolomite use (2.A.3) and Asphalt roofing (2.A.5) are not included.

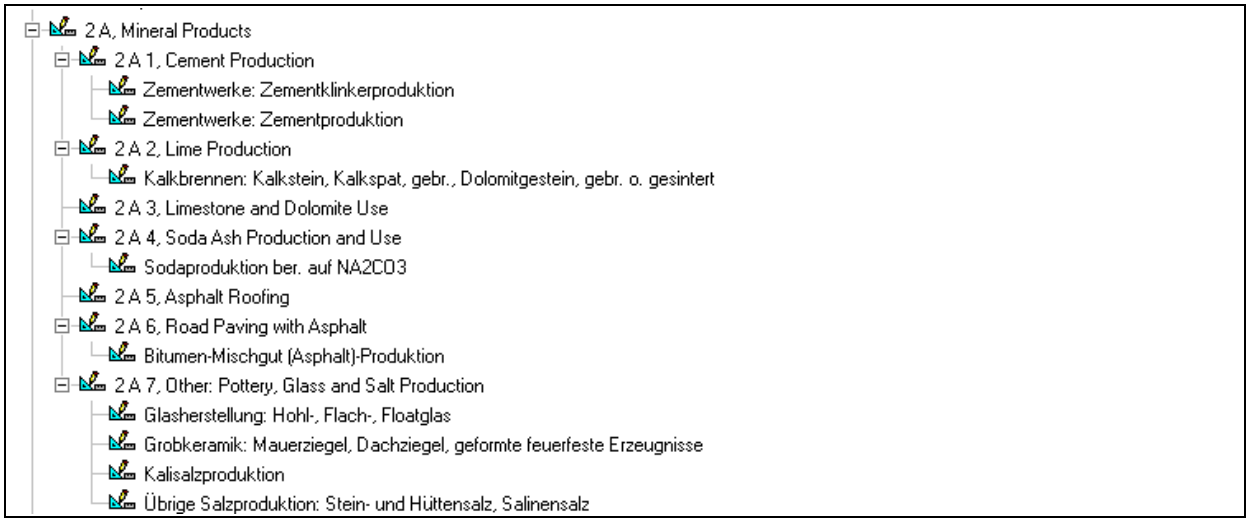


Figure 36: Structural allocation, 2.A Mineral products

4.1.1 Mineral products: Cement production (2.A.1)

4.1.1.1 Source-category description (2.A.1)

CRF 2.A.1					
Key source by level (l) / trend (t)		Gas (key source)	1990 – contribution to total emissions	2003 – contribution to total emissions	**Trend**
Cement production	l / t	CO_2	0,47 %	1,31 %	rising

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor[70] (EF)	CS	NO	NO	NO	NO	NO	NO	NO	NO	CS
EF uncertainties in %	± 20	- -	- -	- -	- -	- -				
Distribution of uncertainties[71]		- -	- -	- -	- -	- -				
Method of EF determination[72]	CS	- -	- -	- -	- -	- -				

In light of its emissions levels and trend, the source category "Cement production" (2.A.1c) is a key source.

70 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
71 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
72 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model

In 2002, a total of 70 ovens for firing of cement clinkers, with a total capacity of 131820 t/d, were in operation throughout Germany. In a breakdown by oven types, the largest group of these consisted of ovens with cyclonic preheaters (46), followed by ovens with grid preheaters (16) and shaft ovens (8) (BDZ, 2004a, p. 7). A total of 31 companies, with 47 cement plants in Germany, are members of the Association of the German Cement Industry (Bundesverband der Deutschen Zementindustrie - BDZ, 2004b).

The clinker-firing process emits climate-relevant gases. CO_2 accounts for the great majority of these emissions. In its monitoring report for 2002, the Association of German Cement Plants (Verein Deutscher Zementwerke - VDZ) reported clinker production of 23,954 kt[73]. The relevant CO_2 emissions that depend on the raw materials used can be estimated using a country-specific emission factor of 0.53 t CO_2/t cement clinkers. Clinker production produced raw-materials-dependent CO_2 emissions of 12 695 kt CO_2 in 2002.

4.1.1.2 Methodological issues (2.A.1)

The activity rates data was compiled by the German Cement Works Association, *Verein Deutscher Zementwerke e.V.* (VDZ) Düsseldorf, by means of surveys amongst German cement factories and via use of BDZ figures. For the most part, the data in question consists of data published in the framework of CO_2 monitoring (RWI, 2000). This data differs from the data published in *Environmental data for the German cement industry (Umweltdaten der deutschen Zementindustrie* - VDZ, 2002). The reason for this is that the production figures in the environmental data, and those in the CO_2-monitoring data, come from different sources and were compiled using different data-survey criteria. Whereas the environmental data draws on BDZ figures, which cover only the BDZ member plants, the VDZ monitoring data cover all German cement plants. At the same time, some of the data is estimated. In addition, the latter source adjusts the activity rates for the German cement industry by deducting imports and exports of cement clinkers, with the result that the CO_2 emissions calculated with the adjusted activity rates refer solely to the amount of cement that was ground from cement clinkers manufactured in Germany. For the years 1991 to 1993, the activity rates exhibit a data gap that the association (VDZ) thus cannot close. For the time being, the data for these years has thus been interpolated. For 2002, the VDZ's draft monitoring report lists clinker production of 23,954 kt.

Table 38 summarises the activity rates, and clinker factors determined on the basis of these rates, for the years 1987 to 2002. The clinker factor is calculated as the quotient of clinker production and cement production, and it is expressed in the units *t clinker / t cement*. This factor is needed for derivation of emission factors for clinker production (see below).

73 This figure is provisional, since the 2002 monitoring report of the Rheinisch-Westfälisches Institut für Wirtschaftsforschung (RWI), an economic research institute located in Essen, has not yet been published.

Table 38: Activity rates and resulting clinker factors in the German cement industry, for the years 1987-2002

Year	Clinker production [kt/a]	Cement production (from German clinkers) [kt/a]	Clinker factor [t clinkers/t cement]
1987	29399	34171	0,860
1990	29054	34749	0,836
1991	29096		
1992	29138		
1993	29180		
1994	29222	35804	0,816
1995	29072	33649	0,864
1996	27668	32858	0,842
1997	28535	33171	0,860
1998	29038	34681	0,837
1999	29462	36558	0,806
2000	28494	34685	0,822
2001	25227	31481	0,801
2002	23954	30773	0,778
2003	25233*	32243	0,782*
Ø			**0,825**

*tentative figures

Emission factors are determined on the basis of a source-category-specific *bottom-up* approach, i.e. the factors are determined via aggregation of plant-specific data. The aggregation was carried out at an early date, at the association level (VDZ, BDZ). The procedure approximately corresponds to the Tier 2 method of the *IPCC-GPG* (IPCC, 2001).

CO_2 emissions in the cement industry are both raw-material-related and energy-related. Raw-material-related CO_2 emissions occur during deacidification of limestone ($CaCO_3$ → $CaO + CO_2$) and account for around 60 % of total CO_2 emissions. Energy-related emissions arise during combustion of fuels and indirectly, via consumption of electrical energy.

Raw-material-related CO_2 emissions released through limestone deacidification in the cement industry were determined, pursuant to *IPCC-GPG*, using the following equation, where the emission factor itself was adjusted to take account of country-specific conditions:

CO_2 emissions = emission factor ($EF_{clinkers}$) x clinker production

The emission factor EF_{brick} depends on factors that include the burnt-limestone content of the clinkers. In Germany, dust from the exhaust gas purification process is added to clinkers. Also as a result of such dust addition, the lime content in clinkers and, thus, the emission factor $EF_{clinker}$, diverge from the IPPC's default value of 64.6 % or 0.5071 t CO_2 / t clinker. With the figures in Table 39, an average raw-material-related emission factor $EF_{clinker}$ of 0.53 t CO_2/t clinker was determined for the years 1999-2002. The figures were taken from *Environmental data of the German cement industry for 2002 (Umweltdaten der deutschen Zementindustrie 2002* - VDZ, 2002). The database was collected by BDZ and entered into the environmental data by VDZ.

Conversion of emission factors EF_{cement} (with units t CO_2/t cement) to the units t CO_2/t clinker requires a recalculation that takes the ratio of clinkers to cement (clinker factor) into account:

$EF_{clinker} = EF_{cement}$ / clinker factor.

Year-specific clinker factors were determined using the activity rates in Table 38.

Table 39: Specific CO_2 emissions from the cement industry in Germany (VDZ, 2002)

Year	Raw-material-related EF [t CO_2/t cement]	Clinker factor [t clinkers/t cement]	Raw-material-related EF [t CO_2/t clinkers]
1999	0,427	0,806	0,530
2000	0,431	0,822	0,525
2001	0,415	0,801	0,518
2002	0,413	0,778	0,531
Ø		**0,829**	**0,526**

Table 40 shows the German cement industry's raw-material-related CO_2 emissions for the years 1987 to 2002, as calculated – by way of example – using the above-described method. This calculated emission factor is applied to the entire time series.

Table 40: Raw material-related CO_2 emissions from the German cement industry

Year	Clinker production [millions of t/a]	CO_2 emissions from raw materials [10^6 t/a]
1987	29,399	15,6
1990	29,054	15,4
1991	29,096	15,4
1992	29,138	15,4
1993	29,180	15,5
1994	29,222	15,5
1995	29,072	15,4
1996	27,668	14,7
1997	28,535	15,1
1998	29,038	15,4
1999	29,462	15,6
2000	28,494	15,1
2001	25,227	13,4
2002	23,954	12,7
2003	25,233	13,4

Emission factor: 0,53 t CO_2/t cllinker

4.1.1.3 Uncertainties and time-series consistency (2.A.1)

Following conversion of activity data to surveys in the framework of CO_2 monitoring, the current status of the discussion on methods now permits near-realistic calculations in the CSE and consistent descriptions in the NIR. Uncertainties still persist in determination of activity rates, since some of the data can only be estimated, using plant data of the VDZ. The clinker factor for conversion of the emission factor EF_{cement} may also be erroneous, as a result of the uncertainties in the activity rates.

With regard to the time-series consistency, cf. also Chapter 4.1.1.6.

The uncertainties listed for the emission factors were determined via experts' judgement pursuant to Tier 1 of the IPCC GPG rules (2001: Chapter 6.3 p. 6.12). The following error

sources entered into estimation of uncertainties for the emission factor for raw-material-related CO_2 emissions:

Uncertainty in collecting and transferring data,
Uncertainty regarding the average amount of limestone used,
Uncertainty resulting from use of average values (for example, for the emission factor for raw-material-related CO_2 emissions).

4.1.1.4 Source-specific quality assurance / control and verification (2.A.1)

For the cement industry, the calculation procedure was adjusted and the bases for calculation were adapted. Previously, the data published in "Environmental data of the German cement industry" were used. In an additional review, it was found that those statistics covered only the producers registered within the association. The actual figures are higher, however. For this reason, the VDZ data provided for the CO_2 monitoring report seems more suitable for the present purposes, since it refers to the amount of cement ground from cement clinkers produced in Germany. In the interest of greater precision and unambiguity, it was decided to change the database – to use the association figures prepared for the CO_2 monitoring report, although they have been published only up to the year 2000 (with data up to 1999).

For purposes of quality assurance, all data used, including data from the BDZ, VDZ and from the literature, was checked for plausibility. The determined emission factor for raw-material-related CO_2 emissions corresponds approximately to the value that the German cement industry has repeatedly published. Furthermore, the determined emission factor for raw-material-related CO_2 emissions has been compared with the relevant figures of other countries. Good agreement was found with figures from Australia, Canada, Denmark, France, Ireland, Spain, the UK and the U.S..

In a quality review carried out by Federal Environmental Agency experts, pursuant to IPCC-GPG (2001: Chapter 2.2.3 and 8.8, p. 2.42. and 8.15, respectively), the country-specific emission factor determined for raw-material-related CO_2 emissions was compared with the IPCC Tier 1 default factor of the IPCC Reference Manual (IPCC et al, 1997: Chapter 2.3.2, p. 2.6). This comparison showed very good agreement.

4.1.1.5 Source-specific recalculations (2.A.1)

The available data is being used to establish time-series consistency for emission factors for the period 1999 to 2002. Source-specific review, along with any then necessary recalculation of emission factors for the time between 1990 and 1999, has not yet been completed. The year-specific emission factors that would be required for this are still lacking. It may be assumed, however, that during this period raw-material-related CO_2 emissions – in contrast to energy-related emissions – either were not significantly higher or were lower, with the result that the relevant emission factor remained about the same.

4.1.1.6 Planned improvements (source-specific) (2.A.1)

In the interest of better evaluation of the database, in future researchers will attempt to compile their own aggregation from the relevant raw data. To date, pre-aggregated data of the Association of German cement works (Verein Deutscher Zementwerke e.V.) has been

used for reporting. Before this procedure can be changed, however, it must be determined whether the data could be provided in such a form.

Plans now call for the revised activity data for 1987-1994 to be entered into the CSE in the near future. Before this is done, however, the interpolated values for the years 1991-93 are to be replaced, in the near term, with values determined via an engineering approach in keeping with the Good Practice Guidance. Furthermore, the emission factor for SO_2 emissions is also to be entered. To this end, relevant calculations must be made and co-ordinated in advance.

In addition, a source-specific review of the specific raw-material-related emissions for the period 1990 to 1999 is to be carried out. This is justified in that only data from the period 1999 to 2002 was used to determine the emission factor for raw-material-related CO_2 emissions. On the other hand, it is not likely that a different emission factor will have to be defined for the period 1990 to 1999.

4.1.2 Mineral products: Lime (2.A.2)

4.1.2.1 Source-category description (2.A.2)

CRF 2.A.2					
Key source by level (l) / trend (t)		**Gas (key source)**	**1990 – contribution to total emissions**	**2003 – contribution to total emissions**	**Trend**
Lime production	l / -	CO_2	0,51 %	0,53 %	Stag-nating

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor[74] (EF)	D	NO	NO	NO	NO	NO	NO	NO	NO	NE
EF uncertainties in %	+10/-30	--	--	--	--	--				
Distribution of uncertainties[75]	L	--	--	--	--	--				
Method of EF determination[76]	D	--	--	--	--	--				

In terms of its emissions levels, lime production is a key source.

In 2002 some 130 ovens for burning limestone were in operation in Germany. As Table 41 shows, lime production in 2002 amounted to 6670 kt of burnt lime. With complete deacidification (0.785 t CO_2/t burnt lime), this amount corresponds to 5236 kt of raw-material-related CO_2 emissions.

Climate-relevant gases are emitted in burning of limestone. CO_2 accounts for the great majority of these emissions. In lime production, raw-material-related CO_2 emissions occur in deacidification of calcium carbonate ($CaCO_3$) to produce burnt lime (CaO).

$$CaCO_3 + \text{heat} \rightarrow CaO + CO_2$$

Production of burnt dolomite ($CaCO_3$*$MgCO_3$ + heat → CaO*MgO) is also possible, but such production plays an insignificant role in Germany in terms of the amounts involved. These raw-material-related CO_2 emissions, therefore, were not included in the estimate.

74 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
75 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
76 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model

4.1.2.2 Methodological issues (2.A.2)

CO_2 emissions in the lime industry are both raw-material-related and energy-related. Raw-material-related CO_2 emissions, which occur during deacidification of limestone ($CaCO_3$ → $CaO + CO_2$), account for about 67 %[77] of total CO_2 emissions. Energy-related emissions, which are not reported here, arise directly, during combustion of fuels, and indirectly, via consumption of electrical energy.

Raw-material-related CO_2 emissions in the lime industry, which are released during limestone deacidification, were determined, in keeping with IPCC GPG, pursuant to the following equation:

CO_2 emissions = emission factor (EF) x burnt lime production

With regard to removal of CO_2 from the raw material, lime, in the burning process, complete deacidification is assumed. The stoichiometry of the chemical compound calcium carbonate produces a proportion by mass of 44 % CO_2 and 56 % calcium oxide. Under complete deacidification, therefore, CO_2 is released at a rate of 44/56, which corresponds to a specific emission factor of 0.785 t CO_2/t burnt lime.

Emissions are determined using aggregated, plant-specific activity rates and the stoichiometric emission factor. Activity rates are aggregated at the association level (Federal Association of the German Lime Industry; BV Kalk). The emissions data is not differentiated by various products (hard, medium, soft burn), because of a lack of data and because such differentiation is not considered necessary for leached lime. The lime-slaking process itself is not emissions-relevant. Emissions from burning of lime destined for further processing have been taken into account, however.

The above-listed stoichiometric emission factor was used to determine the raw-material-related CO_2 emissions, as listed in Table 41, for 1990 and for the period 1995-2002.

Table 41: Raw-material-related CO_2 emissions from the German lime industry

Year of reporting	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003
Production in millions of tonnes	7,50	7,80	7,19	7,29	6,97	6,98	7,16	6,82	6,67	6,86
CO_2 emissions in kt	5891	6124	5.645	5.723	5.469	5.477	5.621	5.356	5.298	5383

The activity rates determined by the BV Kalk lime-producers' association are based only on the association's member lime plants. They represent about 95 % of total production, and thus an extrapolation to fictive 100 % had to be carried out for the present purpose. The 95 % data was published in monitoring reports of the German lime industry, by Rheinisch-Westfälisch Institut für Wirtschaftsforschung (RWI, 2000), an economic research institute located in Essen; publication up to the reference year 1999 has been completed. Data for the years 2000 to 2002 was provided by the Federal Association of the German Lime Industry (Bundesverband der Deutschen Kalkindustrie).

77 This value varies in keeping with the fuels used. Pursuant to the 2000 monitoring report of the Federal Association of the German Lime Industry (Bundesverband der Deutschen Kalkindustrie), the CO_2 emission factor for fuel-induced emissions averages 0.333 t CO_2/t burnt lime. Raw-material-related CO_2 emissions thus account for 66.7 % of emissions.

4.1.2.3 Uncertainties and time-series consistency (2.A.2)

With regard to the time-series consistency, cf. Chapter 4.1.2.6.

As explained above, complete deacidification is assumed for removal of CO_2 from the raw material, lime, in the burning process,. This procedure does not take into account, however, that partial deacidification can also occur, as a result of various production conditions (oven type, burning temperature, product requirements). What is more, dolomite fractions in the raw material, along with other foreign substances, can distort CO_2-emissions data. On the other hand, in light of industry's own quality requirements with regard to its products, such impurities may be neglected with regard to CO_2 emissions. Binding of atmospheric CO_2, during use of burnt lime – for example, in mortar or filter materials – can also lead to discrepancies in CO_2-emissions values. The lime-producing industry is still unable to take account of such CO_2 fixing in its relevant balances. Some sources use fixing rates of up to 30 % in calculations. This was not taken into account in estimation of the overall error.

In addition, the raw-material-related CO_2 emissions from burning dolomite rock in Germany have not been included. With regard to total emissions, however, these emissions play a rather insignificant role, because the production amounts involved are small.

The uncertainties listed for the emission factors were determined via experts' judgement pursuant to Tier 1 of the IPCC GPG rules (IPCC, 2001: Chapter 6.3 p. 6.12). The following error sources entered into estimation of uncertainties for the emission factor for raw-material-related CO_2 emissions:

Uncertainty in collecting and transferring data,
Uncertainty with regard to the various different degrees of deacidification that were not taken into account
Uncertainty with regard to dolomite fractions and other impurities in limestone.

Uncertainties persist in determination of activity rates, since the BV Kalk association's existing plant data only support estimation of production of lime plants that are not members in BV Kalk, as a percentage of total production in the sector.

The estimates do not take account of re-fixing of CO_2 or of CO_2 emissions from burning of dolomite. This also leads to errors – errors which, however, have not entered into the estimation of uncertainties.

4.1.2.4 Source-specific quality assurance / control and verification (2.A.2)

For the lime industry, the calculation procedure was adjusted and the bases for calculation were adapted. The methodological discussion has reached a level that now permits co-ordinated calculations in the CSE and consistent descriptions in the NIR. These two aspects (calculations in the CSE and descriptions in the NIR) now have to be co-ordinated with each other, however.

For purposes of quality assurance, all data used, including data from the BV Kalk lime industry association and from the literature, was checked for plausibility. The stoichiometric emission factor for raw-material-related CO_2 emissions is in keeping with the value used by the German lime industry. Furthermore, the determined emission factor for raw-material-related CO_2 emissions has been compared with the relevant figures of other countries. Significantly, other countries' emission factors for raw-material-related CO_2 emissions are

considerably lower. Presumably, such factors take into account different degrees of product deacidification, and limestone ($CaCO_3$) is used instead of burnt lime (CaO) as the reference element for determining emissions.

4.1.2.5 Source-specific recalculations (2.A.2)

Recalculation has not yet been completed, as a result of a change in the activity data for the period between 1990 and 2002.

4.1.2.6 Planned improvements (source-specific) (2.A.2)

In addition, research is to be carried out to determine the extent to which the calculation procedure needs to be adapted, and can be adapted, to the actual emissions situation (for example, with regard to different product groups or degrees of deacidification). Such adaptation would affect the emission factor. If such a breakdown of product statistics is feasible, it must be determined whether the CSE time series can be retroactively adjusted or whether the calculation procedure must be converted for future reporting.

The activity rates provided by the BV Kalk lime industry association, some of which have not yet been published, have been assessed as plausible with regard to necessary extrapolation to 100 %. Of course, it would be preferable to be able to rely solely on published data in future. The next steps must be decided within the framework of the National System.

At the same time, the BV Kalk industry association's figures for total share of German lime production need to be re-examined. It must be reviewed whether a year-specific share could be determined in retrospect. The time series in the CSE could then be retroactively adapted. The effects of such a measure are expected to be slight, however.

The quality of the uncertainties estimation is to be improved.

For future reporting, plans call for emissions from burning of dolomite to be estimated as well, even though these emissions are assumed to be less significant.

4.1.3 Mineral products: Limestone and dolomite use (2.A.3)

Emissions from this source category are currently not being reported.

Germany is planning to calculate this source category's emissions for the 2006 report. Plans also call for methodically describing all limestone and dolomite use and linking this use with specific emission factors. In this source category, a balance of all production and use outside of 2.A.2 is to be prepared, and relevant comparisons with other source categories are to be carried out.

4.1.3.1 Source-category description (2.A.3)

4.1.3.2 Methodological issues (2.A.3)

4.1.3.3 Uncertainties and time-series consistency (2.A.3)

4.1.3.4 Source-specific quality assurance / control and verification (2.A.3)

4.1.3.5 Source-specific recalculations (2.A.3)

4.1.3.6 Planned improvements (source-specific) (2.A.3)

4.1.4 Mineral products: Soda ash production and use (2.A.4)

4.1.4.1 Source-category description (2.A.4)

CRF 2.A.4					
Key source by level (l) / trend (t)		**Gas (key source)**	**1990 – contribution to total emissions**	**2003 – contribution to total emissions**	**Trend**
	- / -				

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor[78] (EF)	CS	NO	NO	NO	NO	NO	NO	NO	NO	NO
EF uncertainties in %										
Distribution of uncertainties[79]										
Method of EF determination[80]										

The source category "Soda ash production and use" (2.A.4) is not a key source.

In Germany, soda ash is produced only chemically. The country has 3 production facilities, all of which use the Solvay process. With respect to the calcium carbonate it uses, this process is CO_2-neutral, since the carbon dioxide in the limestone is bound within the product, soda ash (Na_2CO_3), and is released only during product use.

On the other hand, coke is used in the calcination part of the process, and this produces additional carbon-dioxide emissions. It is assumed that about 100 kg of coke are used per tonne of soda ash; this figure was determined in a research project in the framework of preparation of BVT information sheets (UBA: German Notes on BAT for the production of Large Volume Solid Inorganic Chemicals – Soda, 2001).

4.1.4.2 Methodological issues (2.A.4)

The figure of about 100 kg of coke per tonne of soda, in connection with the relevant stoichiometric conversion factor (44/12), produces the following emission factor:

$$EF = 103.6 \times (44/12) = 380 \text{ kg } CO_2 / \text{t soda.}$$

78 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
79 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
80 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model

The Federal Statistical Office (DESTATIS) determines the total amounts of soda ash produced in Germany. Since 1995, the sum total has comprised the categories of light soda and heavy soda (production numbers – 2413 33 103, disodium carbonate in powder form, with a fill density of less than 700 g/l; and 2413 33 109, other disodium carbonate). Of these amounts, only the portion "intended for sale" – and not the entire amount produced – is taken into account. This prevents double-counting, since heavy soda is produced from light soda (agreement between DESTATIS and the manufacturers). Only estimated figures are available for production in the new German Länder until 1994.

4.1.4.3 Uncertainties and time-series consistency (2.A.4)

There are uncertainties regarding the production statistics given by DESTATIS, since – for example – the relation between light and heavy soda fluctuates widely, especially in the first years for which separate statistics are provided.

Consistency is not complete, due to the described need to estimate production amounts in the new German Länder. What is more, a break in time-series consistency may be presumed: initially, sales comprised nearly all of the total amount produced; in 1995, when production statistics were changed, sales dropped to about 2/3 of total production, however, and now they account for only about 50 % of production.

4.1.4.4 Source-specific quality assurance / control and verification (2.A.4)

Measures for standardisation of QC/QA are currently being prepared.

4.1.4.5 Source-specific recalculations (2.A.4)

No source-specific recalculations have been carried out to date, since this source category is a new addition.

4.1.4.6 Planned improvements (source-specific) (2.A.4)

No improvements are planned at present.

4.1.5 Mineral products: Asphalt roofing (2.A.5)

Emissions from this source category are currently not being reported.

Germany is planning to calculate this source category's emissions for the 2006 report. In earlier report tables, the error was made of reporting produced amounts of mixed asphalt, due to difficulties in allocation. The current report does not provide any pertinent data; the data survey for this source category is currently underway. The emissions are to be calculated on the basis of the new activity data and specific emission factors. Calculation of the emissions is expected to make it possible to assess this source category's relevance with regard to greenhouse-gas emissions.

4.1.5.1 Source-category description (2.A.5)

4.1.5.2 Methodological issues (2.A.5)

4.1.5.3 Uncertainties and time-series consistency (2.A.5)

4.1.5.4 Source-specific quality assurance / control and verification (2.A.5)

4.1.5.5 Source-specific recalculations (2.A.5)

4.1.5.6 Planned improvements (source-specific) (2.A.5)

4.1.6 Mineral products: Road paving with asphalt (2.A.6)

Currently, the report tables list produced amounts of mixed asphalt products and only NMVOC emissions. Plans call for describing "road paving with asphalt" methodically and then linking this area with specific emission factors for additional greenhouse gases. Calculation of the emissions is expected to make it possible to assess this source category's relevance with regard to greenhouse-gas emissions.

4.1.6.1 Source-category description (2.A.6)

4.1.6.2 Methodological issues (2.A.6)

4.1.6.3 Uncertainties and time-series consistency (2.A.6)

4.1.6.4 Source-specific quality assurance / control and verification (2.A.6)

4.1.6.5 Source-specific recalculations (2.A.6)

4.1.6.6 Planned improvements (source-specific) (2.A.6)

4.1.7 Mineral products: Other – glass industry (2.A.7)

Emissions of CO_2, N_2O and SO_2 are reported. A review of existing calculation procedures, and description of the resulting calculation methods, are planned.

4.1.7.1 Source-category description (2.A.7)

4.1.7.2 Methodological issues (2.A.7)

4.1.7.3 Uncertainties and time-series consistency (2.A.7)

4.1.7.4 Source-specific quality assurance / control and verification (2.A.7)

4.1.7.5 Source-specific recalculations (2.A.7)

4.1.7.6 Planned improvements (source-specific) (2.A.7)

4.2 Chemical industry (2.B)

Source category 2.B is sub-divided into sub-categories 2.B.1 through 2.B.5. These include ammonia production (2.B.1), nitric acid production (2.B.2), adipic acid production (2.B.3) and carbide production (2.B.4).

In the CSE, sub-category Other (2.B.5) includes fertiliser and nitrous oxide production, organic products, soot and titanium-oxide production and sulphuric acid production.

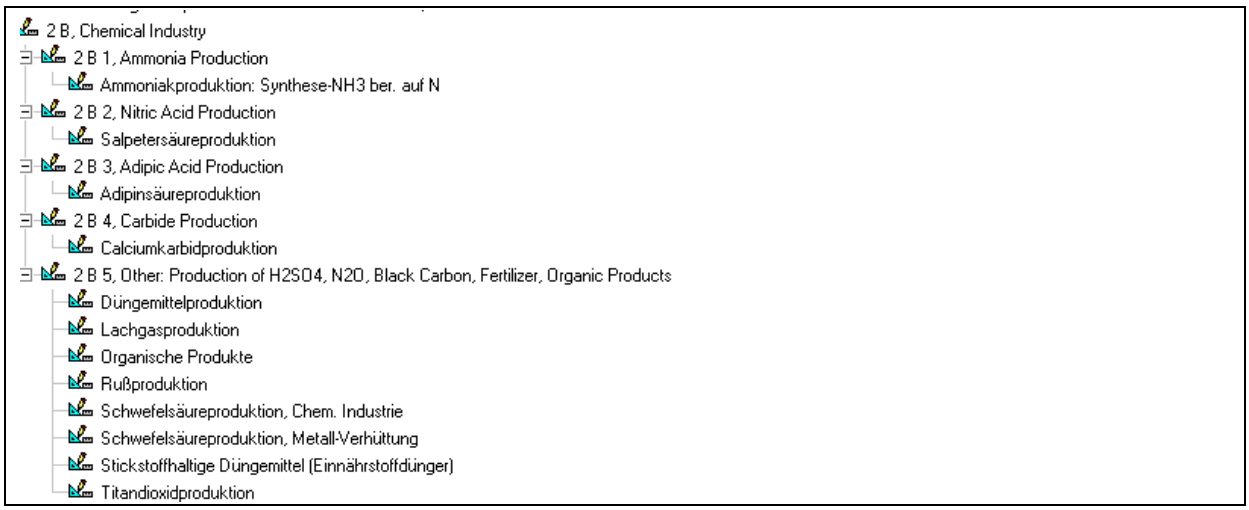


Figure 37: Structural allocation, 2.B Chemical industry

4.2.1 Chemical industry: Ammonia production (2.B.1)

4.2.1.1 Source-category description (2.B.1)

CRF 2.B.1					
Key source by level (l) / trend (t)		**Gas (key source)**	**1990 – contribution to total emissions**	**2003 – contribution to total emissions**	**Trend**
	- / -				

Gas	CO_2	CH_4	HFCs	PFCs	SF_6	N_2O	NO_X	CO	NMVOC	SO_2
Emission factor[81] (EF)	CS	NO	NO	NO	NO	NO	CS	NO	NO	NO
EF uncertainties in %										
Distribution of uncertainties[82]										
Method of EF determination[83]										

The source category "Ammonia production" (2.B.1) is not a key source.

Ammonia is produced on a basis of hydrogen and nitrogen, using the Haber-Bosch procedure. Hydrogen is obtained from synthetic gas. It is generated in a highly integrated procedure within a steam reforming process, generally on the basis of natural gas. Nitrogen is provided by the decomposition of air.

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, a distinction is made between the following processes:

ACP - Advanced Conventional Process with a fired primary reformer and secondary reforming with excess air (stoichiometric H/N ratio)

RPR - Reduced Primary Reformer Process under mild conditions in a fired primary reformer and 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 fractions of heavy mineral oil or vacuum residues in production of synthetic gas

Most plants operate according to the steam-reforming principle, with naphtha or natural gas. Only 3 % of European plants use the partial oxidation procedure.

The more than 15 % decrease in production (corresponding to an amount of about 400 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. The reasons for the re-increase as of 1995, to the 1990 level, are not understood; the re-increase may be due to a change in statistical survey methods, however. After 1990, production levels fluctuated only slightly. In 2003, production increased noticeably – by 9 % - over the previous year.

81 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
82 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
83 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model

4.2.1.2 Methodological issues (2.B.1)

Carbon dioxide emissions are dependent upon the quantity and composition of the input materials. It can be assumed that all the carbon involved is converted into carbon dioxide and will be emitted into the air sooner or later.

In Germany, carbon dioxide is converted into urea at three production sites. At one site, part of the carbon dioxide is filled into bottles for selling. In all cases, however, subsequent emission of carbon dioxide into the air is inevitable.

The emissions are calculated as follows:

Emission (kt) = Ammonia production quantity (kt) x emission factor (kt/kt)

At present, only two of six ammonia-production facilities in Germany use the partial oxidation process. For this reason, the higher emission factor, 1.5 kg CO_2/t, which is proposed as the default value and which presumably should be applied to this process, is not considered representative, and a lower EF is used – 0.69 kg CO_2/t ammonia nitrogen. The facilities in question account for a 33 % share of all facilities. Assuming that the facilities in question have a similar share of total production, this emission factor is on the order of the default value (0.69 kg/t / (17/14) x 0.33 = 1.7 kg/t).

Natural gas is used both as a fuel and as a raw material. It remains to be determined what amount of natural gas Germany's energy balance includes under "non-energy-related consumption".

The amount of ammonia produced in Germany is determined by the Federal Statistical Office (DESTATIS, Fachserie (technical series) 4 Reihe 3.1, 1991-2004). Since the relevant figures are normed to nitrogen content, the above-mentioned emission factor includes a stoichiometric factor of (17/14). Total production comprises "Ammonia, water-free" ("Ammoniak wasserfrei" (Melde Nr. (reporting number) 4142 00 until 1994 and, as of 1995, 2415 10 750), which is far and away the largest component, and "Ammonia in aqueous solution" ("Ammoniak in wässriger Lösung", Melde Nr. 4144 00 until 1994 and, as of 1995, 2415 10 770).

The emission factor for NO_X depends on the type of production in question. The Federal Environmental Agency's internal estimates are 1.1 kg NO_X/t NH_3 for partial oxidation and 0.32 to 0.175 kg NO_X/t NH_3 for steam reforming (with the specific figure depending on what process variation is used). For purposes of emissions calculation, the average for all types of production is assumed to be decreasing over time – from 0.45 kg NO_X/t N in 1990 to only 0.3 kg NO_X/t N in 2010. The interim-year figures used for emissions calculation were interpolated.

4.2.1.3 Uncertainties and time-series consistency (2.B.1)

The CO_2-emission factor is only an average value that, given the various different production conditions involved, cannot fully and precisely reflect the actual situation.

The NO_X-emission factor is also only an average value that, given the various different production conditions involved, cannot fully and precisely reflect the actual situation. This restriction applies all the more for the interpolated figures used for the interim years.

The small production share for "Ammonia in aqueous solution" is secret for several of the years in question. For 1999, this share was estimated on the basis of ratios in neighbouring years, taking the production amounts for "Ammonia, water-free" into account. Among the years 1990 to 1994, only 1993 has a non-secret production figure; this figure was not used for the 4 other years.

It is possible that a change in statistical survey methods, effected from 1994 to 1995, caused an apparent production increase of about 400 kt.

4.2.1.4 Source-specific quality assurance / control and verification (2.B.1)

Measures for standardisation of QC and QA are currently being established.

4.2.1.5 Source-specific recalculations (2.B.1)

Source-specific recalculations were carried out for the listed production amounts, which were previously rounded to the nearest 1000 tonnes. Figures in tonnes are now used for the entire period covered by the report.

The 2000 production figure for "Ammonia, water-free", as used in the previous inventory report, has been corrected on the basis of an updated statistic of the Federal Statistical Office; in addition, several previously rounded figures have been specified more precisely.

4.2.1.6 Planned improvements (source-specific) (2.B.1)

An ongoing research project of the University Utrecht, using the NEAT model (Non-energy Emission Accounting Tables; WEISS, PATEL, n.d.) is studying the extent to which CO_2 emissions occur during non-energy-related consumption during product use and within industrial processes. The project is expected to yield insights regarding how much natural gas for ammonia production the Federal Republic of Germany's energy balance includes under non-energy-related consumption.

Since there are only 6 ammonia manufacturers in Germany, an effort is being made to have the manufacturers directly report their carbon-dioxide and NO_X emissions.

4.2.2 Chemical industry: Nitric acid production (2.B.2)

4.2.2.1 Source-category description (2.B.2)

CRF 2.B.2					
Key source by level (l) / trend (t)		**Gas (key source)**	**1990 – contribution to total emissions**	**2003 – contribution to total emissions**	**Trend**
Nitric acid production	l / t	N_2O	0,38 %	0,65 %	rising

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor[84] (EF)	NO	NO	NO	NO	NO	CS	CS	NO	NO	NO
EF uncertainties in %										
Distribution of uncertainties[85]										
Method of EF determination[86]										

The source category "Nitric acid production" (2.B.2) is a key source in terms of both emissions level and trend.

In production of nitric acid, nitrous oxide occurs in a secondary reaction. In Germany, there are currently only six plants for the production of nitric acid.

HNO_3 production occurs in two process stages:

a) **Oxidation** of NH_3 to NO and

b) **Conversion** of NO to NO_2 and **adsorption** 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 related reaction, according to the Oswald 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.

84 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
85 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
86 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model

4.2.2.2 Methodological issues (2.B 2)

The **activity data** is taken from the Federal Statistical Office (DESTATIS, Fachserie 4, Reihe 3.1: manufacturing sector, production within the manufacturing sector). In general, the cited figures for nitric-acid production are normed to N and are stoichiometrically converted (*63/14), by the Federal Environmental Agency, from N to HNO_3. Since no consistent time series are available, several adaptations had to be made:

Production figures are available for the old German Länder for 1990-1992 and for 1991-1992 for the new German Länder (Melde-Nr. (reporting number) 4123 10). The 1990 production figure for the new German Länder was not available and has been estimated.

Beginning in 1993, production figures are no longer listed separately for the new and old German Länder; for this reason, the 1993 and 1994 figures for the new and old German Länder were determined in keeping with the relevant regions' share of total production in 1992.

For 1995-2001, following conversion of federal statistics, the nitric-acid production figures of Melde-Nr. 2415 10 503, which are still normed to N, are used. Since 2002, the Federal Statistical Office no longer lists this position individually; instead, it lists as part of a sum under Melde-Nr. 2415 10 500 (nitric acid, nitrating acids). For estimation of the relevant share for nitric acid, this sum value is multiplied with nitric acid's share of this sum value in 2001 (0.693).

In 2003, production increased by nearly 2/3 over the 2002 level. Upon enquiry, the Federal Statistical Office attributed this extraordinarily large production increase to the appearance of two additional manufacturers.

The existing data for N_2O is based on measurements. The **emissions** depend on the technological situation and operating conditions, and they vary extensively from one plant to another, and even vary within the same plant. A detailed consideration of the IPCC requirements relative to emissions calculation is provided in the Annex (Chapter 14.2.2.1.1).

Since 1990, the N_2O emission factor used has been consistently given as 5.5 kg N_2O/t HNO_3. In the underlying research project from 1993 (Schön, Waltz et al, 1993), it is assumed, however, that 283 kg NH_3/t HNO_3 are used for production of nitric acid, and that some 1.5 % of this ammonia are converted into N_2O. A check calculation using industry figures (3120 m^3 waste gas/t HNO_3 and 500-1000 ppm N_2O) confirmed the above emission factor, in terms of order of magnitude, by yielding 3.1-6.2 kg N_2O/t HNO_3.

NO_x emissions figures for the entire period are based on UBA-specific emission factors that have decreased strongly over time. This trend is based on a forecast for 2010 pursuant to which in that year the average specific emissions will be on the order of those of state-of-the-art plants in 1997 (0.75 kg/t).

At present, no emission factors from plant data are available.

As of 2010, old plants may no longer exceed the applicable emissions standard, from TA Luft 2002, of 800 mg N_2O/m^3.

Table 42: N_2O and NO_x emission factors from nitric acid production

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
N_2O [kg/Mg]	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5	5,5
NO_x [kg/Mg]	7,9	6,6	5,0	3,7	3,0	2,5	2,1	1,8	1,6	1,5	1,4	1,35	1,29

This EF is likely to decrease further as a result of the above-announced emissions limit for N_2O.

The 2002 emission factors have been used for the emissions calculation for 2003.

Table 43: N_2O and NO_x emissions from nitric acid production

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
N_2O [Gg]	15,1	12,0	11,0	11,0	11,1	12,7	12,1	12,1	12,0	12,5	13,4	11,8	12,9	21,3
NO_x [Gg]	21,7	14,3	10,1	7,3	6,1	5,8	4,6	4,0	3,5	3,4	3,4	2,9	3,0	5,0

4.2.2.3 Uncertainties and time-series consistency (2.B.2)

No uncertainties for activity rates and emission factors have been determined to date.

The emissions-determination process normally requires not only the produced amount sold; it also requires the entire produced amount, including amounts directly processed further within the plant. On the basis of the supposition that a significant portion of production is not sold, it must be determined whether production statistics include produced amounts that do not enter the market. Furthermore, it must be verified whether the Federal Statistical Office takes all plants into account. The Federal Statistical Office's combined listing of nitric acid and nitrating acid as of 2002 should be reviewed.

4.2.2.4 Source-specific quality assurance / control and verification (2.B.2)

A standardised procedure for quality assurance in emissions calculations is currently being established. In addition, it must be determined what QC/QA measures are already in place for the available data sources, and what such measures could be introduced.

4.2.2.5 Source-specific recalculations (2.B.2)

Source-specific recalculations were carried out for listed production amounts, which were previously rounded to the nearest 1000 tonnes. Now figures in tonnes are also used for the years 1990 to 1994.

4.2.2.6 Planned improvements (source-specific) (2.B.2)

Where no emissions measurements for specific plant types are available, but activity rates are available for emission factors, adequate country-specific emission factors should be derived on the basis of the default values from the guidelines. For derivation of emission factors, it is necessary to know whether the activity rates have the same degree of differentiation that the emission factors have. Aggregations should be carried out only where detailed activity rates are lacking for the relevant individual types.

In 2010, all existing plants in Germany must meet the requirements of the Clean Air Directive (TA Luft 2002). The limit of 800 mg/m^3 for N_2O emissions can be met by installing a catalytic reducer. Against this background, it will become possible to obtain more precise emission factors.

N_2O emissions from nitric acid production were a topic considered by one of the working groups at the 1st Workshop on the National System of Emissions Inventories, held in Berlin on 8 and 9 November 2004. The relevant technical body of the Chemical Industry Association (Verband der Chemischen Industrie) has agreed to review the cited issues and will follow-up with a written response.

4.2.3 Chemical industry: Adipic acid production (2.B.3)

4.2.3.1 Source-category description (2.B.3)

CRF 2.B.3					
Key source by level (l) / trend (t)		**Gas (key source)**	**1990 – contribution to total emissions**	**2003 – contribution to total emissions**	**Trend**
Adipic acid production	l / t	N_2O	1,51 %	0,37 %	falling

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor[87] (EF)	NO	NO	NO	NO	NO	D, PS	NE	NE	NE	NO
EF uncertainties in %										
Distribution of uncertainties[88]										
Method of EF determination[89]										

Adipic acid production is a key source in terms of emissions level and trend.

The IPCC has not specified any methods for calculating N_2O emissions from adipic acid production. As the description below indicates, the method used to determine the EF for N_2O may certainly be considered adequate for the Tier 3 approach.

On an industrial scale, adipic acid is produced via oxidation of a mixture of cyclohexanol and cyclohexanone (ratio: 93/7). Pursuant to IPCC-GPG (2000: Tab. 3.7, note a), only one facility, a facility in Japan, is presumed to use pure cyclohexanol (EF there is 264 kg/t); at other facilities, production uses ketone, in various amounts, along with nitric acid. In this 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 patented, and put into operation, a system for thermal decomposition of nitrous oxide into nitrogen and oxygen. Decomposition takes place nearly completely. At the end of 1997, the other producer put a catalytic reactor system into operation that, in constant operation, achieves a N_2O-decomposition rate of 96-98%. In March 2002, operations were begun with a plant, from another producer, that also uses thermal N_2O decomposition. Following initial technical problems, the system has been in constant operation since 2003.

Production fluctuates by up to one-fourth from year to year, depending on the manufacturer. Overall, production has increased markedly since 1990, and in recent years, production increases have repeatedly exceeded 50%.

87 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
88 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
89 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model

4.2.3.2 Methodological issues (2.B.3)

Until around the mid-1990s, producers provided data only on amounts produced. The IPCC default emission factors were used to calculate nitrous oxide emissions for this period. For the period following, manufacturers confidentially reported their N_2O emissions, with necessary background information, along with their production figures. This fact is highly significant with regard to the precision of the reported data; without data on technically unavoidable N_2O production, and – especially – without information as to the operating period of the relevant decomposition facilities, estimates of the reduction in nitrous oxide emissions would have been so imprecise that it would have been necessary to continue using the default EF.

The fluctuations in the emissions data are the result of disruptions of emissions-reduction systems (maintenance work, fire damage, other failure of system components).

The IPCC also lists default EF for NO_X, NMVOC and CO. These values either are questioned by manufacturers or cannot be quantified, since the relevant gas flow is combined with that from HNO_3 production. Since additional information is to be gathered in this regard, the default EF are currently not being used.

4.2.3.3 Uncertainties and time-series consistency (2.B.3)

The uncertainties in time-series consistency have been eliminated, since all manufacturers now provide the relevant data. Corresponding uncertainties result from the IPCC emission factor range of +/- 10 % that was used from 1990 until 1996 (in part).

4.2.3.4 Source-specific quality assurance / control and verification (2.B.3)

Manufacturers' reported data is accorded 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 should be noted, however, that manufacturers have also provided some of the figures used to licensing authorities.

Measures for standardisation of QC/QA are currently being established.

4.2.3.5 Source-specific recalculations (2.B.3)

One manufacturer's data that was lacking for the period since the manufacturer's emissions-reduction facility was commissioned in 1994 has been provided, and relevant source-specific recalculations have been carried out as a result.

4.2.3.6 Planned improvements (source-specific) (2.B.3)

Since all manufacturers now provide the relevant data, no improvements are planned with regard to N_2O. With regard to calculation of NO_X, NMVOC and CO emissions, an effort is being made to obtain useful information from manufacturers.

4.2.4 Chemical industry: Carbide production (2.B.4)

4.2.4.1 Source-category description (2.B.4)

CRF 2.B.5					
Key source by level (l) / trend (t)		**Gas (key source)**	**1990 – contribution to total emissions**	**2003 – contribution to total emissions**	**Trend**
	- / -				

Gas	CO_2	CH_4	HFCs	PFCs	SF_6	N_2O	NO_X	CO	NMVOC	SO_2
Emission factor CaC_2	PS	NO	NO	NO	NO	NO	NO	NO	NO	NO
Emission factor SiC	NE	NE	NO	NO	NO	NO	NO	NO	NO	NO
EF uncertainties in %										
Distribution of uncertainties[90]										
Method of EF determination[91]										

The source category "Carbide production" (2.B.4) is not a key source.

During the reunification period, carbide production took place primarily in the new German Länder. A short time later, production there was discontinued, while only one manufacturer remained the old German Länder. In the period under consideration until 2003, this manufacturer cut his production by about half.

4.2.4.2 Methodological issues (2.B.4)

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.

With covered ovens, manufacturers collect all of the carbon monoxide produced in the process and recycle it for further use. Following such use for energy recovery – i.e. following its combustion to produce carbon dioxide – it serves as an auxiliary substance for production of lime nitrogen and secondary products. Reactions in these processes yield carbon dioxide in mineral form, as black chalk. In this form, it is used in agriculture.

As a result, production in the old German Länder achieves a substantially lower emission factor for carbon dioxide from calcium carbide production.

Upon request, the relevant manufacturer provides the Federal Environmental Agency with data on the degree of reduction achieved – and, thus, on the emission factor involved – and on amounts produced. The total emissions are calculated as the product of activity rate and emission factor.

Since Germany has only one manufacturer, the relevant data must be kept confidential. The only published data consists of that for amounts produced in the former GDR; this data was published, until 1989, by that country's statistical authority. That data, together with existing estimates for 1991 and 1992, has been used to interpolate the production in the new German Länder for 1990.

90 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
91 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model

Carbon dioxide emissions from silicon-carbide production are considered low and are not surveyed. Within the "Carbide" group (2413 54 500), the Federal Statistical Office does not publish any production data that is broken down by sub- source categories (cf. DESTATIS, Fachserie 4 Reihe 3.1, 1991-2004). For this reason, it was not possible to estimate these amounts for application of the Tier 1b method. With regard to the Tier 1a method, this also applies to data on petroleum-coke use.

4.2.4.3 Uncertainties and time-series consistency (2.B.4)

Consistency is not complete, due to the described need to estimate production amounts in the new German Länder.

The uncertainties relative to the data provided by the manufacturer are considered slight overall. On the other hand, the assumed reduction rate of 80% should probably be considered an average value for the time period in question, and the manufacturer has already indicated that even higher reduction rates were achieved in recent years. Before making any use of such lower EF for recalculation, the Federal Environmental Agency will review the data in question, however.

4.2.4.4 Source-specific quality assurance / control and verification (2.B.4)

Manufacturers' 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.

Measures for standardisation of QC/QA are currently being established.

4.2.4.5 Source-specific recalculations (2.B.4)

No source-specific recalculations have been carried out to date, since this source category is a new addition.

No revision of manufacturers' figures is expected. Neither is any recalculation of the production figures for the three reference years in the new German Länder expected.

4.2.4.6 Planned improvements (source-specific) (2.B.4)

No improvements are planned at present.

4.2.5 Chemical industry: Methane emissions from other production processes (2.B.5)

4.2.5.1 Source-category description (2.B.5)

CRF 2.B.5					
Key source by level (l) / trend (t)		**Gas (key source)**	**1990 – contribution to total emissions**	**2003 – contribution to total emissions**	**Trend**
	- / -				

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor[92] (EF) Soot	NO	D	NO	NO	NO	NO	NO	CS	NO	CS
Emission factor[93] (EF) Ethylene, styrene	NO	D	NO	NO	NO	NO	NO	NO	CS	NO
Emission factor[94] (EF) Methanol, ethylene dichloride	NO	D	NO	NO	NO	NO	NO	NO	NO	NO
EF uncertainties in %										
Distribution of uncertainties[95]										
Method of EF determination[96]										

The source category "Methane emissions from other production processes" (2.B.5) is not a key source.

Various chemical production processes, such as production of soot, ethylene (ethene), ethylene dichloride (1,2-dichloroethane), styrene and methanol, are potential sources of NMVOC emissions and methane emissions. CH_4 can occur as a secondary product of industrial processes and then be emitted into the atmosphere. To date, the German greenhouse-gas inventory has not taken all such sources into account.

4.2.5.2 Methodological issues (2.B.5)

The international guidelines give very little attention to this source category. The IPCC Guidelines list as potential emissions sources – without any claim to completeness – production of soot, ethylene, dichloroethylene (presumably, ethylene dichloride is meant; see the remark under footnote **Fehler! Textmarke nicht definiert.**), styrene and methanol. The guidelines list emission factors for the processes that were identified in studies from 1987 and 1988: These IPCC default EF are listed in Table 44 below.

Table 44: IPCC default emission factors ([kg CH_4 / t]) for CH_4 from other chemical industry processes

Soot	**Styrene**	**Ethylene**	**Ethylene dichloride[97]**	**Methanol**
11	4	1	0,4	2

The IPCC Good Practice Guidance does not discuss this subject further.

92 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
93 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
94 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
95 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
96 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model
97 Remark: In this IPCC table (Workbook p. 2.22, Tab. 2-9 and Reference Manual p. 2.23, Tab. 2-10), dichloroethylene has been replaced with ethylene dichloride (1,2–dichloroethane). This seems appropriate, since the relevant subsequent tables (2-10 and 2-11) list only "1,2, dichloroethane" and since the source listed by the IPCC Reference Manual on p. 2.67, Stockton et al., p. 49, also speaks of the substance "ethylene dichloride".

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/m³ (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. For this reason, it is assumed that the German emission factors are also considerably lower than the listed default values.

For pollutants other than the methane considered above, the emission factors listed in Table 45 were used for Germany.

Table 45: Emission factors used in Germany for other pollutants

	Soot [kg CO / t]	**Soot [kg SO_2 / t]**[98]	**Ethylene** [kg NMVOC / t]	**Styrene** [kg NMVOC / t]
1990	4,8 / 5	19,5 /[99]	5	0,25
1991	4,6 / 5	19 / 20	5	0,25
1992	4,4 / 5	18,5 / 20	5	0,25
1993	4,2	18	5	0,25
1994	4	17,5	5	0,25
1995	3,75	17	5	0,25
1996	3,5	16	5	0,25
1997	3,25	15	5	0,25
1998	3	14	5	0,25
1999	2,9	13,4	5	0,25
2000	2,8	12,8	5	0,25
2001	2,7	12,54	5	0,25
2002	2,6	12,28	5	0,25
2003	2,6	12,28	5	0,25

The figures for NMVOC were taken from the European Commission (1994). The EF for CO and SO_2 in soot production are based on assumptions of the responsible Federal Environmental Agency expert, although for the time being continued use of the 2002 EF in 2003 is required.

The production statistics of the Federal Statistical Office (DESTATIS) include the following products (Table 46).

Table 46: Reporting numbers (Meldenummern) from production statistics

Production	**Methanol**	**1,2 - dichloroethane**	**Soot**	**Ethylene**	**Styrene**
- 1994	4232 11	4228 22	4113 70	4221 11	4224 60
as of 1995	2414 22 100	2414 13 530	2413 11 300	2414 11 300	2414 12 500

Most of the following activity rates were taken from production statistics.

[98] Where two EF are listed, the second figure refers to the new German Länder.
[99] No EF is listed for the new German Länder, since these SO_2 emissions can be taken account of only as a lump sum.

Table 47: Activity rates of methanol, 1,2-dichloroethane, soot, ethylene and styrene [t]

Production		Methanol	1,2 - dichloroethane (Ethylene dichloride)	Soot	Ethylene	Styrene
Year	Area					
1990	**D**	**1266239**		**401365**	**3071829**	**1289781**
	ABL	751083	1504577	394365	3071829	1289781
	NBL	515156		7000		
1991	**D**	**1231541**		**381561**	**3059474**	**1208046**
	ABL	716385	1306091	379561	3059474	1208046
	NBL	515156		2000		
1992	**D**	**1290994**		**377384**	**3335942**	**1130836**
	ABL	768831	1512774	376384	3335942	1130836
	NBL	522163		1000		
1993	**D**	**1202189**	**1654694**	**334620**	**3904814**	**1041505**
1994	**D**	**1438327**	**1881032**	**299000**	**4182722**	**1150723**
1995	**D**	**1425795**	**1796930**	**330799**	**4163377**	**1080531**
1996	**D**	**1546958**	**1887791**	**315587**	**3814680**	**1151244**
1997	**D**	**1409850**	**2278858**	**337579**	**4186421**	**1099974**
1998	**D**	**1596258**	**2528542**	**343319**	**4269586**	**1182697**
1999	**D**	**1533113**	**2806415**	**338542**	**4894764**	**1096934**
2000	**D**	**1886429**	**2902378**	**345976**	**5119316**	**1089573**
2001	**D**	**1921680**	**2597093**	**348371**	**5005029**	**957750**
2002	**D**	**1843285**	**3188715**	**338592**	**4944099**	**960561**
2003	**D**	**2008075**	**3184280**	**348318**	**5258006**	**1226236**

D: Germany; ABL: Old German Länder; NBL: New German Länder (ABL/NBL only 1990-1992)

The figure for soot production in the new German Länder in 1990 was taken from the Statistical Yearbook (Statistisches Jahrbuch) for the Federal Republic of Germany (1992a: p. 234); the figures for 1991 and 1992 were estimated, due to confidentiality requirements. The other data for soot production, and for production of ethene, styrene, methanol and 1,2 dichloroethane as of 1990, were provided by the Federal Statistical Office (DESTATIS, Fachserie 4, Reihe 3.1, 1991-2004: manufacturing sector, production within the manufacturing sector).

The reasons for the production fluctuations during the period under consideration are unknown.

4.2.5.3 Uncertainties and time-series consistency (2.B.5)

An emission factor for organic substances (VOC) of 0.066 – 1.0 g/t was determined for one facility in Germany that produces 1,2-dichloroethane. These values are lower, by a factor of 6000 to 400, than the IPCC's default emission factor for CH_4 by itself. Deviations of this order are also likely for the other substances in question. The NaSE workshop of November 2004 is expected to provide more precise data.

Fluctuations in the activity rates have occurred over the period under consideration. The reasons for this are unknown. Since the amounts produced – apart from a few insignificant estimates – have come from a trustworthy source, the pertinent uncertainties may be considered small. Corrections to manufacturers' figures might be made within a three-year period, however. In spite of the survey changes that have occurred within the period under consideration, the data is considered to be consistent.

4.2.5.4 Source-specific quality assurance / control and verification (2.B.5)

The following figures, from inventory reports of other countries, could provide information relative to the EF that should be used for Germany:

Japan:

From representative waste-gas measurements, EF were formed that, in some cases, are more than 30 to 80 times smaller than the IPCC defaults. This is due to reduction measures (methane recovery, flaring) that, presumably, have not yet been taken into account in the IPCC defaults.

Portugal:

This country's EF for soot production, which is 25 % below the IPCC default, was obtained from measurements made in 1990-94 at the country's sole producer.

No source-specific quality assurance / control and verification has been carried out to date.

4.2.5.5 Source-specific recalculations (2.B.5)

Source-specific recalculations were carried out for soot production for the period 1990 to 1994, because the values given by the Statistical Yearbook (Statistisches Jahrbuch), which are rounded to the nearest 1000 tonnes, have been replaced by more precise figures (in tonnes) from production statistics.

In addition, for the first time ethylene dichloride (1,2-dichloroethane) and methanol have also been taken into account – along with the products soot, ethylene (ethene) and styrene, which the calculations already covered – with the result that all five production processes cited by the Guidelines as potential methane sources are covered for the entire relevant period.

4.2.5.6 Planned improvements (source-specific) (2.B.5)

Since the IPCC guidelines do not list all chemical industry processes, it should be determined whether other relevant areas emit significant amounts of methane and, if this is the case, the availability of data for these areas should be reviewed.

The NaSE workshop of November 2004 and follow-up discussions with industry associations are expected to provide indications in this connection.

It must be determined whether the IPCC default emission factors used are representative for Germany or should be replaced with other national emission factors.

4.3 Metal production (2.C)

Source category 2.C is sub-divided into sub-categories 2.C.1 through 2.C.5. In the CSE, sub-category Iron and steel production (2.C.1) includes iron and steel production and tempered castings, pig-iron production, sinter production and steel products. Production of ferroalloys (2.C.2) is listed directly as such in the CSE. 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.5) is not further sub-divided. In the CSE, sub-category Other (2.C.5) includes lead production, thermal galvanisation, copper production and zinc production.

Figure 38: Structural allocation, 2.C Metal production

4.3.1 Metal production: Iron and steel production (2.C.1)

The currently determined total CO_2 emissions of the iron and steel industry have customarily been reported in Sector 1.A.2 and, as top-gas use, under 1.A.1.a and 1.A.1.c. Since the existing approach does not conform to the IPCC Guidelines, however, as of 2006 process-related emissions – initially, for für CO_2 – will be reported under 2.C.1, in keeping with the requirements of the IPCC Guidelines (Reference Manual, 1996b: p. 2.26 ff) and the IPCC Good Practice Guidance (2000: p. 3.25 ff), and in the Annex (Chapter 14.2.3.1). As a result, in future it will also be necessary to check the sectors 1.A.2.a and 2.C.1 against each other – i.e. the CO_2 inventories then reported as process-related emissions, in 2.C.1, will have to be calculated out of those in 1.A.2.a, in order to prevent double-counting.

The CH_4 emissions are based on older Federal Environmental Agency estimates and will have to be verified in coming report cycles (2006/2007).

4.3.1.1 Source-category description (2.C.1)

4.3.1.2 Methodological issues (2.C.1)

4.3.1.3 Uncertainties and time-series consistency (2.C.1)

4.3.1.4 Source-specific quality assurance / control and verification (2.C.1)

4.3.1.5 Source-specific recalculations (2.C.1)

4.3.1.6 Planned improvements (source-specific) (2.C.1)

4.3.2 Metal production: Ferroalloys production (2.C.2)

Emissions from this source category are currently not being reported.

To date, only obsolete activity data has been available for emissions calculation from ferroalloys production, and there was a complete lack of suitable emission factors. For this reason, this issue was discussed, with experts, at the 1st workshop on the national system that was held in November 2004. It emerged that the activity rates used to date are considerably higher than the actual rates. Following the final evaluation of the workshop results, emissions from production of ferroalloys will be calculated on the basis of new data sources. The results will then be presented in the 2006 report.

4.3.2.1 Source-category description (2.C.2)

4.3.2.2 Methodological issues (2.C.2)

4.3.2.3 Uncertainties and time-series consistency (2.C.2)

4.3.2.4 Source-specific quality assurance / control and verification (2.C.2)

4.3.2.5 Source-specific recalculations (2.C.2)

4.3.2.6 Planned improvements (source-specific) (2.C.2)

4.3.3 Metal production: Primary aluminium production (2.C.3)

4.3.3.1 Source-category description (2.C.3)

CRF 2.C.3					
Key source by level (l) / trend (t)		**Gas (key source)**	**1990 – contribution to total emissions**	**2003 – contribution to total emissions**	**Trend**
Aluminium production	- / t	PFCs	0,20 %	0,04 %	falling

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor[100] (EF)	CS	NE	NO	CS	NO	NO	NE	CS	NO	CS
EF uncertainties in %	15			15						
Distribution of uncertainties[101]	N			N						
Method of EF determination[102]	T3			T3						

In terms of its trend, primary aluminium production (2.C.3) is a key source.

In Germany, aluminium is produced at five 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 hall roofs. The principal climate-relevant pollutants emitted are CO, CO_2, SO_2, CF_4 and C_2F_6.

100 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
101 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
102 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model

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. In this area, PFCs are produced in the production process as secondary products of electrolytic reduction of aluminium oxide (from alum earth) to aluminium. Thanks to extensive modernisation measures in German aluminium foundries, and to decommissioning of production capacities, absolute emissions from this sector fell by 71 % between 1995 and 2003. As to the future development of PFC emissions, stagnation at a low level can be expected.

4.3.3.2 Methodological issues (2.C.3)

The production figures for the year 2003 were taken from the monitoring report by the aluminium industry for the year 2003. The average anode consumption is 430 kg of petrol coke per tonne of aluminium. Table 48 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 hall 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 that can be used to calculate an SO_2 emission factor. Theoretically, the CO_2 emission factor must be reduced by the proportion resulting from a CO component 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 48 were compared with the emission data in Best Available Technology (BAT) data sheets and other sources (such as VDI Guideline 2286 sheet 1).

Table 48: Activity rates and process-related emission factors for primary aluminium production in 2003

		Emission factors						
	Production [kt]	**CO_2 [kg/t]**	**CF_4 [kg/t]**	**C_2F_6 [kg/t]**	**NO_X [kg/t]**	**SO_2 [kg/t]**	**C total [kg/t]**	**CO [kg/t]**
Primary aluminium	661201	1367	0,097	0,009	No entry	6,02	No entry	180

Emission data is available for PFC emissions from primary aluminium foundries, 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 is not published, but is made available to the Federal Environmental Agency.

The measurements conducted in all German foundries in the years 1996 and 2001 form the basis for calculation of CF_4 emissions. In this context, specific CF_4 emission factors per

anode effect[103] were calculated, in keeping with the technology used. The number of anode effects is recorded and documented in the foundries. The total CF_4 emissions in 2003 were calculated by multiplying the total anode effects by the specific CF_4 emissions per anode effect determined in 2003. The total emission factor for CF_4 is obtained by adding the CF_4 emissions of the five foundries and then dividing the sum by the total aluminium production of the foundries. C_2F_6 and CF_4 occur in a constant ratio of about 1:10. The above-described method was applied to the entire time series, and emissions for the years 1990 to 1996 were filled in via recalculations.

4.3.3.3 Uncertainties and time-series consistency (2.C.3)

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, in the framework of voluntary commitments no survey of the plant-specific number of anode effects in 1991, 1992, 1993 and 1995 was conducted, and no calculation was carried out for these years (cf. 4.3.3.6)

4.3.3.4 Source-specific quality assurance / control and verification (2.C.3)

The industry conducts annual surveys of activity data and reports this data to (inter alia) the Federal Statistical Office and the Federal Office of Economics and Export Control. The relevant time series seems plausible and shows no inconsistencies. It is assumed that collection of this data is subject to quality assurance measures.

Specific PFC emissions during anode effects were determined via industry measurements carried out in 1996 and 2001 at all plants in Germany that produce primary aluminium. In each case, the amount of PFCs produced depends on the duration and frequency of the relevant anode effects. In recent years, the duration and frequency of anode effects have been considerably reduced via computer-aided process control. The German emission factor for CF_4 resulting from anode effects is 0.097 kg/t aluminium. This factor is slightly below the average international factor, as reported by the International Aluminium Institute (IAI), of 0.11 kg/t for point-feeder systems. The emission factor thus appears to have been verified.

Measures for standardisation of QC/QA are currently being prepared.

4.3.3.5 Source-specific recalculations (2.C.3)

For the years 1990, 1994 and 1996, PFC emissions from the primary aluminium industry were determined via the described method (Tier 3b). In the process, recalculation was carried out for these years on the basis of the specific CF_4 emission factors per anode effect measured in 1996, as well as of the relevant numbers of anode effects, determined in each case on a plant-specific basis. In 2000, determination via recal was carried out on the basis of measurements made in 2001. Recalculation for the years Jahre 1991, 1992, 1993 and 1995 is also possible. For it to be carried out, however, operators must provide the plant-specific numbers of anode effects involved. As described in 4.3.3.2, the Federal Environmental Agency has received measurement data, from the aluminium industry, for 1997, 1998 and 1999.

103 „...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

4.3.3.6 Planned improvements (source-specific) (2.C.3)

Closing of the gaps in the time series, via operator surveys relative to anode-effect frequency in the years 1991, 1992, 1993 and 1995, and recalculation on the basis of specific emission factors determined through measurements in 1996. Uncertainties determination is to be carried out with the involvement of the industry association.

4.3.4 Metal production: SF_6 used in aluminium and magnesium foundries (2.C.4)

4.3.4.1 Source-category description (2.C.4)

CRF 2.C.4					
Key source by level (l) / trend (t)		**Gas (key source)**	**1990 – contribution to total emissions**	**2003 – contribution to total emissions**	**Trend**
SF_6 in aluminium and magnesium production	- / t	SF_6	0,01 %	0,12 %	rising

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor[104] (EF)	NO	NO	NO	NO	D	NO	NO	NO	NO	NO
EF uncertainties in %					-					
Distribution of uncertainties[105]					-					
Method of EF determination[106]					D					

All remarks in this chapter refer to emissions data for the 2003 report year; the emissions data on which these remarks is based is available as necessary in Germany. For technical reasons, it was not possible, however, to integrate the available data in the newly prepared CSE database. As a result, the CRF 2005 report tables, which belong to the NIR 2005, and which have been obtained from the CSE, do not yet contain any emissions data for 2003. Intensive efforts are currently underway to eliminate these technical problems.

In terms of trend, use of SF_6 in aluminium and magnesium production is a key source. Aluminium and magnesium production accounted for about 36% of SF_6 emissions in the year 2003.

Prior to casting of molten aluminium, the inert gases nitrogen and/or argon are introduced to remove (degas) hydrogen, as well as alkaline and alkaline earth metals and solids; this prevents porosity in cast pieces. Halogens (chlorine, fluorine, etc.) are introduced for cleansing purposes. 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 in a few – usually smaller – secondary aluminium foundries and in laboratories. A review of the market for SF_6 in aluminium production revealed that such purification systems were last used in 1999 (no sales have occurred in Germany since 2000). In isolated cases, pure SF_6 has been used as a purification gas since 1999, however. Consumption of pure SF_6 has increased steadily since then.

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from CO_2 to CO and 5 to 20% CF_4...." (ÖKO-RECHERCHE 1996)

104 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model

105 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)

106 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model

In magnesium casting, SF_6 is used as a protective gas over molten magnesium to prevent its oxidation and ignition. SF_6 has been used in this application since the mid-1970s. Use of this gas has competed with use of SO_2. Because SF_6 is easier to handle than the highly toxic SO_2, it became widely used in many new foundries. Since 2003, HFC-134a has been used, on a trial basis, instead of SF_6 or other protective gases. The amounts used in 2003 were still very small, however. In Germany, protective gas is only used for the processing of magnesium that has been imported in ingot form.

4.3.4.2 Methodological issues (2.C.4)

All of the SF_6 used in Germany to purify molten aluminium is emitted completely upon use (consumption = emission; EF = 1). The practice of assuming the equivalence between consumption (AR) and emissions conforms to the IPCC method (IPCC, 1996a: 2.34).

SF_6 consumption was determined via direct surveys, regarding sales, of the few providers of the SF_6-containing gas mixture. The survey for the report year 2000 revealed that the gas mixture has no longer been sold since 2000.

For the report year 2002, a first survey of gas providers' SF_6 sales figures was carried out, and these figures were compared with data obtained from a first survey of amounts consumed by industry. This made it possible to identify SF_6 users, in the area of aluminium casting, who use pure SF_6. Since 2002, annual surveys have been conducted of sales figures relative to the application "aluminium casting".

The quantity of SF_6 used for magnesium-cast production (consumption = AR) is equated with emissions, in accordance with the revised IPCC Guidelines (IPPC, 1996a: 2.34). SF_6 consumption is determined via direct surveys of foundries aimed at determining annual consumption levels. This is a feasible approach, since there are not a great many foundries. The usage data obtained is cross-checked against gas sellers' sales figures for this sector (these figures are also obtained via surveys).

The method outlined was applied for the report years 1995, 1997, 1998, 2000, 2001, 2002 and 2003. The missing annual data has been obtained by means of interpolation.

The emission factors listed in the CRF tables, up to the report year 2002, are obtained, via recalculation, from metal-production figures and the determined emissions (= consumption). The factors have not been used for emissions calculations. As of report year 2003 (current NIR), the "amount of SF_6 use" will be given as the activity rate, instead of the amount of Mg produced ("mg production") . Since emissions are calculated on the basis of this AR, 100% emissions (see above) yields an IEF of 1000 kg/t.

Table 49 contains an overview of the current status of data reporting (report year 2003). For the report years 1995 to 2000, certain other factors apply in some cases.

Table 49: Overview of data reporting and emission factors used in TABLE 2(II)s1, C. Metal Production

	Reported data 2003	**Substance**	**EF**
SF_6 in aluminium production	yes	SF_6	1 (100%)
SF_6 in magnesium foundries	yes	SF_6	1 (100%)

4.3.4.3 Uncertainties and time-series consistency (2.C.4)

Recent studies have shown that part of the SF_6 – for example, that in Mg production – is broken down. For this reason, the assumption that amounts used are emitted to a degree of 100% (EF=1) probably overstates the emissions. Without more precise measurements that would make it possible to determine an average degree of decomposition in the process, the uncertainties cannot be quantified.

What is more, the uncertainties for the emissions result directly from the uncertainties for the identified usage amounts. The usage amounts determined for Mg foundries are considered sufficiently precise, since they were obtained via direct surveys of purchasing data. The usage amounts determined via the two different procedures (foundries, gas sellers; see above) show good agreement. The relevant uncertainties cannot be quantified.

In 2004, figures for sales of SF_6 to Al foundries were retroactively reviewed. This has made it possible to recalculate the time series for SF_6 emissions from aluminium production. The data now available is considered to be of good quality. The relevant uncertainty cannot be quantified.

4.3.4.4 Source-specific quality assurance / control and verification (2.C.4)

Quality assurance / control for amounts consumed in Mg foundries was carried out via a one-time comparison of findings from foundry surveys with producers' total SF_6 sales figures – and with data of gas sellers. As to amounts consumed by Al foundries, for the 2002 report year, sales figures were compared for the first time with amounts used by industry, and this comparison revealed a discrepancy. This led to identification of a new source (aluminium casting, see above). For report year 2004, sales figures were again compared with the amounts used by industry.

The data for the 2003 report year, like the data for most of the previous years, was collected by an external expert working under commission to the Federal Environmental Agency. For the most part, quality assurance was carried out by an external expert. In addition, where possible, the data is checked by the relevant Federal Environmental Agency specialist upon receipt.

Measures for standardisation of QC/QA are currently being established.

4.3.4.5 Source-specific recalculations (2.C.4)

No recalculations have been carried out to date, although recalculations are required for the source SF_6 from aluminium production for report years prior to 2002. One recalculation was carried out in connection with the data survey for report year 2003, but the results have not been entered into the databases.

4.3.4.6 Planned improvements (source-specific) (2.C.4)

There are plans to review the market development of SF_6 in aluminium production regularly over the next few years. Such review will include gas sellers and users of SF_6. Plans also call for reaching agreements with users on regular data provision. This has not yet been accomplished.

There are also plans to work with magnesium users, and relevant system providers, in implementing out future options and improvements for collection of data on SF_6 and 134a.

As of 2007, surveys of SF_6 sales figures will be carried out in keeping with the Environmental Statistics Act (UstatG). Suitable survey parameters are currently being prepared by the Federal Environmental Agency and the Federal Statistical Office, in co-operation with gas sellers and the producer.

4.3.5 Metal production: Other (2.C.5)

Emissions from this source category are currently not being reported.

4.3.5.1 Source-category description (2.C.5)

4.3.5.2 Methodological issues (2.C.5)

4.3.5.3 Uncertainties and time-series consistency (2.C.5)

4.3.5.4 Source-specific quality assurance / control and verification (2.C.5)

4.3.5.5 Source-specific recalculations (2.C.5)

4.3.5.6 Planned improvements (source-specific) (2.C.5)

4.4 Other production (2.D.)

4.4.1 Other production: Pulp and paper (2.D.1)

4.4.1.1 Source-category description (2.D.1)

CRF 2.D.1					
Key source by level (l) / trend (t)		**Gas (key source)**	**1990 – contribution to total emissions**	**2003 – contribution to total emissions**	**Trend**
	- / -				

Gas	CO_2	CH_4	HFCs	PFCs	SF_6	N_2O	NO_X	CO	NMVOC	SO_2
Emission factor[107] (EF)	NO	NO	NO	NO	NO	NO	NO	NO	NO	CS
EF uncertainties in %										
Distribution of uncertainties[108]										
Method of EF determination[109]										

The source category "Other production" (2.D.1) is not a key source with regard to production of pulp and paper.

All emissions of climate-relevant gases from the pulp and paper industry in Germany result from combustion of fuels; for this reason, they are reported in Chapter 3.1 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 *IPCC Good Practice Guidelines* (2000).

In pulp production with the sulphate procedure (one of five pulp plants in Germany), carbonate is extracted from the circulation of lye via bonding with calcium (causticising) and then, in a separate lime oven, is burned to burnt lime, a process that releases CO_2; the burnt lime is then reused for causticising. Fuel-related CO_2 emissions from lime ovens are taken into account, via fuel data, as energy-related emissions. Pursuant to the *IPCC Good Practice Guidance*, CO_2 released from $CaCO_3$ is assigned an emission factor of "0", since all of its carbon comes from pulped wood. Calcium loss from the cycle is compensated for solely via addition of burnt lime and thus, for the present purposes, also does not lead to report-relevant CO_2 emissions (the CO_2 released in production of burnt lime is already included in the figures for the lime industry (CRF 2A2)).

In 2003, the following amounts were produced, in a total of 118 plants (Verband Deutscher Papierfabriken, 2004):
Production of paper, cardboard and carton (PCC): 19.310 million tonnes
Raw-material production:

Paper pulp	847,722	t
of this, sulfite pulp	537,478	t
of this, sulfate pulp	310,244	t
Wood pulp	1,344,025	t
Recycled paper (from 12 448 996 t of used paper)	10,208,000	t

A detailed description of the processes used is provided in Annex 2, Chapter 14.2.4.1.

107 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
108 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
109 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model

In the CSE, 2.D.1 Pulp and paper includes particle-board production and pulp processing.

Figure 39: Structural allocation, 2.D Other production

4.4.1.2 Methodological issues (2.D.1)

These are not relevant, since the pulp, paper and printing industry produces no process-related emissions of climate-relevant gases within the meaning of the *IPCC Good Practice Guidance* (IPCC, 2000).

4.4.1.3 Uncertainties and time-series consistency (2.D.1)

These are not relevant, since the pulp, paper and printing industry produces no process-related emissions of climate-relevant gases within the meaning of the *IPCC Good Practice Guidance* (IPCC, 2000).

4.4.1.4 Source-specific quality assurance / control and verification (2.D.1)

These are not relevant, since the pulp, paper and printing industry produces no process-related emissions of climate-relevant gases within the meaning of the *IPCC Good Practice Guidance* (IPCC, 2000).

4.4.1.5 Source-specific recalculations (2.D.1)

These are not relevant, since the pulp, paper and printing industry produces no process-related emissions of climate-relevant gases within the meaning of the *IPCC Good Practice Guidance* (IPCC, 2000).

4.4.1.6 Planned improvements (source-specific) (2.D.1)

These are not relevant, since the pulp, paper and printing industry produces no process-related emissions of climate-relevant gases within the meaning of the *IPCC Good Practice Guidance* (IPCC, 2000).

4.4.2 Other production: Food and drink (2.D.2)

4.4.2.1 Source-category description (2.D.2)

CRF 2.D.2					
Key source by level (l) / trend (t)		**Gas (key source)**	**1990 – contribution to total emissions**	**2003 – contribution to total emissions**	**Trend**
	- / -				

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor[110] (EF)	NO	NO	NO	NO	NO	NO	NO	NO	CS/ IPCC	NO
EF uncertainties in %										
Distribution of uncertainties[111]										
Method of EF determination[112]										

The source category "Other production: food and drink" (2.D.2) is not a key source.

In the CSE, emissions from the food and drink industry are shown via data on production of beer, bread (consumption of bread-grain flour), wine and sugar.

Figure 40: Structural allocation, 2.D.2 Food and drink

The process-related emissions reported are NMVOC emissions (IPPC Workbook, 1996a: p. 2.41). Energy-related emissions from the food and drink industry are described in CRF 1.A.2. Carbon dioxide emissions from food inputs that occur during certain production processes are not reported in CRF 2.D.2., since they result from use of biological carbon and do not contribute to net CO_2 emissions (IPPC Workbook, 1996a: p. 2.41).

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.

With revenue of about EUR 128 billion, the food and drink industry was one of the most important industries in Germany in 2003. Nation-wide, about some 5,880 industry companies employed about 525,300 people (BVE 2004). Pursuant to the 1993 Classification of Economic Activities (WZ 93), the food and drink industry is divided into nine groups and a total of 33 classes. Governmental statistical evaluations are oriented to this classification. The German food industry includes an especially large number of small and medium-sized enterprises (SMEs); nearly 80 percent of its companies have fewer than 100 employees, and only 3 percent have more than 500 employees (BpB 2002, p.51).

110 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
111 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
112 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model

Pursuant to the IPCC, the following products are considered for emissions reporting relative to the food and drink source category; for these products, emission factors for NMVOC emissions are recommended (IPPC Workbook, 1996; p. 2.41f):

- Alcoholic beverages
- Wine
- Beer
- Spirits
- Bread and others
- Meat, fish and poultry
- Sugar
- Margarine and solid cooking fats
- Cake, biscuits and breakfast cereals
- Bread
- Animal feed
- Coffee roasting

4.4.2.2 Methodological issues (2.D.2)

Data is collected, and calculations carried out, relative to the indirect greenhouse gases involved.

The Central System of Emissions (CSE) lists activity rates (produced amounts) and emission factors for NMVOC emissions for the areas of bread, beer, wine and sugar.

The activity rates for wine, beer and sugar are provided by the Federal Statistical Office (DESTATIS). For bread, the product of per-capita wheat-flour / rye-flour consumption and total population is listed. For 2003, the activity rates were as follows:

- Wine:
  5,397,000 hl white wine and must and 2,713,000 hl red wine and must (DESTATIS 2004 a); a total of 81,111,000 hl, or 811,100 t.
- Beer:
  98,933,000 hl (DESTATIS, Fachserie 4 Reihe 3.1, 1991-2004: No. 1596 10 000)
- Sugar:
  3,913,126 t (DESTATIS, Fachserie 4 Reihe 3.1, 1991-2004: No. 1583 12 300)
- Bread:
  a) Population: 82,537,000 (statistics portal 2004).
  b) Consumption of wheat flour in 2002/03: 68.1 kg per inhabitant and year (DESTATIS 2004 b).
  c) Consumption of rye flour in 2002/03: 9.6kg per inhabitant and year (DESTATIS 2004 b).
  d) Total: 77.7 kg. Estimated bread production for 2003: 77.7 kg multiplied by 82,537,000 equals 6,413,124.9 t.

The emission factors are older values, taken primarily from CORINAIR (1994) and partly agreeing with IPCC.

The emissions are calculated pursuant to the IPCC Workbook (1996a: p. 2.81); this means that production figures are multiplied by emission factors.

For source category 2.D.2, this yields a total of 25.5 Gg NMVOC emissions (up from 21.77 Gg NMVOC in 2002).

4.4.2.3 Uncertainties and time-series consistency (2.D.2)

The uncertainties for activity rates and emission factors have not been considered to date.

4.4.2.4 Source-specific quality assurance / control and verification (2.D.2)

Other countries' reports contain very little information about 2.D.2, and thus no comparisons are possible.

4.4.2.5 Source-specific recalculations (2.D.2)

No source-specific recalculations have been carried out for the area of the food and drink industry.

4.4.2.6 Planned improvements (source-specific) (2.D.2)

The emission factors used need to be adjusted to the actual emissions situation, in co-operation with the German Länder and with the relevant associations.

Production figures and relevant emission factors need to be determined for the industrial branches that are still not represented.

4.5 Production of halocarbons and SF_6 (2.E)

CRF 2.E					
Key source by level (l) / trend (t)		**Gas (key source)**	**1990 – contribution to total emissions**	**2003 – contribution to total emissions**	**Trend**
Production of halocarbons and SF_6; here, fugitive emissions	- / t	HFCs	0,28 %	0,12 %	falling

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor[113] (EF)	NO	NO	0,003	NO	0,005	NO	NO	NO	NO	NO
EF uncertainties in %			-		-					
Distribution of uncertainties[114]			-		-					
Method of EF determination[115]			-		-					

All remarks in this chapter refer to emissions data for the 2003 report year; the emissions data on which these remarks is based is available as necessary in Germany. For technical reasons, it was not possible, however, to integrate the available data in the newly prepared CSE database. As a result, the CRF 2005 report tables, which belong to the NIR 2005, and which have been obtained from the CSE, do not yet contain any emissions data for 2003. Intensive efforts are currently underway to eliminate these technical problems.

In terms of levels of fugitive emissions, and of its trend, production of halocarbons (HFCs) and SF_6 is a key source. In 2003, this source category accounted for 1% of HFC emissions and <10% of SF_6 emissions.

113 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
114 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
115 D= IPCC Default, RA= Reference Approach, T1= IPPC tier 1, T1a/ T1b/ T1c= IPPC tier 1a/ 1b/ 1c, T2= IPPC tier 2, T3= PPC tier 3, C= CORINAIR, CS= Country specific, M= Model

It has not yet been possible to provide an emission factor for the HFC substance group, since several different sources are involved and since different emission factors are used to calculate the emissions from these sources. As a result of production-process changes, the EF for report year 2003 is about 0.3%, for all three sources, and thus a single EF can be determined.

Table 50 contains an overview of the current status of data reporting (report year 2003). Some of the reporting (production-related emissions) is sub-divided, for greater precision, into further sub- source categories.

Table 50: Overview of data reporting and emission factors used in TABLE 2(II)s1, E. (a) Production of halogenated hydrocarbons and SF_6

	Reported data 2003	**Substance**
1. By-product emissions		
Production of H-CFC-22	yes	HFC-23
Other	NO	
2. Manufacturing-related emissions	yes	HFC, SF_6

4.5.1 By-product emissions (2.E.1)

4.5.1.1 Source-category description (2.E.1)

HFC-23 is incurred as a by-product of manufactured H-CFC-22. According to the larger of the two producers in Germany, the amount in question is about 3% of the entire H-CFC-22 production; this amount is always incurred in synthesis and is not collected for further processing (for example, for production of refrigerants) or for decomposition for substance recovery. For technical reasons, it is impossible to prevent part of this amount from escaping into the atmosphere.

In 1994, in Frankfurt, a CFC-cracking plant went into operation that cracks, at high temperature, excess HFC-23 produced during production of H-CFC-22 and that recovers hydrofluoric acid; i.e. no emissions are produced. HFC-23 produced at the second German production facility is largely captured at the production system itself; the substance is then sold as a refrigerant or – following further distillative purification – as an etching gas for the semiconductor industry. For the past several years, the excess amount that cannot be sold is delivered to the cracking facility in Frankfurt. Since 1995, emissions have been substantially reduced through this measure. At the same time, a considerable portion of the substance is not collected, however; the second H-CFC-22 facility generates by-product emissions on a level now estimated by the operator as about 0.3 % of H-CFC-22 production (1 % in the 2001 report year). In 2003, a plasma burner was installed. This has led to a further emissions reduction.

4.5.1.2 Methodological issues (2.E.1)

For the 1995 to 2003 report years, emissions of the latter producer have been calculated (via mass balance) on the basis of the amount of H-CFC-22 produced, of annual measurements of HFC-23 concentrations in the facility's waste gas, of amounts of HFC-23 sold and of the amounts of HFC-23 delivered to the cracking facility; for the 1995 report year, emissions-reduction measures (cracking facility) have been taken into account, as of the middle of the year, for the first production facility. The producer has reported the relevant production

amounts of R 22 and of amounts of HFC-23 sold and managed as waste. The emission factor listed in the CRF tables has been obtained via recalculation from the production amount and the relevant emissions determined on the basis of the mass balance.

The IPCC default emission factor is not used, since emissions-reduction measures have been taken (cracking facility).

4.5.1.3 Uncertainties and time-series consistency (2.E.1)

The emissions calculation obtained via the aforementioned mass balance is considered to be very accurate. The relevant uncertainties cannot be quantified (pursuant to IPCC, the maximum emissions are 4 % of the amount produced).

In co-operation with the manufacturer of R 22 (this applies only to the second production facility, since the first production facility, as described in 4.5.1.1, does not produce any emissions), continual efforts are being made to improve data quality (including the emission factor).

4.5.1.4 Source-specific quality assurance / control and verification (2.E.1)

Measures for standardisation of QC/QA are currently being established.

4.5.1.5 Source-specific recalculations (2.E.1)

In co-operation with the second producer, the data for the previous report years is being checked further for plausibility and improved as necessary. This can lead to recalculations.

4.5.1.6 Planned improvements (source-specific) (2.E.1)

No improvements are planned at present.

4.5.2 Production-related emissions (2.E.2)

4.5.2.1 Source-category description (2.E.2)

In Germany, only one company produces these gases; its HFC und SF_6 production takes place at two locations. Since 2001 (retroactively to the start of production), the company has been reporting both production and the associated losses. Emissions trends are tied to trends in amounts produced. As the only HFC producer in Germany, and now the only producer of SF_6 in Europe, the company enjoys protected confidentiality. The data is reported to the Federal Environmental Agency. It is reported further only in aggregate form.

While SF_6 and HFC-134a are produced in Germany, no complete synthesis of HFC-227ea takes place domestically. Part of the HFCs produced in Tarragona, Spain, undergo subsequent distillation to pharmaceutical purity in Germany (use in dosing aerosols). This process generates further minor losses.

4.5.2.2 Methodological issues (2.E.2)

The producer reports emissions of 134a, 227ea and SF_6. From this data, and from production figures, implied rates (both groups of data are reported confidentially) of fugitive emissions can be calculated; this rate has proven to be relatively constant. The rate for SF_6,

about 0.5%, is higher than that for production of HFC-134a (0.3%) and that for purification of HFC-227ea (0.3%).

4.5.2.3 Uncertainties and time-series consistency (2.E.2)

The production data (AR) is very reliable, since it consists of internal records of the firm of Solvay Fluor und Derivate GmbH.

The emissions are obtained via mass-balancing. The mass balance can be understood as the difference between production as derived from raw-material inputs and production as derived from the produced amounts actually placed in tanks.

Due to imprecision in allocating amounts produced in Europe to the various locations involved (one producer!), until 2001 assumptions regarding amounts produced in Germany were overly high – especially those for HFC-227ea – and thus the relevant emissions reports were too high. For the 2002 report year, the required separation, within the relevant companies, between production, purification and sales was improved. Since then, the production figures, for the various locations in question, on which the emissions calculation is based may be considered exact.

4.5.2.4 Source-specific quality assurance / control and verification (2.E.2)

Measures for standardisation of QC/QA are currently being established.

4.5.2.5 Source-specific recalculations (2.E.2)

No recalculations have been carried out to date, but recalculations will become necessary, for report years until 2001, once the quantities actually produced in Germany have been determined.

4.5.2.6 Planned improvements (source-specific) (2.E.2)

No improvements are planned.

4.5.3 Other (2.E.3)

No other sources of greenhouse-gas emissions are known.

4.6 Consumption of halocarbons and SF_6 (2.F)

CRF 2.F					
Key source by level (l) / trend (t)		**Gas (key source)**	**1990 – contribution to total emissions**	**2003 – contribution to total emissions**	**Trend**
Consumption of halocarbons and SF_6	l / -	SF_6	0,30 %	0,27 %	stagnating
Consumption of halocarbons and SF_6	l / t	HFCs	0,00 %	0,69 %	rising

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor[116] (EF)			s. Text	s. Text	s. Text					
EF uncertainties in %			-	-	-					
Distribution of uncertainties[117]			-	-	-					
Method of EF determination[118]			cf.text	cf.text	cf.text					

All remarks in this chapter refer to emissions data for the 2003 report year; the emissions data on which these remarks is based is available as necessary in Germany. For technical reasons, it was not possible, however, to integrate the available data in the newly prepared CSE database. As a result, the CRF 2005 report tables, which belong to the NIR 2005, and which have been obtained from the CSE, do not yet contain any emissions data for 2003. Intensive efforts are currently underway to eliminate these technical problems.

Consumption of halocarbons (HFCs) and SF_6 is a key source for HFCs, in terms of emissions levels and trend, and a key source for SF_6 in terms of the 1990 emissions level.

Halocarbons and SF_6 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. It is thus neither possible nor useful to provide a mean emission factor. Most of the EF used are CS; although some are D or M.

The "current emissions (A)", as listed in Table 2(I)s2, consist of the quantities of HFCs, PFCs and SF_6 that, during a report year, slowly escape from "stocks" and that are emitted in production and waste management. On the other hand, the "stocks" – actually, the average quantities present in the report year in question (average annual stocks) – correspond to the potential emissions (P) listed in Table 2(II)s2. The "stocks" do not include quantities from storage only. These amounts vary widely, and thus neither is it possible to determine these quantities nor is it useful to work with an average value. For reasons of confidentiality, potential emissions for the sub- source categories "solvents" and "semiconductor manufacture" cannot be given. For open applications (aerosols / metered dose inhalers), annual emissions are equated with the quantities sold within the relevant 12-month period (100 % emissions in the relevant year of sales). As a result, this area has no "stocks" that increase annually. The potential emissions thus correspond approximately to the current emissions in the report year in question. In individual cases involving "open" applications, a

situation can arise, as a result of the calculation method chosen and the difference in reference period, in which A>P and, thus, the relationship P/A < 1.

Table 51 contains an overview of the current status of data reporting (report year 2003). For the report years 1995 to 2002, certain other factors apply in some cases. In contrast to the overview shown here, many areas of the pertinent complete report are divided into further sub-groups, and individual factors are provided for these sub-groups.

116 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
117 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
118 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model

Table 51: Overview of data reporting and emission factors used in TABLE 2(II)s1, F. (a) Consumption of halocarbons and SF_6: in this case: consumption of halocarbons

	Reported data 2003	Substance	EF production [-][119]	EF use [-]
1. Refrigeration and air-conditioning systems (2.F.1) [Tier 2]				
Household refrigeration	yes [Tier 2a]	HFC	NA	0,003
Commercial refrigeration	yes [Tier 2a]	HFC, PFC	0,002 (CS)	0,015-0,15
Transport refrigeration	yes [Tier 2a]	HFC	0,002-0,005 (CS)	0,15-0,25
Industrial refrigeration	yes [Tier 2a]	HFC	0.0015 (CS)	0,07
Stationary air-conditioning systems	yes [Tier 2a]	HFC	20 g/system (CS)	0,06
Room air conditioners	yes [Tier 2a]	HFC	NA	0,025
Mobile air-conditioning systems				
Mobile air-conditioning, trucks	yes [Tier 2a]	HFC	0,002 (CS)	0,10-0,15
Mobile air-conditioning, cars	yes [Tier 2a]	HFC	2 g/system (CS/D)	0,1
Mobile air-conditioning, buses	yes [Tier 2a]	HFC	5 g/system (CS)	0,15
Mobile air-conditioning, ships	yes [Tier 2a]	HFC	0.01 (CS)	0,05
Mobile air-conditioning, rail vehicles	yes [Tier 2a]	HFC	0,002 (CS)	0,15-0,25
Mobile air-conditioning, land machines	yes [Tier 2a]	HFC	5 g/system (CS)	0,15-0,25
2. Foam production (2.F.2) [Tier 2]				
Hard foam with 365mfc/134a	yes [Tier 2a]	HFC	0,10 (CS/D)	0,005
Sandwich components	yes [Tier 2a]	HFC	0,10 (D)	0,005
Integral foam	yes [Tier 2a]	HFC	1 (CS)	NA
PUR foam (134a)	yes [Tier 2a]	HFC	1.5 g/can (CS)	1
PUR foam (152a)	yes [Tier 2a]	HFC	1.5 g/can (CS)	1
XPS foam (134a)	yes [Tier 2a]	HFC	0.26 (CS)	0,0066
XPS foam (152a)	yes [Tier 2a]	HFC	1 (CS)	NA
Soft foam	NO	HFC		
3. Fire extinguishers (2.F.3)	yes [CS]	HFC	0.001 (CS)	0,005
4. Aerosols/metered dose inhalers(2.F.4)				
Metered dose inhalers	yes [CS]	HFC	0.15 g/can (10ml) (CS)	1 (D)
Other	yes [Equ. 3.35]	HFC	0,015	1 (D)
5. Solvents (2.F.5)	yes [Equ. 3.36]	HFC	NA	1 (D)
6. Semiconductor production (2.F.6)	yes [Tier 2]	HFC, PFC, SF_6	NA	(CS)

Equ. = Equation; equation from the IPCC GPG (2000)

[119] Unitless, unless indicated otherwise

Table 52: Overview of data reporting and emission factors used in TABLE 2(II)s1, F. (a) Consumption of halocarbons and SF_6; here: consumption of SF_6

	Reported data 2003	Sub-stance	EF production [-]	EF use [-][120]	EF disposal [-]
7. Electrical operating equipment (2.F.6)					
Switching equipment	yes [Tier 3a]	SF_6	0,02	0,001-0,01	0,02
Other	Yes [CS]	SF_6	0,15-1		
8. Other (2.F.6)					
Sports shoes	yes [Equ. 3.23]	SF_6	NA	NO	1
Car tyres	yes [Equ. 3.23]	SF_6	0,002	NO	1
Insulating glass panes	yes [Equ. 3.24ff]	SF_6	0,33	0,01	1
Tracer gas	Yes [CS]	SF_6	NA	1	NO

Equ. = Equation; equation from the IPCC GPG (2000)

4.6.1 Refrigeration and air-conditioning systems (2.F.1)

Since the early 1990s, companies have been using partially halogenated CFCs (HFCs) on an increasing scale, primarily as substitutes for ozone-depleting and climate-damaging CFCs and H-CFCs. HFC emissions have increased sharply since 1995.

Use of refrigerants in stationary and mobile cooling/refrigeration systems now accounts for 50 % of HFC emissions and is thus the primary source of such emissions. The entire source category 2.F.1 is divided into two sub- source categories: Refrigeration and stationary air-conditioning systems and mobile air-conditioning systems.

4.6.1.1 Refrigeration and stationary air-conditioning systems (2.F.1)

4.6.1.1.1 Source-category description (2.F.1)

This sector can be roughly divided into the sub- source categories household refrigeration, commercial refrigeration, transport refrigeration, industrial refrigeration and stationary air-conditioning systems (cf. Table 51). In 2003, stationary refrigeration and air-conditioning systems accounted for over 20 % of HFC emissions.

By far the most important pure HFC refrigerants in Germany are HFC-134a and the mixtures 404A and 507, both of which consist primarily of 125 and 143a. Together, 134a and 404A/507 account for more than 90% of annual new consumption. Because 404A and 507 are nearly identical in composition, and because they are thus used in the same areas, it is impossible to separate these two refrigerant mixtures. The two mixtures are thus reported as "404A".

The time-series development (increase) is directly related to increased use of HFC as a substitute for CFC, in refrigeration, and to the resulting increasing potential and current emissions. The increase, which was initially sharp, has been slowing somewhat. Before a reliable interpretation of this development can be provided, the emissions of the coming years will have to be awaited.

[120] Unitless, unless indicated otherwise

4.6.1.1.2 Methodological issues (2.F.1)

The total emissions for each sub- source category, and for each refrigerant, consist of the sub-emissions in the areas of production, usage and disposal. Emissions in these areas are determined separately. Disposal emissions occurred for the first time in 2003.

For calculation of HFC emissions from the sub-categories of refrigeration and stationary air-conditioning systems, individual data is collected/estimated, or refrigerant models used, for each group in question. Table 53 provides an overview of the methods used. It is followed by a short description of the refrigerant models applied. Plans call for publishing a comprehensive description of the models on the Federal Environmental Agency's Website in 2005.

Table 53: Overview of methods used for sub-categories pertaining to "refrigeration and stationary air-conditioning systems"

Sub-category	**Method**	
Household refrigeration		Detailed description of the methods used for the various sub-categories are provided in the Annex, Chapter 14.2.5.1
Commercial refrigeration	Refrigeration model for "commercial refrigeration systems""	
Transport refrigeration/refrigerated vehicles	Refrigeration model for "transport refrigeration systems""	
Industrial refrigeration	Refrigeration model for "industrial refrigeration systems""	
Stationary air-conditioning systems	Refrigeration model for "stationary air-conditioning systems"	
Room air conditioners	Refrigeration model for "room air-conditioners""	

The emission factors used are the result of surveys of experts.

4.6.1.1.3 Uncertainties and time-series consistency (2.F.1)

The emission factors are subject to considerable uncertainties. The literature (cf. refrigeration models: Annex, Chapter 14.2.5.1) contains a broad range of emission factors for identical applications. This is only partly a consequence of technical changes in systems' air-tightness or a manifestation of national differences. For the most part, it reflects real uncertainty, since too few solid empirical studies of these factors have been carried out (one of these is a study of supermarket emissions in Germany; ILK Dresden, 1999).

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 is considered too imprecise. In order to improve the reliability of data provided, the data was compared with the sales data (substance-oriented) of the manufacturers.

Until the 2001 report 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 report year, the emissions for the report years 1995 to 1998 were reviewed and updated on the basis of new findings on input quantities and emission factors. Such information is often available only after a considerable delay; initially, therefore, it must be estimated. All data is thus being improved on an ongoing basis. To date, the relevant uncertainty has not been systematically quantified.

4.6.1.1.4 Source-specific quality assurance / control and verification (2.F.1)

The data for the 2003 report year, like the data for most of the previous years, was collected by an external expert working in the framework of a research project under commission to the Federal Environmental Agency.
"Emissions and forecast of emissions of HFCs, PFCs and SF_6 in Germany – current status and development of a system for relevant annual determinations." FKZ 202 41 356 and
"Emissions, activity rates and emission factors for fluorinated greenhouse gases (F gases) in Germany for the years 1995-1998: Adaptation to requirements for international reporting, and implementation of the relevant data within the Central System of Emissions (CSE)" FKZ 20141261/01).

For the most part, quality assurance was carried out by an external expert. In addition, where possible, the data is checked by the relevant Federal Environmental Agency specialist upon receipt.

Measures for standardisation of QC/QA are currently being established. The collected data on the size of source-category-specific HFC stocks, on composition of these stocks with regard to various HFC refrigerants, on EF, etc. are subject to continual quality assurance / control and verification, although this process has not yet been standardised. On a regular basis, various sources (environmental statistics[121], production and sales figures[122], etc.) are consulted, and experts (users, refrigerant manufacturers, suppliers, etc.) are consulted to determine the sources' reliability.

4.6.1.1.5 Source-specific recalculations (2.F.1)

Due to the complexity of this area, and of the large number of facilities involved, constant efforts are made to improve the database (breakdown of types of refrigeration systems, of refrigerants and coolants, of numbers of facilities, etc.). The new findings obtained via annual data surveys are continually applied to emissions calculations. As a result, changes occur in emissions figures for previous report years. For the 2003 report year, extensive recalculation on the basis of the then latest knowledge was planned; this recalculation had to be postponed until 2005.

4.6.1.1.6 Planned improvements (source-specific) (2.F 1)

In future, efforts will be made to improve data by means of prompt enquiries regarding consumption levels (repairs, refill quantities, etc.). Such information can then be compared with model data. In view of the large number of systems involved (several million), however, emissions data is likely to remain subject to uncertainties. Additional possibilities for collecting and improving data are currently being evaluated. This includes, inter alia, adaptation of surveys, pursuant to Art. 11 Environmental Statistics Act (UstatG), to reporting requirements, and assessment of IT-based programmes for collecting data on refrigeration systems.

[121] Surveys pursuant to Art. 11 of the Environmental Statistics Act (UstatG).
[122] Surveys pursuant to the Foreign Trade Statistics Act (AHStatGes) and production statistics.

4.6.1.2 Mobile air-conditioning systems (2.F.1)

4.6.1.2.1 Source-category description (2.F.1)

"Mobile air-conditioning systems" comprises vehicle air-conditioning systems in passenger cars, trucks and commercial vehicles, buses, agricultural machinery, rail vehicles and ships. In terms of coolant stocks, consumption and emissions, car systems predominate, accounting for 90 % of each category. Overall, car air-conditioning systems account for about half of all refrigerant emissions (including those from stationary sources). In 2003, this area accounted for a total of 27 % of all HFC emissions. In 2003, mobile air-conditioning systems accounted for about 30 % of HFC emissions.

Since about 1993, partially halogenated CFCs (HFCs) have been used as ozone-neutral substitutes for CFCs and H-CFCs. R134a now accounts for nearly 100 % of the HFC coolant used in mobile air-conditioning systems. In conversion of old R12 air-conditioning systems, a drop-in coolant (mixture) was used instead of R134a in a small proportion of cases; this coolant itself consists of 88 % R134a.

The time series show a significant increase in emissions since 1995. In the area of mobile air-conditioning systems, this increase is directly related to increased use of air-conditioning systems in vehicles, the resulting increased use of HFC and the resulting increasing potential and current emissions.

4.6.1.2.2 Methodological issues (2.F.1)

The total emissions for vehicle air-conditioning systems, for each vehicle model and each refrigerant, comprise sub-emissions in the areas of production, usage and disposal. Emissions in these areas are determined separately.

The procedure for calculating HFC emissions (solely HFC-134a) from mobile air-conditioning systems is described in the Annex, Chapter 14.2.5.2.

Since the 2002 report year, less relevant sources (such as agricultural machinery) have been included for the first time. In another change, carried out for the first time in this report year, only ships sailing under German flags – rather than all German ships – have been taken into account. The resulting changes are marginal, however.

4.6.1.2.3 Uncertainties and time-series consistency (2.F.1)

The quality of data on emissions from mobile air-conditioning systems is quite good; in fact, it is better than that for refrigeration systems and air-conditioning systems.

As a general principle, the above statements on the stationary systems sector also apply here. However, annual levels of HFC consumption may be calculated fairly precisely from statistics that cover the bulk of this sector, including new car registrations, production quantities and imports and exports of cars. Thanks to annual determination of model-specific rates of air-conditioning installation, and of the relevant fill amounts, the AR are very precise. Only in the area of commercial vehicles is the data subject to major uncertainties.

The emission factors previously assumed have been confirmed via the results of an expert report by the Federal Environmental Agency (UBA) and an EU study on leakage rates from mobile air-conditioning systems (ÖKO-RECHERCHE / ECOFYS, 2003). Overall, the EF are

considered to be good. For precise information on uncertainties, the reader is referred to the aforementioned study/report.

4.6.1.2.4 Source-specific quality assurance / control and verification (2.F.1)

The data for the 2003 report year, like the data for most of the previous years, was collected by an external expert working under commission to the Federal Environmental Agency (cf. Chapter 4.6.1.1.4). For the most part, quality assurance was carried out by an external expert. In addition, where possible, the data is checked by the relevant Federal Environmental Agency specialist upon receipt.

Measures for standardisation of QC/QA are currently being established. Since 1993, all data required for calculations (see above) has been collected on an ongoing basis and checked for plausibility; it is not yet subject to standardised quality assurance / control and verification, however.

4.6.1.2.5 Source-specific recalculations (2.F.1)

Only minor recalculations are required for this area. The required recalculations have to do with additional, rather insignificant, sources and with reorganisation of emissions allocation.

4.6.1.2.6 Planned improvements (source-specific) (2.F 1)

Discussion on additional options for improvement is just beginning. Because the relevant data is already very precise, this discussion does not have priority, however.

4.6.2 Foam blowing (2.F.2)

Since 1993, companies have used hydrofluorocarbons (HFCs) as substitutes for ozone-depleting, climate-harming CFCs and H-CFCs. HFC emissions have increased sharply since 1995.

Use of HFCs as blowing agents for foam production is another main source of HFC emissions, accounting for 45 % of such emissions. The entire area is divided into three sub-groups: PU foam products, PU installation foam and XPS hard foam.

4.6.2.1 PU foam products (2.F.2)

4.6.2.1.1 Source-category description (2.F.2)

The sub-category "PU foam products" accounted for 2.1 % of HFC emissions in 2003.

PU foam products are composed of soft foam, integral foam and hard foam. For soft foam, HFC is not required as a blowing agent. HFCs have been used as blowing agents for hard foams only since 1998. Between 1995 and 1997, HFCs were used only for integral foams.

The time series, which does not begin until after 1995, shows a small initial increase in emissions. Both of these factors – the time of commencement and the small initial increase – agree with the historical development of HFC use in this application area, an area which arose only slowly, as a result of the long period of utilisation of H-CFC.

In addition to the HFCs 134a, 245fa and 152a, a new blowing agent is being used: HFC-365mfc, with a small HFC-227ea additive component. HFC-365mfc cannot yet be included in CRF-table reporting, since the specified formats do not take account of it. According to our surveys in 2003, 21.5 t of HFC-365mfc emissions must be allocated to the application "PU foam products" in the 2002 report year, while 21.8 t of such emissions must be allocated to that application in the 2003 report year. Assuming a GWP_{100} of 890 for this substance, these levels correspond to emissions of 0.02 million t CO_2 equivalents in 2002 and 0.02 million t CO_2 equivalents in 2003.

4.6.2.1.2 Methodological issues (2.F.2)

The emissions data consists of:

1. Production emissions for each product group
   (= $EF_{production}$ * new domestic consumption (AR)),
2. Use emissions for each product group
   (= EF_{use} * systems in service (AR)),
3. Disposal emissions (not relevant to data (NO)).

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 is based on the amounts of foam products used in Germany (sales in Germany) since the introduction of HFCs. The data on new domestic consumption and domestic sales of foam products is obtained annually, through surveys of producers, surveys of users, association information, etc.. The EF on which emissions data is based are shown in Table 51.

The emission factors used are largely in keeping with the IPCC's published default values (D). They have been checked with national experts, however, and adjusted in part.

4.6.2.1.3 Uncertainties and time-series consistency (2.F.2)

The emissions data for prior years is considered fairly accurate, since the quantities of HFCs used are still rather small at present. In future, however, it will become more difficult to obtain a good market overview in view of the anticipated product diversity.

It is not possible to quantify the uncertainties for the EF and the AR. While the EF are considered sufficiently precise, the AR are subject to considerable uncertainties, due to the product diversity involved. Because use of HFCs is still limited, however, the market can still be studied well via surveys and estimates.

4.6.2.1.4 Source-specific quality assurance / control and verification (2.F.2)

The data for the 2003 report year, like the data for most of the previous years, was collected by an external expert working under commission to the Federal Environmental Agency (cf. Chapter 4.6.1.1.4). For the most part, quality assurance was carried out by an external expert. In addition, where possible, the data is checked by the relevant Federal Environmental Agency specialist upon receipt.

Measures for standardisation of QC/QA are currently being established.

4.6.2.1.5 Source-specific recalculations (2.F.2)

HFCs have only been in use since 1996, and thus only the data for the report years 1998 to 1996 is reviewed within the context of emissions surveys for the 2001 report year. The results have not yet been entered into the CSE database; this is expected to be carried out by the next report. In all likelihood, no additional recalculations will be required.

4.6.2.1.6 Planned improvements (source-specific) (2.F.2)

New possibilities for data collection are currently being evaluated. A first assessment of these possibilities has shown that it may be possible to obtain the AR for "new domestic consumption" via the Environmental Statistics Act (UstatG). At present, it is unclear whether data obtained in this manner will be available on time for reporting and whether it will be possible to take account of all HFC users relative to PU-foam production. Furthermore, it has emerged that existing statistics cannot be used to survey imports and exports of foams – and, thus, to survey domestic sales – since these statistics do not differentiate between the various relevant blowing agents. An effort is being made to find other solutions in this area.

4.6.2.2 PUR foam (2.F.2)

4.6.2.2.1 Source-category description (2.F.2)

The sub-category "PUR foam" accounted for 15 % of HFC emissions in 2003.

Germany is the world's largest single market for polyurethane foam in can form. Can sizes of between 300 and 750 ml[123] are sold. HFC and propane/butane are used in conjunction with dimethyl ether (DME) as propellants. In Germany and, generally, in central Europe, industry has reduced its HFC use, largely for economic reasons. Increasingly, HFC-152a – which has a lower greenhouse gas potential – is being used instead of HFC-134a. In addition, per-can quantities of HFCs have been reduced by increasing proportions of flammable propellants.

The time series for this application begins before 1995, due to the early discontinuation of CFC use in this area, and it shows a decreasing emissions trend. This is due to continuous reduction of HFC quantities per can (through increased use of halogen-free propellants).

4.6.2.2.2 Methodological issues (2.F.2)

In computational terms, an average can has a foam weight of 660 g, approximately 18 % of which is propellant. In 1997, propellants were mixtures of which approximately 40 % consisted of the highly flammable gases propane, butane, and dimethyl ether (DME), and approximately 60 % consisted of HFCs, which are low-flammable (152a) or non-flammable (134a). Proportions of HFCs in propellants have been decreasing since 1995: In 1995, the HFC component in a 660-g can weighed 84 grams, while in 1997 it weighed only 75 g. Today, cans often contain less than 50 g of HFCs. On the average for all cans (winter foams, pistol foams, etc.), each can contains nearly 40 g of HFCs.

When calculating emissions, it is assumed that cans are used promptly by the professional craftsmen or do-it-yourselfers who buy them. In conformance with the IPCC Guidelines (IPCC Reference Manual, 1996b: p. 2.52) the HFC emissions of year n are thus considered equal to the sales for year n.

The following data is obtained for calculation of emissions from use (surveys of experts and manufacturers):

1. Domestic can sales,
2. Average amount of HFC per can,
3. Contained fractions of the propellants 152a and 134a.

Along with usage emissions, filling losses from domestic production must also be considered, for the year in question n. For calculation of these losses, experts are surveyed regarding HFC consumption for production.

The EF on which the emissions data is based are listed in Table 51. The $EF_{production}$ was determined via surveys of experts and manufacturers. In keeping with the IPCC method (IPCC 1996b, 2.52), it is assumed that all HFCs used are emitted. 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 propellant. The bulk of this propellant eventually enters the atmosphere after a certain delay. The same also applies to the cans that, in Germany, are brought to the central recovery plant for PU foam cans. In contrast to the IPCC method, it is assumed that all emissions occur in the year of sale, since use and disposal occur promplty.

The consumption quantities are based on sales (cans) and on the average quantity of HFCs per can.

4.6.2.2.3 Uncertainties and time-series consistency (2.F.2)

In the NIR 2003, it was noted that manufacturers' figures on amounts of contained HFC tended to be considered low. In 2004, it was again impossible to verify the manufacturers' figures with any conclusiveness. New information from a Swiss producer and from a recycling company (for the years 2003 and earlier) did lead to changed assumptions and AR, however – also for earlier years.

4.6.2.2.4 Source-specific quality assurance / control and verification (2.F.2)

Cf. Chapter 4.6.2.1.4.

4.6.2.2.5 Source-specific recalculations (2.F.2)

In the 2001 report year, recalculations were carried out, on the basis of discussions with the "Working Group on Polyurethane Foams", concerning the quantities of HFCs in individual cans and the ratio between 152a and 134a in HFC composition. Due to existing uncertainties, recalculations may again be necessary in the next report year.

4.6.2.2.6 Planned improvements (source-specific) (2.F.2)

The procedure corresponds to the Tier 2 approach. Data is available for domestic production, exports and imports. Additional verification is needed solely with regard to the average HFC quantity. Co-operation with manufacturers has not been possible to date.

[123] Since 2003, the largest size is normally only 600 ml.

4.6.2.3 XPS hard foam (2.F.2)

4.6.2.3.1 Source-category description (2.F.2)

The sub-category "XPS hard foam" accounted for nearly 30 % of all HFC emissions in 2003.

For XPS boards, no consumption or emissions of HFCs occurred prior to 1999, since H-CFCs or CO_2 were still being used at that time.

As of 2000, some domestic producers switched to HFCs. Since 2001, 152a and 134a have been used as blowing agents, either alone or mixed together, in addition to CO_2.

The time series, which does not begin until after 1995, shows a considerable increase in emissions. Both factors – the time of commencement and the increase in emissions – agree with the historical development of HFC use in this application.

4.6.2.3.2 Methodological issues (2.F.2)

The total emissions from this area consist of:

1. Production emissions (= $EF_{production}$ * new domestic consumption (AR)),
2. Use emissions (= EF_{use} * systems in service (AR)),
3. Disposal emissions (not relevant to data (NO)).

The basic data for determining new domestic HFC consumption consists of the total volume of XPS insulation foam (in m^3) produced annually with the two HFCs in question (134a and 152a).

In the case of 134a, 3.2 kg are required for production of one cubic metre of XPS foam; in the case of 152a, 3.0 kg are required. From these figures, as well as from the total amounts of XPS in m^3 (see above) produced annually with HFCs, the relevant new HFC consumption can be calculated.

The amount of HFC lost in the first year following production (production emissions) is calculated from the $EF_{production}$ and the annual new domestic consumption. The EF on which the emissions data is based are listed in Table 51. The $EF_{production}$ for HFC-152a is practically 100% (=1); i.e. this is a case of direct, open application. With HFC-134a, only part of consumption is emitted upon blowing; most of the substance enters into the product. Empirically, $EF_{production}$ was found to be 30% in 2001, 27% in 2002 and 26% in 2003. A total of 25% of domestic consumption is considered a desirable value. Collection and recovery trials have been conducted, but to date no relevant systems have been implemented, for both technical and economic reasons.

Use emissions are calculated from the average amount of HFCs in XPS insulating foams in domestic service. This amount increases annually through new addition of insulating boards containing 134a. Given a product lifetime of 50 years, removals from products in service do not yet play any significant role. New additions of HFC products do not correspond to the annual new consumption, less production emissions, since foreign trade has a considerable impact on potential new additions. For XPS products containing 134a, Germany is far and away a net exporter. The adjusted export rate [124] for domestic production amounted to 75%

[124] "Adjusted" means that the balance of exports and imports of products containing 134 is used.

for the years under consideration. In other words, the new HFC additions to the HFCs in domestic service consist of only 25% (the complement of the export rate) of the HFC-134a contained in products, following the blowing process.

The mean amount of HFC in service for a given year n is half of the sum of the final amount for the previous year, n-1, and of the final amount for the current year, n.

All of the activity data were provided by the German industry association FPX, by Dow, the market leader and by the European Extruded Polystyrene Insulation Board Association (EXIBA). The data was compared with that of other manufacturers.

The $EF_{production}$ were reported by the industry association at both the German and European levels (FPX and EXIBA).

The spokesman for the FPX industry association estimated annual degassing from enclosed HFC-134a cell gas as amounting to less 1 % – 0.66 % ($EF_{production}$ = 0.0066) in 2002. This figure is based, inter alia, on an internal BASF study on the half lives of the cell gases CFC-12, H-CFC-142b, H-CFC-22, HFC 134a and HFC 152a (WEILBACHER 1987). The study found that 134a degases with about the same speed as H-CFC-142b, while H-CFC-22 and HFC-152 degas virtually immediately. Fugitive emissions from boards depend on board thickness, and they can be given only as average values, or as values for specific board thicknesses. In the case of 134a, the half-life for 70 mm boards is about 35 years. It increases exponentially with increasing thickness. The figure of 0.66 % refers to medium board thickness.

4.6.2.3.3 Uncertainties and time-series consistency (2.F.2)

It is not possible to quantify the uncertainties for the EF and the AR. Because it includes only a small number of manufacturers, the German XPS market is not complex. Since the EF and AR were prepared in co-operation with manufacturers, they are considered sufficiently precise.

Since 2001, the industry association has carried out research to determine production of XPS (AR) and consumption of the two HFCs 152a and 134a (AR). 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 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. For 2001 and 2002, the data for direct losses in use of 134a was based on measurements carried out by Dow Deutschland at its Rheinmünster plant. The rate of emissions from products in service (EF_{use}; 0.66%) lies within the range of customary estimates of 1%. But since results from a laboratory study yield a value of about 0.66%, this value will be used as long as no reliable measurements with insulating boards in actual service have been carried out; such measurements could be considered more conclusive than laboratory values.

Production emissions develop proportionally to the annual domestic HFC consumption.

The time series presented in Table 54 shows the mean annual volume in service. The mean annual amount of HFC-134a in domestic service in XPS insulating boards was first

determined in 2001. As expected, this figure increased sharply in the second and third years of application.

Table 54: Mean amount of HFC-134a in XPS insulation in Germany

Year	Mean amount of 134a in service [t]
2001	144
2002	471
2003	842

4.6.2.3.4 Source-specific quality assurance / control and verification (2.F.2)

Cf. Chapter 4.6.2.1.4.

4.6.2.3.5 Source-specific recalculations (2.F.2)

No recalculations have been carried out.

4.6.2.3.6 Planned improvements (source-specific) (2.F.2)

The option of a monitoring system, with formalised data transmission, is currently being discussed with the manufacturers and industry associations. This process is just getting underway.

New possibilities for data collection are currently being evaluated. A first assessment of these possibilities has shown that it may be possible to obtain the AR for "new consumption" via the Environmental Statistics Act (UstatG). At present, it is still unclear whether the data obtained via this pathway will be available in time for reporting. And existing statistics cannot be used to survey imports and exports of foams – and, thus, to survey domestic sales – since these statistics do not differentiate between the various relevant blowing agents.

4.6.3 Fire extinguishers (2.F.3)

4.6.3.1 Source-category description (2.F.3)

The sub-category "fire extinguishers" accounted for nearly 0.02 % of all HFC emissions in 2003.

Halons, which were permitted as fire extinguishers until 1991, have since been largely replaced by ecologically sound substances. In interior room sprinkler systems, inert gases (nitrogen, argon) are normally used instead of halon 1301. Hand-held fire extinguishers that produce a targeted jet of extinguisher now contain powder, CO_2 or foam instead of halon 1211.

HFC-227ea, one of the of the substances proposed by the U.S. as halon substitutes (HFC-23 and 236fa, HFC-227ea, PFC-218 and PFC-3110), was licensed in Germany in 1997. It is sold under the commercial name "FM-200" – essentially, by one licensed company. A further HFC (HFC-23) was licensed in the year 2002 but has not been used to date. HFC 236fa, which has been certified since 2001 for use in Germany, is used only in the military sector.

The time series, which do not begin until after 1995, show increasing emissions; this is in agreement with increasing use of HFCs as fire extinguishing agents.

4.6.3.2 Methodological issues (2.F.3)

The emission figures for HFC 227ea are based on statistical surveys by one company, covering the aspects of input quantities, refill quantities, accidental releases, releases in case of a fire, and trial floodings in Germany (by analogy to Tier 2). As a result, the entire market is not covered, since there is another seller. This seller has a very small market share, however. This seller is taken into account via addition of about 5 % (already included in the data; estimate of the market leader).

The figures for HFC-236fa are based on obligations, at set forth in certifications, to report to the certification authority.

The IEF_{use} for HFC-227ea is calculated from the emissions data for the year in question, the annual amounts used (AR) and the mean annual amount in service. The EF_{use} for HFC-236 is estimated to be the same. The calculated IEF produces a false picture, since releases are still taking place, on a considerable scale, via tests.

The $EF_{production}$ are based on experts' estimations.

4.6.3.3 Uncertainties and time-series consistency (2.F.3)

The data on HFC-227ea and HFC-236 is considered good and very good, respectively.

4.6.3.4 Source-specific quality assurance / control and verification (2.F.3)

Cf. Chapter 4.6.2.1.4.

4.6.3.5 Source-specific recalculations (2.F 3)

No recalculations have been carried out.

4.6.3.6 Planned improvements (source-specific) (2.F.3)

No improvements are required at present.

4.6.4 Aerosols / metered dose inhalers (2.F.4)

4.6.4.1 Metered dose inhalers (2.F.4)

4.6.4.1.1 Source-category description (2.F.4)

The sub-category "metered dose inhalers" accounted for nearly 3.4 % of all HFC emissions in 2003.

In Germany, the first metered-dose inhaler containing the propellant 134a was introduced on the market in April 1996; it was followed by two more such inhalers in 1997 and 1998. Enough HFC-powered metered-dose inhalers are now available for almost all active-ingredient groups, and thus use of CFCs in this area is no longer required. In addition to HFC-134a, HFC-227ea is also used.

The time series does not begin until 1996, the year when HFCs were first used in this area, and it shows increasing emissions, which agrees with increasing use of HFCs as substitutes for CFCs. A large change occurred in 2001. As of that year, CFCs were prohibited for the

largest group of active ingredients, the short-acting beta-mimetics. In light of the increasing use of dry powder inhalers, it is likely that former CFC usage levels of over 400 t/a will no longer be reattained – at least for the medium term.

4.6.4.1.2 Methodological issues (2.F.4)

The emission data is based on figures on sales of metered-dose inhalers in Germany, as obtained via surveys of producers. A surcharge factor of 13% is applied for hospitals and doctors' samples.

In agreement with IPCC specifications (IPCC, 1996b, 2.61), a 100% emissions level (EF_{use} = 1) is assumed; this is appropriate and justified. Inhaled HFCs are not broken down in bronchial passages; they are released into the atmosphere, without undergoing any changes, upon exhalation.

Apart from doctors' samples, metered dose inhalers are purchased from chemists/pharmacies (Apotheken), for direct subsequent use. As a result, the time period between pharmacy sales and use is short. The reference figure for emissions – in contrast to IPCC equation 3.35 (IPCC, 2000) – thus is not the sum of half the purchases (sales) of year n-1 and half those of year n. That approach would be appropriate if the data were for produced, rather than sold, inhalers, since considerable amounts of time (for transport and storage) do pass between production and use.

The production emissions are added to the usage emissions. The EF_{use} on which production emissions is based is itself based on very precise producer determination of filling emissions. These amount to about 1%, with respect to new consumption for filling. This translates to about 0.15 g per 10 ml inhaler. Part of the emissions are collected with cold traps and then incinerated. Without such collection, the emissions would be higher.

4.6.4.1.3 Uncertainties and time-series consistency (2.F.4)

The data is considered to be of good quality. The reliability of sales data is considered high.

The surcharge factor for hospitals and doctors' samples can vary, by ±2%, from the above-cited 13%.

4.6.4.1.4 Source-specific quality assurance / control and verification (2.F.4)

Cf. Chapter 4.6.2.1.4.

4.6.4.1.5 Quellenspezifische Rekalkulation (2.F.4)

No recalculations have been carried out.

4.6.4.1.6 Planned improvements (source-specific) (2.F.4)

No further improvements are planned at present.

4.6.4.2 Other aerosols (2.F.4)

4.6.4.2.1 Source-category description (2.F.4)

The sub-category "other aerosols" accounted for nearly 4.5 % of all HFC emissions in 2003.

In Germany, six types of general aerosols (includes neither medical sprays nor novelties) containing HFC are sold:

- Compressed-air sprays (30-40%),
- Cooling sprays (30 %),
- Drain-opener sprays (30%),
- Lubricant sprays (2%),
- Insecticides (2%) and
- Self-defence sprays (2%).

Emissions from such sprays amounted to about 170 t in 2003. To these must be added "novelty" sprays (artificial snow, streamer sprays, etc.), which emit about 100 t HFC/year.

4.6.4.2.2 Methodological issues (2.F.4)

The usage emissions data is based on estimates of aerosol sales in Germany, obtained via surveys (producers/fillers, association). In keeping with IPCC specifications (IPCC, 1996b, 2.61), a 100% emissions level ($EF_{use} = 1$) is assumed; this is appropriate and justified. Of the sprays sold in Germany, it is assumed that one-half are used in the same year they are purchased and the other half are used in the following year.

Emissions for general aerosols also include filling emissions (= production emissions). The $EF_{production}$ is based on experts' estimations. No novelties are produced in Germany.

4.6.4.2.3 Uncertainties and time-series consistency (2.F.4)

In comparison to the emission data on metered-dose inhalers, this data is not considered to be very 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. At present, the uncertainties cannot be quantified.

Since the shift from CFCs to chlorine-free propellants had already been completed by the beginning of the 1990s, the time series has been largely unchanged since 1995.

4.6.4.2.4 Source-specific quality assurance / control and verification (2.F.4)

Cf. Chapter 4.6.2.1.4.

Collected data is checked for plausibility via comparison with data from the previous year; the reasons for any marked changes are explored.

4.6.4.2.5 Source-specific recalculation (2.F.4)

No recalculations have been carried out.

4.6.4.2.6 Planned improvements (source-specific) (2.F.4)

Improvements have been initiated in collaboration with the industry association. In addition, the possibility of using additional data sources is being reviewed. A first assessment of such data sources has shown that it may be possible to obtain the AR for "new consumption" via the Environmental Statistics Act (UstatG). And existing statistics cannot be used to survey

imports and exports – and, thus, to survey domestic sales – since these statistics do not differentiate between the various relevant propellant gases.

4.6.5 Solvents (2.F.5)

4.6.5.1 Source-category description (2.F.5)

The sub-category "solvents" accounted for 0.02 % of all HFC emissions in 2003.

Use of HFCs as solvents was banned in Germany up until the year 2001 (2nd Ordinance on the Implementation of the Federal Immission Control Act – 2. BimSchV) and remains heavily restricted to this day, since individual applications must be submitted for each form of use. The applications are examined, and approval is only granted in exceptional cases. Virtually no applications are known to date. Due to the very minor importance of this sub- source category, a detailed description is not provided. The emissions figures are based on sales data from the authorised seller. $EF_{use} = 1$. The reader's attention is called to Table 51.

4.6.6 Other (2.F.6)

4.6.6.1 Semiconductor manufacturing (2.F.6)

4.6.6.1.1 Source-category description (2.F.6)

In 2003, semiconductor manufacturing (including circuit boards, an area no longer considered separately later on, due to its low relevance) accounted for 30% of all PFC emissions, 0.02 % of all HFC emissions and 1.4% of all SF_6 emissions.

The semiconductor industry currently emits PFCs (CF_4, C_2F_6, C_3F_8, c-C_4F_8), HFCs (CHF_3), nitrogen trifluoride (NF_3) and 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 relevant emissions cannot be determined solely on the basis of the quantities used (sales by the gas trade). The difference between consumption and emissions results, firstly, in that only partial chemical conversion occurs in plasma reactors and, secondly, from the effects of downstream gas purification systems. Furthermore, a residue of approximately 10 % per gas bottle must be taken into account as non-consumption. The effective emissions depend primarily on the waste-gas-scrubbing technologies used.

The time series shows a continual increase in emissions until the year 2000. One of the reasons for this is that the number of reporting companies doubled from 1995 to 1999 – from seven to 14. This group includes not only new plants; it also includes plants that were already producing in 1995 but not yet participating in monitoring (no extrapolations were carried out). For this reasons, emissions prior to 1999 were systematically underreported. Emissions increased again in 2002, following a significant decrease in 2001. The decrease is due to economic influences (reduction of semiconductor production) and, possibly, to the effects of emissions-reduction measures. Before any differentiated assessment can be carried out, further developments will have to be awaited.

4.6.6.1.2 Description of methodology (2.F.6)

As the result of a voluntary commitment by the semiconductor industry, good emissions figures are available for this sub- source category, for all individual substances, from the year 2001 onwards. In keeping with a standardised calculation formula (Tier 2c approach), the emissions data is 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) to the Federal Environmental Agency. The basic data for calculation, the the emissions data, is not publicly accessible, but it may be inspected for review purposes. Since only emissions – and not the underlying consumption – are reported, no IEF can be provided/calculated.

4.6.6.1.3 Uncertainties and time-series consistency (2.F.6)

In general, the data is considered to be of very good quality.

Until the 2000 report year, emissions data was 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. This emissions data is likewise considered to be fairly accurate.

4.6.6.1.4 Source-specific quality assurance / control and verification (2.F.6)

Cf. Chapter 4.6.2.1.4.

In addition, the data has been checked for plausibility, and the association has subjected it to an internal quality assurance / control and verification process.

4.6.6.1.5 Source-specific recalculation (2.F.6)

No recalculations have been carried out.

4.6.6.1.6 Planned improvements (source-specific) (2.F.6)

Efforts are being made, in collaboration with the industry association, to specifiy data-collection, emissions-calculation and documentation procedures precisely.

4.6.6.2 Electrical equipment (2.F.6)

4.6.6.2.1 Source-category description (2.F.6)

The sub-category "electrical equipment" accounted for 14 % of all SF_6 emissions in 2003.

Electrical equipment for power supply is by far the largest single consumer of SF_6 in Germany. Given the high export ratio of over 80 %, however, only a small proportion of consumption is added to new equipment and systems in the national inventory.

SF_6 is used primarily in switching systems and equipment in high-voltage (110-380 kV) and, increasingly, in medium-voltage (10-30 kV) networks. The gas, which is used instead of air,

serves as both a fire retardant and insulator. It is not commonly used in the low-voltage segment (< 1 kV).

Furthermore, SF_6 is used in components manufacture.

As a result of first-time inclusion, in the 2002 report year, of additional SF_6 applications, the time series shows a marked jump in emissions in 2002. In contrast to the high-voltage sector, which is growing only slowly, the medium-voltage sector is growing dynamically. The volume of products in service increased sharply from 1995 to 2003. Due to the low EF_{use} (see above) involved, the relevant emissions grew to a smaller degree.

4.6.6.2.2 Description of methodology (2.F.6)

Since 1996, emissions have been determined on the basis of a highly detailed concept developed by the Federal Environmental Agency in collaboration with manufacturers and operators. The installed quantity at the end of a given year and the emissions at the relevant individual sources (manufacturers' factory losses, manufacturers' assembly losses, leakage at operators' facilities (including maintenance), and disposal) are ascertained:

1. SF_6 emissions in production

Production emissions are determined separately, in keeping with their occurrence at the plant or installation site of the relevant domestic operator:

a) Domestic plant losses, especially losses occurring in development and in filling for product checks (about 95% of production emissions), broken down by high-voltage gas-insulated switching systems, high-voltage power switches, medium-voltage switching systems and high-voltage/medium-voltage components.

b) Domestic installation / assembly losses (ca. 5%) for high-voltage-gas-insulated switching systems, high-voltage power switches, medium-voltage switching systems and outdoor high-voltage transformers. In components that are part of high-voltage gas-insulated switching systems (inlets, voltage converters), no losses occur in assembly that are not counted with those for high-voltage gas-insulated switching systems.

Until NIR 2003, domestic plant and assembly/installation losses were considered; these, in turn, were broken down by high-voltage gas-insulated switching systems, high-voltage power switches and medium-voltage switching systems – i.e. products that go directly to domestic or foreign operators. Reporting did not include emissions from production of components purchased by switching-system manufacturers (such as transformers and inlets for high-voltage gas-insulated switching systems, medium-voltage converters). Emissions from production of outdoor transformers were also not reported. Via intensive discussion (monitoring, measures), SF_6 applications in component production were identified; these were included in reporting for the first time in the 2002 report year.

The emissions data is based primarily on a mass balance and not on the calculation using EF and AR.

2. Usage emissions

Ongoing emissions from products in service include the amount of SF_6 in service, as accumulated since 1970 via annual additions of switching systems; they are given as the

average for year n. This mean amount in service for a given year n is half of the sum of the final amount for the previous year (n-1) and of the final amount for the current year (n).

The final amount of SF_6 in all electrical equipment for a given year n changes annually by the balance of new additions and removals. Some removals (high voltage) have been registered since 1997; systematic removals of products from entire years cannot be expected before 2010, in light of the products' estimated 40-year service lifetime.

Three special aspects must be taken into account in reporting relative to switching systems.

a) 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 switching systems, because operators/manufacturers estimated the SF_6 stocks in service for 1995. Their estimate was broken down into high voltage and medium voltage (770 t and 157.6 t, respectively).

b) In the area of high voltage, stocks in service and emissions are determined not via the above-cited equation but via regular direct surveys of the some 100 operators. These operators are surveyed directly with regard to their current stocks of SF_6 in operating equipment (gas-insulated switching systems, power switches, outdoor converters) and to their annual refilling (for operating equipment) to compensate for emissions.

c) The group of operators of medium-voltage switching systems is very numerous and highly diverse. It is thus not feasible to conduct direct surveys. Manufacturers of medium-voltage systems have themselves taken responsibility for updating their domestic stock data on the basis of their sales data. Emissions determination is possible in that the systems are practically maintenance-free and have only minimal emissions (usually only as a result of external influences), emissions that can be taken into account by means of a lump-sum emissions factor (survey 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 considered not only "closed for life", but also "sealed for life". As a result, the impact of older systems with emissions rates greater than 0.1% has diminished.

3. Disposal emissions

Because switching systems have long service lifetimes (40 years), and because the first use of SF_6 dates from the late 1960s, disposal emissions are just now beginning to occur, on a small scale. The amounts of SF_6, from old high-voltage systems, that now need to be disposed of thus simply have been roughly estimated to date (at a constant 3 t/a). As of the 2004 report year, amounts for disposal from systems removal are being determined precisely for the first time. For this reason, plans call for first provision of a precise methods description next year.

4.6.6.2.3 Uncertainties and time-series consistency (2.F.6)

Since there are only about ten different manufacturers of high-voltage operating equipment (including inlets and transformers), the consumption data is very reliable – especially since, in principle, the data consists of purchasing data for which internal records are kept.

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 for testing, in empyting of devices following 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, as well as 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.

The data for the medium-voltage sector can be considered very reliable, since it is based on sales data. Each company keeps lists of the numbers of switching systems it sells within the country each year, together with the pertinent standard SF_6 fill amounts.

Emissions from production of switching systems and devices have decreased markedly since 1995. The implicit emission factor decreased from 5.5% in 1995 to 1.9% in 2002. The main reason for this consists of considerably reduced plant losses in connection with high-voltage gas-insulated switching systems. This, in turn, is a result of more careful plant handling of SF_6. Domestic installation losses ("on site") have decreased sharply for all products – and, again, most sharply for high-voltage gas-insulated switching systems.

The emissions rate of 0.1% in the medium-voltage sector may be considered acceptable for the stocks from recent years. Since the Association of German Network Operators (VDN) has always, in its surveys, included queries concerning refills of medium-voltage systems, samples for checking can now be taken: VDN documents show SF_6 losses of only 0.06% for medium-voltage switching systems (circuit breakers) in the years 1998/1999.

Emissions in the high-voltage sector are determined via refilling, which is carried out by operators' own personnel or by manufacturers' service networks. (Refilling is carried out when the fill level drops below 90% of the desired fill level; normally, devices are equipped to show any need for refilling). This method can be considered very reliable, i.e. the deviations from the actual value are about ±10%. All surveys to date have produced similar results for emissions; all results are within a range from 0.88 to 0.82%.

In the year 2000, an unusual development occurred in high-voltage in-service stocks and, thus, in emissions, both of which had been increasing since 1995: a decrease with respect to the previous year. For in-service stocks, the decrease amounted to over 25 t, while for emissions it amounted to 0.85 t. This decrease, which is due to trends in high-voltage gas-insulated switching systems (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 VDN, which carries out the surveys, 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 these changes, the staff responsible for operating equipment in service was repeatedly replaced. As a result, it is possible that double-counting occurred in 1999, and that some operating equipment was not counted in 2000.

4.6.6.2.4 Source-specific quality assurance / control and verification (2.F.6)

Cf. Chapter 4.6.6.1.4.

4.6.6.2.5 Source-specific recalculation (2.F.6)

Since insufficient information is available about the quantities used, in past years, in the "new" applications, no recalculations have been carried out. Extensive recalculations are planned for the NIR 2006.

4.6.6.2.6 Planned improvements (source-specific) (2.F.6)

Discussion is currently in progress, within the EU, on standardisation of existing monitoring systems. Similar discussion is being carried out in connection with revision of the IPCC guidelines for reporting. In the process, discussion on the German monitoring system is being welcomed. Proposals for improvement that emerge from such discussion could thus lead to changes in the monitoring system.

4.6.6.3 Sports shoes (2.F.6)

4.6.6.3.1 Source-category description (2.F.6)

The sub-category "sports shoes" accounted for 3% of all SF_6 emissions in 2003. SF_6 is used in soles of athletic shoes in order to improve shock absorbency.

4.6.6.3.2 Description of methodology (2.F.6)

The emissions data (relevant sales of such sports shoes in Germany and, hence, the total quantity in Germany) is based on manufacturers' information with regard to the EU. These figures have been broken down, on the basis of Germany's population, to obtain figures for Germany. The data has been available to the Federal Environmental Agency since the 2001 report year, but it is published only in aggregate form, for reasons of confidentiality.

The emissions may be considered equivalent to the amounts used, although, by analogy to the IPCC method (IPCC, 2000: Equ. 3.23) for automobile tyres, a delay of three years is assumed.

4.6.6.3.3 Uncertainties and time-series consistency (2.F.6

In spite of the good quality of the data for the EU, the breakdown by Member States is subject to not inconsiderable uncertainties.

The relevant uncertainties cannot be quantified.

4.6.6.3.4 Source-specific quality assurance / control and verification (2.F.6)

This is not carried out, due to the insignificance of this emissions source.

4.6.6.3.5 Source-specific recalculation (2.F.6)

No recalculations have been carried out.

4.6.6.3.6 Planned improvements (source-specific) (2.F.6)

No improvements are needed. SF_6 was used for the last time in 2003.

4.6.6.4 AWACS (airborne warning and control system) maintenance (2.F.6)

4.6.6.4.1 Source-category description (2.F.6)

The sub-category "AWACS maintenance" accounted for 4% of all SF_6 emissions in 2003.

SF_6 is used as an insulating medium for radar in 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. The emissions data is based on information provided regarding quantities consumed in filling/refilling NATO's NAEWF fleet. The emissions figures for report years until 2001 are based on estimates made via a 1996 survey. The emissions data for the years 1997 to 2001 is thus imprecise. New surveys of consumption quantities were carried out for the 2002 report year. They showed a significant increase over the 2001 report year.

A detailed description is not provided, however, due to the low significance of this sub-source category.

4.6.6.5 Automobile tyres (2.F.6)

4.6.6.5.1 Source-category description (2.F.6)

The sub- source category "automobile tyres" accounted for 3% of all SF_6 emissions in 2003.

In the past, automobile tyres were filled with SF_6 for reasons of image (the resulting improved pressure constancy is not relevant in practice). Because of the climate relevance of SF_6, tyre manufacturers have stopped advertising this application. This has led to a considerable reduction. The bulk of today's emissions originates from gas in old tyres.

The peak consumption year was 1995, when over 500 of the 3,500 or some tyre-sales outlets in Germany had the option of filling tyres with SF_6 gas. Emissions are determined on the basis of consumption quantities, which are obtained from gas dealers and manufacturers (SF_6). In each case, emissions follow consumption with a time lag of approximately 3 years, when the tyre is dismantled. This assumption is in keeping with the IPCC method (cf. Table 51).

A detailed description is not provided, however, due to the low significance of this sub-source category.

4.6.6.6 Insulating glass windows (2.F.6)

4.6.6.6.1 Source-category description (2.F.6)

The sub-category "insulating glass windows" accounted for 27% of all SF_6 emissions in 2003.

Insulated multiple glazing gained popularity over single-glazing for windows and glass facades in the 1970s, and since 1975 SF_6 has been filled into the cavity between the glazing to enhance noise insulation. At present, emissions from sound-proof windows represent the largest source of SF_6 emissions. However, the slight improvement in soundproofing obtained by using SF_6 tends to have a negative effect on thermal insulation performance. The higher priority given to thermal insulation – e.g. by the Thermal Insulation Ordinance

(Wärmeschutzverordnung) – along with awareness of the higher greenhouse potential of SF_6, have led to a reduction in use of SF_6 in this application since the mid-1990s.

The decreases in production emissions result from decreases in consumption and are proportional to them. They respond very flexibly to changes in consumption. Unlike emissions from in-service stocks or disposal, this form of emissions is immediately terminated by discontinuation of filling. The time series for emissions from in-service stocks and disposal reflect use in previous years.

4.6.6.6.2 Description of methodology (2.F.6)

The emissions data consists of:

1. Production emissions (= $EF_{production}$ * new domestic consumption (AR)),
2. Use emissions (= EF_{use} * systems in service (AR)),
3. Disposal emissions ($EF_{disposal}$ * remaining products (n-25)).

Production emissions (filling losses resulting from overfilling) occur solely in the year of relevant production. Experts indicate that in filling of cavities between panes, about one-third of the SF_6 consumed is lost. The $EF_{production}$ is thus 33%, with respect to new annual consumption. 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 the average, i.e. throughout the entire spectrum of filled windows, of all shapes and sizes, the overfill level amounts to 50% of the amount actually contained between the panes. This represents one-third (33%) of the relevant consumed amounts.

Since the technique used to fill windows (slow inflow via a drilled hole or pried-open crack, usually from the bottom to the top, and at atmospheric pressure) has remained unchanged for many years, and since the spectrum of window shapes has not changed significantly, it is unlikely that the emission factor has changed. It is treated as a constant.

The new annual consumption is determined via top-down survey (domestic sales by the gas industry)

Use and "stock" emissions consist of gas losses from filled panes; they total approximately 1 % per annum throughout panes' entire service lifetimes, which average 25 years. The final SF_6 stocks for year n change annually, through additions and removals. Since the products' service lifetime is 25 years, systematic removals did not begin until 2000. Ongoing emissions from products in service refer to the total amount of SF_6 in service, as accumulated since 1975 via annual additions in installed windows; they are given as the average for year n. This mean amount in service for a given year n is half of the sum of the final amount for the previous year (n-1) and the final amount for the current year (n).

A DIN standard (DIN, 1989: DIN 1286, Part 2) specifies an upper limit of 10 per mil for annual losses of filled gas from panes' peripheral seals. Experts agree that the actual gas losses are normally considerably lower, as long as windows remain intact. Nonetheless, a level of 1 % ongoing gas losses may be considered realistic, in light of the need to take

account of glass breakage during transport, installation and use, and of leakage from peripheral seals, which increases with windows' age.

Finally, disposal losses are incurred at the end of panes' service lifetimes (utilisation periods), or an average of 25 years after the filling emissions. Since each year a window loses 1 % of its gas level from the previous year, windows dating from a given year will no longer contain their original filling when they are disposed of 25 years later; their fill levels will have been reduced by 25 ongoing per-year losses. Since no recycling takes place, the entire amount disposed of becomes emissions ($EF_{disposal} = 1$).

4.6.6.6.3 Uncertainties and time-series consistency (2.F.6)

The data for annual new consumption, which is based on commercial sales data, may be considered sufficiently reliable and complete. For practical reasons, producers' sales data cannot be used as bottom-up check sample – the number of producers, at nearly 400, is too large.

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, virtually conclusively, that the mean filling loss ranges between 30 % and 40 %.

A 1 % rate is considered realistic for ongoing gas losses (see above).

4.6.6.6.4 Source-specific quality assurance / control and verification (2.F.6)

Cf. Chapter 4.6.2.1.4.

In 2001, quality assurance / control and verification were carried out via plausibility control, with the aid of the calculation model.

4.6.6.6.5 Source-specific recalculation (2.F.6)

No recalculations have been carried out.

4.6.6.6.6 Planned improvements (source-specific) (2.F.6)

Because prohibition of this application is expected, no further improvements are planned.

4.6.6.7 Trace gas (2.F.6)

4.6.6.7.1 Source-category description (2.F.6)

In 2003, the sub- source category "trace gas" accounted for 0.3% of SF_6 emissions.

SF_6, as a stable and readily detectable trace gas, even at extremely low concentrations, is used to investigate ground-level and atmospheric airflows and gas dispersions. Emissions may be equated with the quantities used. The quantities used are determined via experts' estimations. Relevant surveys are conducted only around every five years (1996, 2002) since, according to experts, the quantities used vary only minimally.

A detailed description is not provided, however, due to the low significance of this sub-source category.

4.7 Other areas (2.G.)

No other sources of greenhouse-gas emissions are known.

5 SOLVENT AND OTHER PRODUCT USE (CRF SECTOR 3)

5.1 Source-category description (3)

CRF 3					
Key source by level (l) / trend (t)		**Gas (key source)**	**1990 – contribution to total emissions**	**2003 – contribution to total emissions**	**Trend**
	- / -				

Gas	CO_2	CH_4	HFCs	PFCs	SF_6	N_2O	NO_X	CO	NMVOC	SO_2
Emission factor[125] (EF)	NE	NO	NO	NO	NO	CS	NO	NO	CS	NO
EF uncertainties in %										
Distribution of uncertainties[126]										
Method of EF determination[127]										

The source category "Solvent and other product use" (CRF 3) is not a key source.

This source category comprises emissions from the use of chemical products. At present, it includes a rough estimation of emissions from the use of N_2O for narcotic purposes and data on the release of solvents from their use in industry, commerce and private households. Emissions from direct use of CO_2 in products have been neglected to date.

The inventories do not take account of chemical processes in the atmosphere by which released carbon (for example, in NMVOC) is transformed into CO_2.

NMVOC emissions released via use of solvents and solvent-containing products are covered by all of the sub-categories of this source category that are listed in the following Table 55.

Table 55: CRF categories in main category 3

CRF reporting categories	Category name
3.A	Paint application
3.B	Degreasing & dry cleaning
3.C	Chemical products manufacture & processing
3.D	Other

The four reporting categories vary widely in structure. To take account of this variation, data surveys for the present report were carried out with the UNECE/EMEP sub-structures based on the CORINAIR97 (CORINAIR: **CO**ordination d' **IN**formation Environmentale; sub-project **AIR**) SNAP system[128] .

Category 3D "other" includes the following applications and activities:

- Treatment of glass and rock wool
- Printing industry (printing applications)
- Extraction of oils and fats
- Use of glues and adhesives
- Use of wood preservatives
- Undersealing and wax treatments for automobiles

125 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
126 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
127 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model
128 In the present area, this involves "SNAP Level 3" detailing.

- Household use of solvents (not including paints and lacquers)
- Automobile-wax stripping
- Manufacturing of pharmaceutical products
- Household use of pharmaceutical products
- Other

"NMVOC" is defined in keeping with the VOC definition found in the EC solvents directive[129]. For purposes of the definition of solvents, the term "solvent use" is also defined in keeping with the EC solvents directive[130].

It is important to note, however, 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 source category.

Delimitation of this source category as outlined above takes a highly diverse range of emissions-causing processes into account. This applies for:

- 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.

Source category 3 Solvents and other product use is divided into the categories listed above in Table 55. In the CSE, "Other" (3.D) includes emissions of laughing gas, emissions from SCR systems and the above-detailed other solvent uses that cannot be allocated to source categories 3A through 3C.

129 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.
130 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.

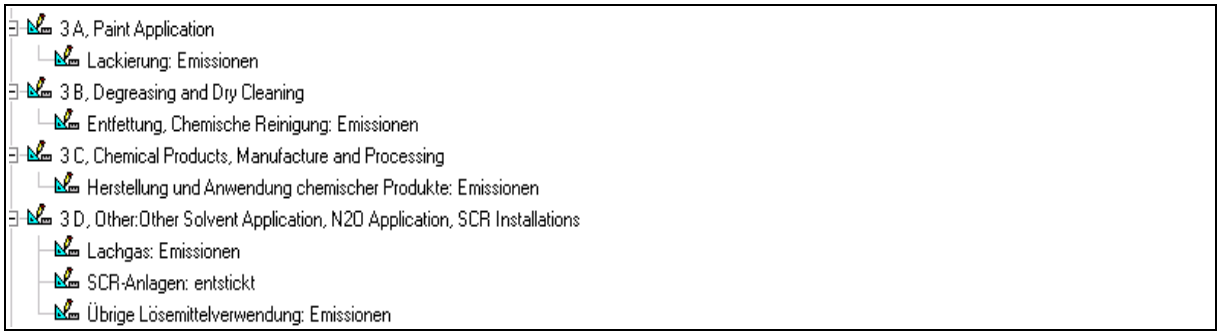

Figure 41: Structural allocation, source category 3 Solvent and other product use

5.2 Methodological issues (3)

Calculation of N_2O emissions from the use of narcotics 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 narcotic purposes had existed in the former GDR. At the time, the plant had not yet been operational for long (it was constructed in 1988). The annual production capacity was approximately 1200 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 emission calculated from this for the former GDR, and assuming identical conditions, an N_2O emission of 6200 t for Germany was roughly estimated. Since then, this figure has been continually updated.

NMVOC emissions are calculated in keeping with a product-consumption-oriented approach. 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 are calculated 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 source category.

Use of this method is possible only with valid input figures – differentiated by source categories – in the following areas:

- 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 the sub-categories 3A – 3D, these input figures are determined on the level of 37 differentiated source areas (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' estimations (expert opinions and industry

dialog) relative to the various source categories and source-category areas. These efforts lead to the NMVOC emissions from solvent use shown in Table 56.

Table 56: NMVOC emissions from solvent use in 2002

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	NMVOC [Gg]
Total solvent and other product use	**749.962**
A. Paint application	291.157
B. Degreasing and dry cleaning	42.958
C. Chemical products, manufacture and processing	35.429
D. Other (as specified)	380.418

The necessary basic statistical data required for calculation of NMVOC emissions in 2003 is not yet available; as a result, the data obtained for 2002 will continue to be used in current reporting. For this reason, it is expected that this data will be revised later on. Since 1990, so the data, NMVOC emissions from use of solvents and solvent-containing products have decreased by about 35 %. The greatest part of this emissions reduction has occurred in the past four years. This successful reduction occurred especially as a result of regulatory provisions such as the 31st Ordinance on the execution of the Federal Immissions 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 TA Luft. The German "Blauer Engel" ("Blue Angel") environmental quality seal, which is used to certify a range of products, including low-solvent paints, lacquers and glues, 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 more than compensated for 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.

5.3 Uncertainties and time-series consistency (3)

The data for N_2O emissions from narcotic use is the result of an estimate which was updated over the entire time series. As such, the time series is consistent, but also entails a high level of uncertainty.

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' judgements for all input figures (in all 37 differentiated source areas). Table 57 shows the thus-determined error ranges for the report categories.

Table 57: Experts' judgement of uncertainties (Tier 1)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	Uncertainties	
Total solvent and other product use	**+ 32,4 %**	**- 31,8 %**
A. Paint application	+ 32,0 %	- 33,6 %
B. Degreasing and dry cleaning	+ 71,5 %	- 50,6 %
C. Chemical products, manufacture and processing	+ 9,9 %	- 10,8 %
D. Other	+ 30,1 %	- 30,0 %

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 source areas with highly differing emissions conditions.

5.4 Source-specific quality assurance / control and verification (3)

The NMVOC-emissions data for 2001 and 2002, as used in the emissions inventory, was obtained via a research project and was evaluated, in the framework of this project, for methodological and material consistency, plausibility and completeness. In the course of this review, the relevant methods were optimised in co-operation with the affected industry sectors.

Comparisons with older emissions calculations involve product-based reviews, as well as correction of errors resulting from erroneous production statistics. In the past, relevant quantities (> 100 kt) of base substances for the chemical industry were erroneously reported as "other organic solvents". This correction led to a reduction – also amounting to ca. 100 kT – of total emissions in the area of source category 3.

5.5 Source-specific recalculations (3)

As a result of repeated changes in the underlying basic statistical systems, it is difficult to carry out consistent source-specific recalculation for NMVOC emissions; as a result, such recalculation is not currently planned.

Reliable data for the area of N_2O emissions will not be available before the relevant research project is completed (cf. the following chapter).

5.6 Planned improvements (source-specific) (3)

In 2004, a research project was commissioned that, *inter alia*, will examine emissions from the material release of N_2O in the various relevant potential applications. The project will consider the various pertinent potential emissions sources (including explosives production), as listed in the IPCC Good Practice Guidance (2000), and it will specify methods, prepare documentation, carry out relevant recalculations and make pertinent additions to the inventory. The results will be incorporated in next year's reporting.

To reduce data uncertainty in the area of NMVOC, for other emissions-relevant source-category areas, plans call for comparing the input figures used (quantities and VOC concentrations) with industry data.

In addition, as part of periodical updates of source-category emissions, additional discussions will have to be carried out with industry associations, aimed at reaching agreements on regular provision of differentiated industry data. Relevant activities are planned for the 1st half of 2005.

The possibility of including emissions calculations for CO_2 within this source category will be reviewed in 2005, via analysis of other countries' reporting.

6 AGRICULTURE (CRF SECTOR 4)

The German inventories for the gases methane (CH_4), non-methane volatile organic compounds (NMVOC), carbon dioxide (CO_2), ammonia (NH_3), nitrous oxide (N_2O) and nitrogen monoxide (NO), from agricultural sources, have been prepared with the help of the relevant manuals of the UN ECE (EMEP, 2003), the IPCC Guidelines (IPCC, 1996b) and the IPCC Good Practice Guidance (IPCC-GPG, 2000), as well as on the basis of other documented sources. The relevant emissions of dinitrogen (N_2) are required for calculation of indirect emissions. Relevant surveys were also carried out.

Emissions are categorised in accordance with the reporting categories CRF (Common Reporting Format, IPCC) and NFR (Nomenclature for Reporting, UNECE / EMEP), for the relevant emissions sources.

The calculation methods and provision of activity data are described in detail in DÄMMGEN et al. (2004).

Activity data is taken from official German agricultural statistics, in keeping with availability. For 2003, only provisional animal-herd figures are available for the various German Länder.

German agricultural statistics do not include herd-size figures for goats, donkeys and mules. Some indications as to the sizes of the relevant herds are available, however. According to these indications, there are some 165,000 goats in Germany, or far fewer than the country's some 2.7 million sheep. As a result, the goat herds in question, and their emissions, are considered negligible (NE). As to donkeys and mules, about 6,000 to 8,000 donkeys, and about 500 mules, are kept in Germany (DÄMMGEN et al., 2004). The pertinent emissions are considered negligible (NE). Official animal censuses do not include all horses, and thus the pertinent figures for horses are likely to be too low.

As to animals raised for fur, the Federal Ministry of Consumer Protection, Food and Agriculture (BMVEL) obtains the pertinent figures for calculation of NH_3 emissions from the Länder; in some cases, the figures are estimated. CH_4 and N_2O emissions do not occur (NO) in connection with animals raised for fur (CRF category "Others") and thus such emissions, in this context, are not of relevance for GG reporting.

Models have been prepared for important parameters relative to keeping of animals, storage of farm manure and spreading of such manure. The basic outset data for this is being obtained via questionnaires. These surveys are being carried out in the second half of 2004 and thus their results will not be available until the NIR 2006.

CO_2 emissions and fixing in agricultural soils are reported under CRF 5.D (cf. Chapter 7.2).

Source category 4 in Germany includes Enteric fermentation (4.A), Manure management (4.B) and Agricultural soils (4.D).

No emissions from Rice cultivation (4.C) occur in Germany. Prescribed burning of savannas (4.E) is not practiced in Germany (NO) and Field burning of agricultural residues (4.F) is not permitted in Germany (it is not feasible to collect data on the few permitted exceptions). Such exemptions are considered to be irrelevant (not occurring).

6.1 Enteric fermentation (4.A)

In the area of animal husbandry, CH_4 emissions from enteric fermentation (4.A) must be reported. Microbial conversion in stomachs of ruminants – especially conversion of cellulose – releases CH_4. The quantities released per animal and unit of time depend on the animal species in question, individual-animal efficiency and feed composition.

The relevant source categories (animal species) in 4.A are considered in combination.

In the CSE, source category 4.A Enteric fermentation is divided into the sub-categories of cattle, sheep and goats, horses, mules and asses and swine. Category "CRF 4.A Cattle" consists of the sub-categories "dairy" and "non-dairy" (aggregated figures for other cattle). The group of "non-dairy cattle" includes calves, bulls, heifers and mother cows.

Category CRF 4.A.8, Swine, includes fattened swine and sows. The animal statistics, in correlation with the various relevant forms of animal husbandry, are described in detail in DÄMMGEN et al, 2004.

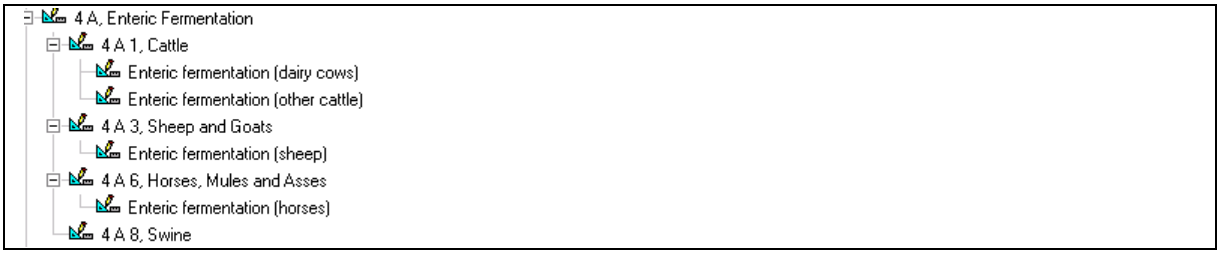

Figure 42: Structural allocation, 4.A Enteric fermentation

6.1.1 Source-category description (4.A)

CRF 4.A					
Key source by level (l) / trend (t)		**Gas (key source)**	**1990 – contribution to total emissions**	**2003 – contribution to total emissions**	**Trend**
Enteric fermentation, dairy cattle (CRF 4.A.1a)	l / -	CH_4	1,01 %	0,93 %	falling
Enteric fermentation, non-dairy cattle (CRF 4.A.1b)	l / t	CH_4	1,61 %	1,40 %	falling

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor[131] (EF)	NO	CS/C/D/ T1	NO	NO	NO	NO	NO	NO	NO	NO
EF uncertainties in %		30								
Distribution of uncertainties[132]		-								
Method of EF determination[133]		CS/C/D/ T1								

The source category Enteric fermentation (4.A) is a key source in terms of emissions level (in one area, it is also a key source in terms of trend); in the area of non-dairy cattle, the source category is also a key source in terms of trend.

Germany reports on the emissions of methane (CH_4) from enteric fermentation in the stomachs of dairy cows, other cattle (calves, bulls, heifers and mother cows), swine, sheep

131 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
132 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
133 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model

and horses. There is a lack of methods for treating poultry in this context (NA); in accordance with the IPCC Guidelines (IPCC, 1996b, Chapter 4, Tab. A-4), the relevant quantities are considered negligible and are not calculated (entry pursuant to IPCC Guidelines: not occuring).

A chronology of total emissions is presented in Table 58, while

Figure 43 breaks down the emissions by animal species.

Almost all agricultural CH_4 emissions in Germany originate in keeping of cattle (94 %). The relevant proportions for keeping of swine are small (3 %), while those for all other animals are small enough to be neglected. Dairy cows are the most important source category within the cattle category. Decreases in emissions since 1990 (with increasing emission factors for dairy cows and constant emission factors for all other animals) are a result of decreases in animal herds that, in turn, have resulted from changes in consumers' choices. Detailed data on CH_4 emissions (national and at the Länder level) is provided by LÜTTICH et al (2004).

Table 58: CH_4 emissions E_{CH4} from animal husbandry (enteric fermentation) [Tg CH_4 a^{-1}].

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
E_{CH4}	1,63	1,44	1,38	1,35	1,36	1,36	1,35	1,32	1,30	1,29	1,26	1,28	1,23	1,20

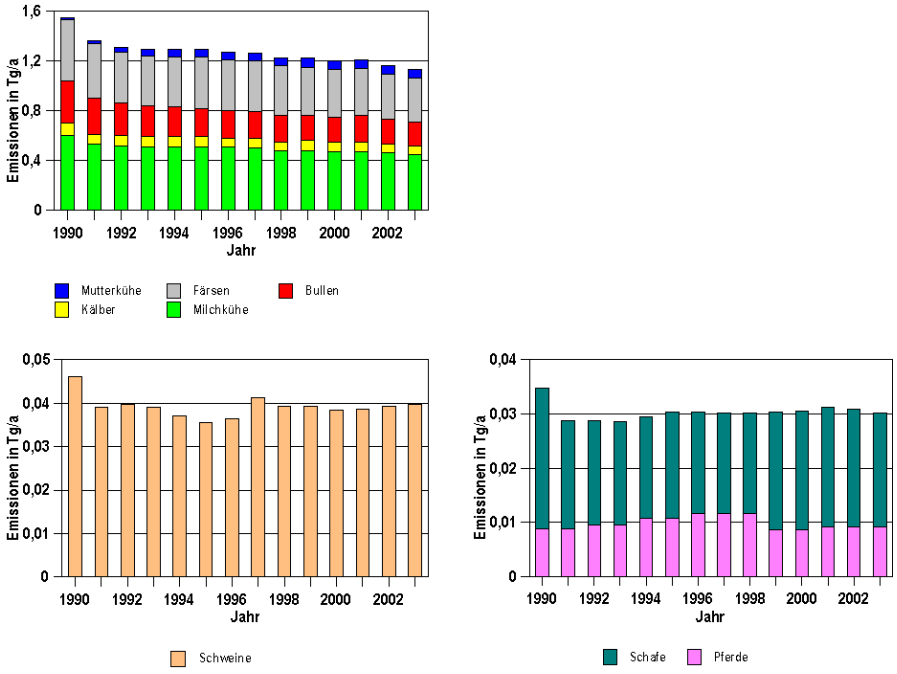

Figure 43: Time series for CH_4 emissions ECH_4 (enteric fermentation) for the animal categories considered. Above left: cattle; below left: swine; below right: horses and sheep [Tg CH_4 a^{-1}]

6.1.2 Methodological issues (4.A)

Two different methods are available for determining the emissions occurring in fermentation. A simple method, using emission factors based on estimates (Tier 1), and a more detailed method, using country-specific emission factors (Tier 2).

In principle, Tier 1 and Tier 2 are calculated via the following steps:

1. Animal-herd sizes, for each animal species and category
2. Emission factors for each animal category
3. Calculation of total emissions

In the simpler Tier 1 procedure, the emission factors for the individual animal species / categories are based on internationally accepted estimates. For determination of methane emissions, the emission factors are multiplied by the number of animals for each category.

IPCC Good Practice Guidance (IPCC, 2000) calls for the more detailed Tier 2 method to be used in cases in which a country has listed methane emissions from animal husbandry as a key source for its inventories.

Tier 2 requires differentiated characterisation of animal herds. Where a sub-category contributes significantly to digestion-related methane emissions, the emissions must be determined pursuant to Tier 2. This means that a country-specific emission factor must be determined for the relevant animals, in accordance with the following equation:

Equation 1: Determination of specific emission factors

$$EF_i = \frac{GE \cdot Y_m \cdot a}{E_{CH4}}$$

where *EF* Emission factor for each sub-category i [%]
GE Gross energy requirements [MJ/(animal and day)]
Y_m Methane-conversion rate (percentage of gross energy that is converted to methane)
a Conversion factor (365 d a^{-1})
E_{CH4} Energy content of methane (55.65 MJ kg^{-1} CH_4)

The gross energy requirements are calculated using the *Detailed characterisation of livestock herds* and the methane-conversion rate from the IPCC-GPG (2000: Table 4-8) and from national data. Since the methane-conversion factor (MCF) is an important factor in this equation, it should also be differentiated by animal species, age/weight and feed.

Total emissions are then determined as follows:

Equation 2: Complete emissions from the enteric fermentation source category

$$E_{CH4} = b \cdot \sum EF_i \cdot n_i$$

where: E_{CH4} Methane emissions [Gg a^{-1}]
$EF_{iCH4,}$ Emission factor for each sub-category i [kg $animal^{-1}$ a^{-1}]
n_i Population size for each sub-category i [number of animals]
b Conversion factor [10^6 kg Gg^{-1}]

More detailed population data is required for the Tier 2 approach. Emission factors are determined for the various significant animal categories on the basis of country-specific data, and in several steps.

Where other methods are available, these may be used if they lead to more precise results and if their origin is adequately documented.

In analysis of key sources in agriculture, CH_4 emissions from dairy cows and other cattle in category 4 A, enteric fermentation, were identified as key sources. As a result, emissions

from enteric fermentation, especially such fermentation in cattle, must be determined on the basis of differentiated characterisation of animal herds.

Since the available data is inadequately differentiated, a nationally improved approach was chosen for dairy cows; to date, only the Tier 1 approach can be used for calculation of emissions from other cattle (cf. DÄMMGEN et al., 2004). The default values for western Europe (IPCC, 1996b), and the EF from the EMEP/CORINAIR manual (EMEP, 2003), are used. In principle, the emission factors reflect the situation in Germany. Calculation was carried out on the rural-district level.

6.1.2.1 Characterisation of animal herds

The total animal population is divided into sub-groups for which activity data and emission factors are available. Disaggregation is carried out only where emission factors differ significantly, for given uncertainties. The following table provides a comparison of German sub-groups with the IPCC proposals.

Table 59: Detailed characterisation of animal herds pursuant to IPCC, and the breakdown used for Germany

	IPCC main categories	IPCC sub-categories	Germany (Deutschland)
Cattle	Dairy cows	Subdivision into two or more performance classes	Dairy cows, performance-/feed-oriented survey for each rural district
	Adult cattle, "other"	Male/female Fattening and additions	Mother cows, bulls, heifers
	Young animals	Heifers, calves, young male cattle	Calves
Swine	Sows	Pregnant sows Farrowing sows	Sows (including piglets and boars)
	Boars	---	---
	Young animals	Suckling piglets Growing young animals Slaughter-ready animals	Fattening swine
Sheep	Ewes	Pregnant ewes Dairy sheep	Sheep, ewes
	Sheep >1 year	---	
	Young animals	Male animals, castrated animals, female animals	
Other	Horses, poultry, goats, donkeys, mules, camels, fur-bearing animals, etc.	---	Horses, poultry (laying hens, broilers (male and female), young hens, geese, ducks, turkeys), fur-bearing animals

IPCC GPG (2000)

Milk production figures for dairy cows are taken from public statistics at the district level, while all other variables are modelled (on the basis of data outside of official statistics, including questionnaires and special evaluations).

Furthermore, a differentiation is made between calves, male and female fattening animals (referred to as "heifers" and "bulls") and mother and nursing cows. The basic reason for this differentiation is that animals listed under "female cows for beef" either may be used to supplement and rejuvenate herds or may be slaughtered. Cattle used to supplement and rejuvenate herds and animals destined for slaughter do not differ in terms of the feed they are given and the conditions under which they are kept. The main basis for the activity data

consists of the animal censuses of 1990, 1992, 1994, 1996, 1999 and 2001. The herd figures were not interpolated to permit description of years without herd-size statistics; instead, the herd figures were assumed to remain constant (LÜTTICH et al., 2004). The gaps in the new German Länder data for the years 1990 to 1993 were closed by means of experts' estimations. The relevant procedure is described in detail in Chapter 2 of the research report of Döhler et al. (UBA, 2002a). Detailed figures for 2003 are not yet available.

Further sub-grouping is not required for all other animals for which calculations are carried out in accordance with the Tier 1 approach. There are no default emission factors for sub-categories. What is more, it is not useful to use such factors in cases in which the relevant national data is not available. Detailed data on animal herds (national and at the Länder level), as well as additional information, is provided by LÜTTICH et al (2004).

6.1.2.2 Calculation of CH_4 emissions from keeping of dairy cows

For the time being, the emission factor for dairy cows is determined with the help of a regression approach that takes yields and body weight into account. Due to a lack of relevant data, body weight is also calculated from milk yield (DÄMMGEN et al., 2004: Chapters 4.4.1 and 6.3). Feeding patterns (grass/grass silage or corn/corn silage) are derived as model variables (here, A and B) from the RAUMIS (Regionalisiertes Agrar- und Umweltinformationssystem für Deutschland – regionalised agricultural and environmental information system for Germany) agricultural sector model (cf. DÄMMGEN et al., 2004, Chapter 4.4).

$$EF_{CH4} = \alpha \cdot \left(\beta + \gamma \cdot Y + \delta \cdot w^{0.75}\right)$$

with (A) feeding based on grass / grass silage
(B) feeding based on corn / corn silage

where				
EF_{CH4}	methane emissions			[kg animal^{-1} a^{-1} CH_4]
α	constant			0.365 kg g^{-1}d a^{-1}
β	Constants	A:	β = 55 g animal^{-1} d^{-1} CH_4	
		B:	β = 26 g animal^{-1} d^{-1} CH_4	
γ	Factor	A:	γ = 4.5 g kg^{-1}	
		B:	γ = 5.1 g kg^{-1}	
Y	Milk yield			[kg animal^{-1} d^{-1}]
δ	Factor	A:	δ = 1.2 g animal$^{-0.25}$ d^{-1} CH_4	
		B:	δ = 1.8 g animal$^{-0.25}$ d^{-1} CH_4	
w	Live weight			[kg animal^{-1}]

The average milk yield for Germany, weighted by Länder and oriented to the base year 1990, is 12.9 kg animal^{-1}d^{-1}, which differs slightly from the IPCC Guidelines' suggested value for western Europe, 11.5 kg d^{-1} (IPCC, 1996b: Table A-1). Taking increased yields into account, a value of 17.0 kg animal^{-1}d^{-1} is calculated for 2002. Additional information on milk yields, body weight, types of husbandry and VS excretion[134] is provided by LÜTTICH et al. (2004).

The CH_4 emission factors in Germany range between 85.4 kg animal^{-1} a^{-1} CH_4 (1990) and 131.5 kg animal^{-1} a^{-1} CH_4 (2002); the national averages are 94.3 kg animal^{-1} a^{-1} CH_4 (1990) and 102.7 kg animal^{-1} a^{-1} CH_4 (2002). An overview of the emission factors used is provided in Lüttich et al. (2004).

134 Volatile solids; readily decomposing components of excrement, calculated as dry matter [kg d-1 TS]

Comparative calculations with other regression calculations, and calculations with complete data records from models, showed that use of the above-mentioned regression equation can be expected to underestimate methane emissions (DÄMMGEN et al., 2004: Chapter 6.3).

6.1.2.3 Calculation of CH_4 emissions from keeping of all other animals

For all other mammals, the Tier-1 approach, in keeping with:

$$E_{CH4_A} = EF_A \cdot n_A$$

where E_{CH4} CH_4 emissions [kg a^{-1} CH_4]
A Animal class
EF Emission factor [kg $animal^{-1}$ a^{-1} CH_4]
n Number of animals

was used. For each animal species, the default values (emission factors) pursuant to IPCC (1996b: Chapter 4) were used:

Table 60: Default values (emission factors) pursuant to IPCC

Animal category	**EF pursuant to IPCC (1996b: Chap. 4) [$animal^{-1}$ a^{-1} CH_4]**	
Male and female beef cattle	84 kg	(Table A-2)
Calves	33 kg	(Table A-2)
Mother cows	100 kg	(Table 4-4)
Sheep	8 kg	(Table 4-3)
Horses	18 kg	(Table 4-3)
Swine	1.5 kg	(Table 4-3)

In the area of cattle, correlation of German statistics with the IPCC categorisation is considered inadequate. Divergences of implicit emission factors can occur via differences in correlation of official animal statistics with the IPCC categories.

For the reasons discussed above, Germany cannot report emissions of donkeys, mules and goats (NE).

6.1.3 Uncertainties and time-series consistency (4.A)

6.1.3.1 Relevant herd sizes

The uncertainties in the animal figures, per class, are on the order of 10 % (EMEP, 2000_ Chapter B1040-6). For the new *Länder*, herd sizes and their regional distribution for the years 1990 and 1991 were calculated using the RAUMIS model (RAUMIS, 1996), which provides regional data for agricultural production and products. As the data sources do not vary with the years, the time series is considered to be basically consistent. The Agricultural Statistics Act (Agrarstatistikgesetz) was amended in 1998. This changed the survey bases for determining herd sizes – considerably, in some cases.

Impacts were seen especially in numbers of horses. Table Table 61 shows the impacts of the amendment of the Agricultural Statistics Act, as determined for the state (Land) of Thuringia:

Table 61: Percentage changes in herd sizes resulting from the amendment of the Agricultural Statistics Act (Agrarstatistikgesetz) (BML, 1998). Sample results for Thuringia (TMLNU, 2000)

Category	**Difference** (old - new)/new (%)
Cattle	1,2
Swine	1,3
Sheep	10,6
Horses	40,3
Poultry	4,3

The number of horses actually present in Germany may be assumed to be about twice as large as the relevant figure from the agricultural statistics.

6.1.3.2 Emission factors

The uncertainties in the methane emission factors are on the order of 30 % (EMEP, 2000: Chapter B1040-6).

The emissions calculated for *keeping of dairy cows*, using the method that takes yield and body weight into account, are probably too low, for systematic reasons (cf. DÄMMGEN et al., 2004: Part 3, Chap. 6.2 and BERTILSSON, 2002).

By analogy to the CORINAIR manual, Chapter B1040-6 (EMEP, 2003), an error on the order of 30 % is listed for emission factors.

6.1.4 Source-specific quality assurance / control and verification (4.A)

The data is reviewed for transcription errors made between the original data and the calculation tables, and it is checked for errors with regard to units and orders of magnitude. For future QA/QC procedures, relevant methods will have to be improved (use of Tier 2) and activity data will have to be broken down more finely (especially district-level data on feeding). In addition, emission factors, except where confidential, will be made publicly available via the German Emission Factor Database (GEREF). This will enable experts to review and comment on the data.

A comparison made with the aid of the "implied emission factors" provided by the UNFCCC Secratariat's *Data Locator*, for individual countries, shows that the method used for Germany – and the resulting factors for methane emissions of dairy cows for 1990 (94.3 kg/(head*a)) and 2002 (102.7 kg/(head*a)) – lie within the middle of the relevant spread.

Table 62: Digestion-related methane emissions of dairy cows of various countries, via a comparison of implied emission factors (IEF, emission factors calculated from emissions and dairy-cow herd sizes); for Germany, the IEF for 2003 was used in the comparison.

Country	IEF (calculated EF) methane [kg/(head*a)]
Denmark	104
Germany	103
Finland	114
France	103
UK	117
Ireland	100
Italy	111
Sweden	127
Canada	80
Netherlands	81
Austria	101
Switzerland	104
Spain	106
U.S.	99

Source: CRF data for individual countries

6.1.5 Source-specific recalculations (4.A)

IIn contrast to earlier calculations, emissions calculation now also took account of animals in the city-states Bremen, Hamburg and Berlin, with the result that total emissions increased slightly from 1990 to 2003. No source-specific recalculations were carried out. The provisional figures for 2002 were replaced with final figures. This changed the 2002 emission factor for dairy cows. Emissions from enteric fermentation were calculated according to the same method for the entire time series (default emission factors). Previously, default emission factors have also been used for calculation of emissions from keeping of dairy cows. The present report uses national emission factors that reflect CH_4 emissions' yield and feed dependence in use of default values (NIR 2003: UBA, 2003c) and national values (NIR 2004: UBA, 2004a) (cf. Table 63). Transfer errors made in preparation of

Figure 43 have been corrected in the present NIR.

Table 63: Comparison of the mean CH_4 emission factors used in the NIR 2004 and NIR 2005 for animal husbandry (enteric fermentation). Figures for dairy cows in Germany in kg animal^{-1} a^{-1} CH_4.

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
NIR 2004	94,3	94,6	96,3	97,1	97,2	98,2	98,7	99,1	99,8	101,0	101,9	102,7	102,7	
NIR 2005	94,3	94,6	96,3	97,1	97,2	98,2	98,7	99,1	99,8	101,0	101,9	102,7	102,9	103,0

6.1.6 Planned improvements (source-specific) (4.A)

In the NIR 2006, Germany will report for the first time on emissions from keeping of goats.

There are plans to calculate enteric fermentation according to the Tier 2 method from 2004 onwards (NIR 2006). For it to be possible to use the relevant equations (cf. DÄMMGEN et al., 2004: Part 3, Chapter 6.3), however, the database for describing frequency distributions in dairy-cow rationing and in yields (weight gains) of beef cattle and fattening swine must be

determined via surveys. In addition, plans call for reviewing the CH_4 emission factor for 4.A.1.a (dairy cattle) by the 2006 report.

The data provided by the literature is not useful for national issues in some areas of implementation of requirements for emissions reporting. Significant problem areas with inadequate data quality or availability will be identified in a workshop that is to take place in November 2004. The aims of this effort are to identify specific relevant calculation methods, along with the options for their use, and to discuss the experimental design of data surveys required for emissions reporting. These aims also apply to source category 4.B.

6.2 Manure management (4.B)

6.2.1 Source-category description (4.B)

CRF 4.B					
Key source by level (l) / trend (t)		**Gas (key source)**	**1990 – contribution to total emissions**	**2003 – contribution to total emissions**	**Trend**
Manure management dairy cattle (CRF 4.B.1a)	l / -	CH_4	0,70 %	0,77 %	rising
Manure management non-dairy cattle (CRF 4.B.1b)	l / t	CH_4	0,48 %	0,38 %	falling
Manure management swine (CRF 4.B.8)	l / t	CH_4	0,98 %	1,09 %	rising

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor[135] (EF)	NO	C/D	NO	NO	NO	D	D	-	CS	NO
EF uncertainties in %		30				NE				
Distribution of uncertainties[136]		-				NE				
Method of EF determination[137]		C/D/T1				CS/C				

The source category "manure management" (4.B) is a key source.

CH_4 and NMVOC, and NH_3, N_2O, NO, and N_2, are released in storage of farm manure in stalls, on paved areas outside of stalls and in storage facilities (in the narrower sense), and such emissions are also released when manure is spread. NMVOC emissions can also include sulphur-containing compounds. Emissions depend on a range of factors, including animal species, animal yield, feed, time spent in specific types of quarters (pasture, stall, paved areas), species-specific behaviour, stall type, use of straw, type and duration of manure storage, time and place of manure spreading, method used to spread manure and ways in which manure is worked into the soil.

Germany does not report on donkeys, mules and goats (NE).

In the CSE, source category 4.B Manure management is divided into the sub-categories shown in Figure 44.

135 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
136 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
137 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model

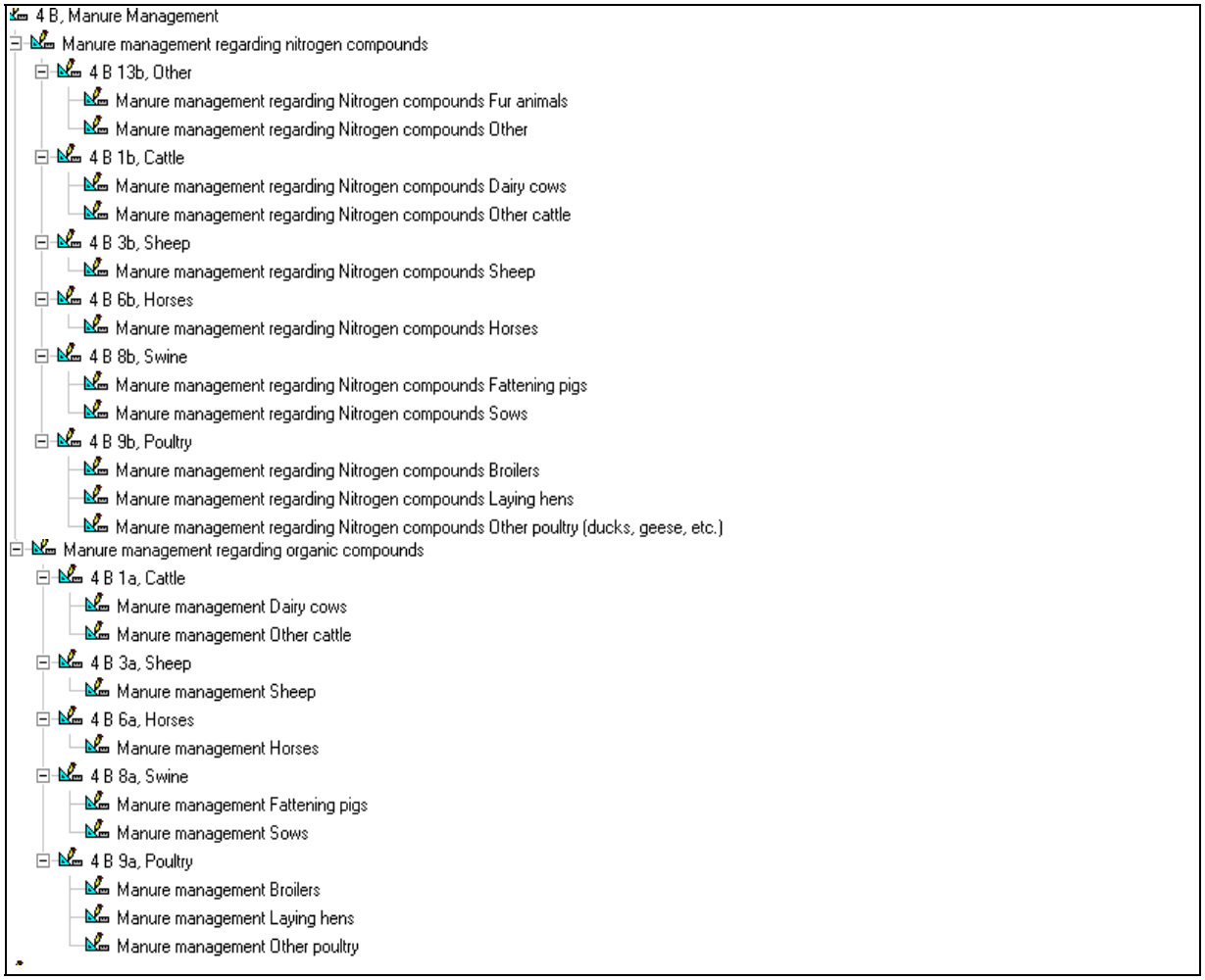

Figure 44: Structural allocation, 4.B Manure management

6.2.1.1 Methane emissions from manure management (4.B)

Table 64 presents the time series for CH_4 emissions from manure management. It shows an emissions decrease that is limited primarily to the years after German reunification and that points primarily to decreases in herd sizes (Figure 45). Of total emissions, cattle contribute two-thirds (63 % for 1990) and swine contribute one-third (36 % for 1990). As these figures indicate, emissions from keeping of poultry, and from keeping of horses and sheep, are negligible (cf. Figure 45).

Table 64: CH_4 emissions E_{CH4} from animal husbandry (manure management). [Tg a^{-1} CH_4.]

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
E_{CH4}	1,29	1,12	1,09	1,07	1,16	1,13	1,14	1,18	1,13	1,14	1,11	1,12	1,10	1,10

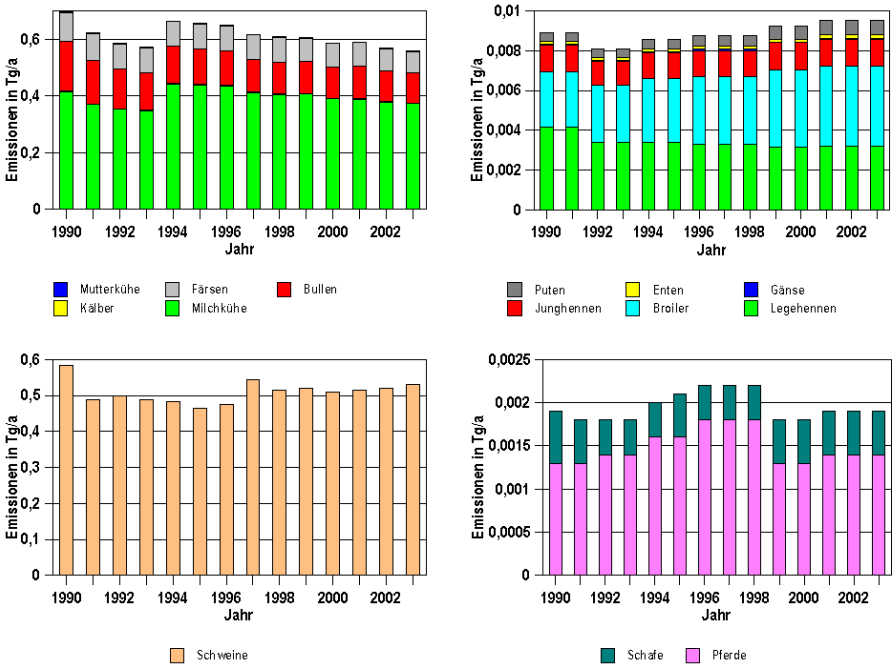

Figure 45: Time series for CH_4 emissions E_{CH4} for animal categories considered. Above left: cattle; below left: swine; above right: poultry; below right: horses and sheep. [Tg a^{-1} CH_4].

6.2.1.2 NMVOC emissions from manure management

Microbial conversion of proteins in farm manure (about 50 % of the nitrogen contained in excretions is bound in proteins) produces both ammonia (NH_3) and non-methane volatile organic compounds (NMVOC). In the UK, the consistent proportionality seen between NH_3 emissions and NMVOC emissions from a range of different farm manures was used in preparation of a first NMVOC-emissions inventory. Germany has used that inventory's relative emission factors to prepare a first estimate of NMVOC emissions from animal husbandry (details in DÄMMGEN et al., 2004, Part 3, Chapter 4.5.1.2.1). The time series for NMVOC emissions is presented in Table 65, and the emitter composition is shown in Figure 46. Beginning in about 1994, following a decrease in animal-herd sizes, resulting from German reunification, emissions remained constant. Although no figures for horses are available, due to the lack of a relevant calculation procedure, their emissions can be assigned largely to "keeping of cattle", especially "keeping of dairy cows".

Table 65: NMVOC emissions E_{NMVOC} from animal husbandry (manure management). [Tg a^{-1} C]

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
E_{NMVOC}	0,30	0,27	0,26	0,26	0,24	0,24	0,24	0,24	0,24	0,24	0,23	0,23	0,23	0,23

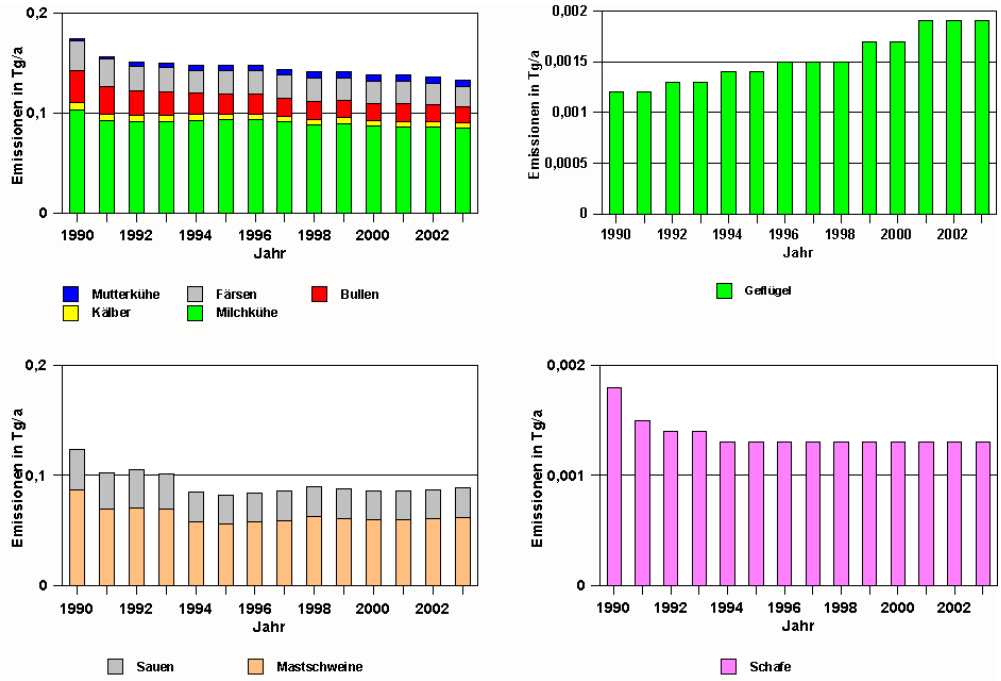

Figure 46: Time series of NMVOC emissions E_{NMVOC} (manure management) for the animal categories considered. Above left: cattle; below left: swine; below right: poultry and sheep. [Tg a^{-1} C].

In modelling of NMVOC emissions, it was also found that considerable amounts of dimethyl sulfide are emitted.

Pursuant to these estimates, the emissions of sulphur bound in NMVOC amount to about 0.03 to 0.04 Tg a^{-1}. Additional discussion regarding the possible significance of these emissions for SO_2 concentrations and flows, and for ecosystem acidification, is presented in DÄMMGEN et al. (2004: Part 3, Chapter 6.5).

6.2.1.3 Nitrous oxide, nitrogen monoxide and ammonia emissions from manure management

The results of calculations of NH_3, N_2O and NO emissions are shown in Table 66; Figure 47 and Figure 48 present the results with reference to emitters. Since N_2O and NO emissions are proportional, NO emissions were not considered separately. N_2O and NO emissions have been decreasing considerably with regard to the base year. Cattle account for the major part of N_2O and NO emissions (66 % in 1990, and a decrease to 63 % in 2000). With respect to 1990, a total of 62 % of NH_3 emissions were emitted by cattle farms, 30 % were emitted by swine farms and 6 % were emitted by poultry operations. A total of 67 % of N_2O and NO emissions originate in keeping of cattle, while 17 % originate in keeping of swine and 10 % originate in keeping of poultry. In 2000, the respective shares for NH_3 were 64 %, 27 % and 7 %. The respective shares for N_2O and NO in 2000 were 62 %, 13 % and 12 %.

Table 66: N_2O and NO emissions E_{N2O} and E_{NO} from animal husbandry (manure management) [Gg a^{-1} N_2O and NO].

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
E_{N2O}	14,4	12,8	12,5	12,4	10,1	10,1	10,2	10,1	10,0	9,8	9,7	9,8	9,6	9,4
E_{NO}	19,7	17,5	17,0	16,9	13,8	13,8	14,0	13,8	13,7	13,4	13,2	13,3	13,1	12,9
E_{NH3}	581	514	503	496	474	471	474	467	468	461	452	458	449	446

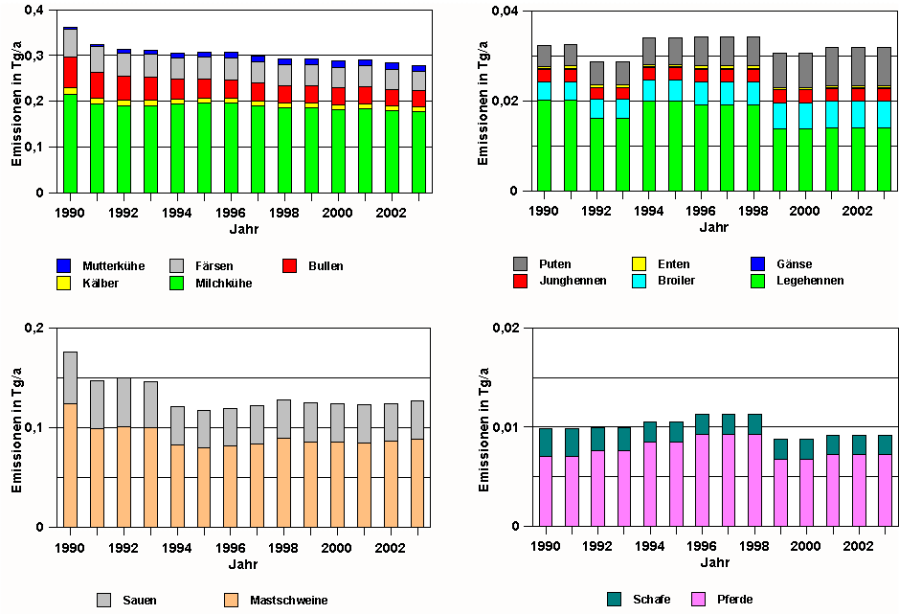

Figure 47: Time series for NH_3 emissions E_{NH3} for animal categories considered. Above left: cattle; below left: swine; above right: poultry; below right: horses and sheep. [Tg a^{-1} NH_3]

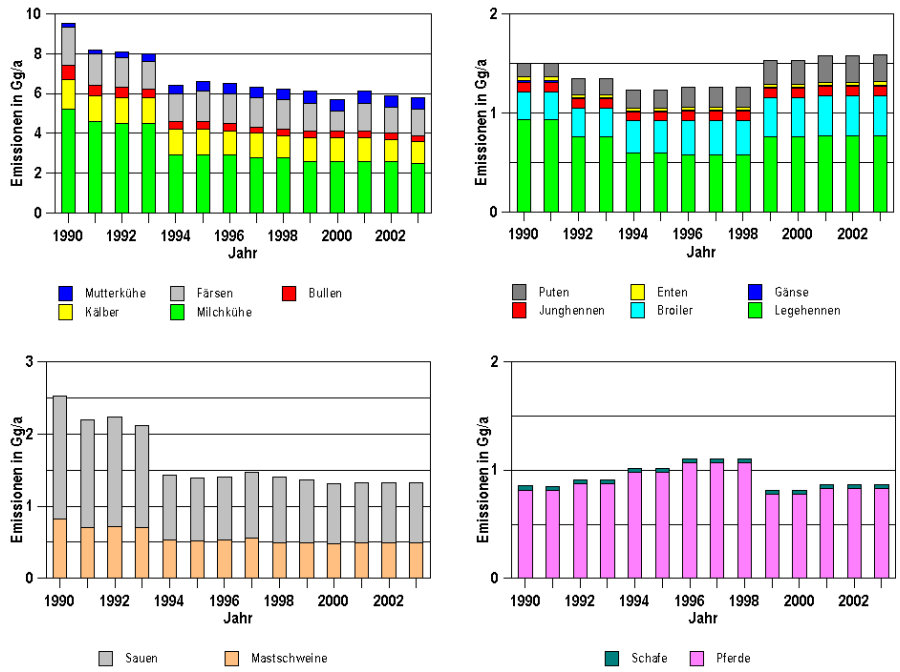

Figure 48: Time series for N_2O emissions E_{N2O} for animal categories considered. Above left: cattle; below left: swine; above right: poultry; below right: horses and sheep. [Gg a^{-1} N_2O]

6.2.2 Methodological issues (4.B)

6.2.2.1 Methodological issues and requirements, CRF 4 B (CH_4)

The IPCC Guidelines specify two methods for determining quantities of CH_4 emissions from animal excrement. In emissions calculation pursuant to the Tier 1 procedure, data on animal herds (species and category) and on climate is required, and IPCC Default EF are used. The Tier 2 procedure calls for detailed determination of methane emissions from manure management. Pursuant to the IPCC GPG (2000), the Tier 2 procedure is to be used in cases in which a significant portion of a country's methane emissions comes from animal excrement. In Germany, this is the case for at least the categories of cattle, dairy cows and swine.

Country-specific emission factors are determined with the help of detailed data on animal herds and on manure management. The data may be obtained directly, via measurements and model formation, or may be acquired implicitly. The implicit procedure requires data on feed rationing and digestibility, as well as data on the type of manure involved (solid or liquid) and on its storage (duration, temperature records, storage system). Finally, the emission factor is determined via the following equation:

Equation 3: Determination of the implicit emission factor for methane from animal excrement, pursuant to Tier 2

$$EF_i = VS_i \cdot a \cdot B_{oi} \cdot \rho_{CH4} \cdot \sum_{jk} MCF_{jk} \cdot MS_{ijk}$$

where
- EF_i Emission factor for each sub-category i [kg animal^{-1} a^{-1} CH_4]
- a Time conversion (365 d a^{-1})
- VS Volatile solids (excretion of readily decomposable material, dry mass - DM) for the sub-category i [kg d^{-1} DM]
- B_{oi} Methane-formation potential with regard to VS [m^3 kg^{-1}]
- ρ_{CH4} Methane density (0.67 kg m^{-3})
- MCF Methane-conversion factor for storage system j in climate region k [kg kg^{-1}]
- MS Share of sub-category whose farm manure is treated in storage system j

As it did with digestion-related emissions, the Tier 2 procedure requires detailed characterisation of animal herds.

In the German inventory report, CH_4 emissions from management of manure from dairy cows, cattle and swine are classified as a key source. Since the database is not sufficiently reliable, CH_4 emissions are calculated using only the method described by the CORINAIR manual (EMEP, 2003) as a "simpler" method. This is in keeping with the IPCC method, pursuant to the Tier 1 approach for treatment of liquid manure (IPCC-GPG, 2000: Table 4.10). In principle, the emission factors reflect the situation in Germany. The default values for western Europe are still used for excrement (VS) and the maximal methane-formation capacity (B_o) (EMEP, 2003: Chapter B1040-4 and IPCC, 1996b: Table B-2). The calculations are carried out for rural districts (Dämmgen et al., 2004: Part 3, Chap. 4.4).

6.2.2.2 Methodological issues and requirements, CRF 4 B (N_2O, NO and N_2)

Since 2004, the mass-flow procedure (for a detailed explanation, cf. the Annex, Chapter 14.4.3) pursuant to EMEP/CORINAIR is used for calculation of losses of gaseous N species (cf. DÄMMGEN et al., 2004: Part 3, Chap. 4.9).

The procedure for calculating N_2O and NO emissions, and the relevant standard values for types of storage, were taken from the IPCC Guidelines (IPCC, 1996b). The procedure and standard values were applied to the nitrogen quantities calculated for storage, using the mass-flow procedure. Neither the IPCC Guidelines (1996) nor the IPCC-GPG (2000) unambiguously classify the various methods for determining emissions from manure management into separate tiers. The more precise methods use country-specific emission factors for intake, retention (for example, in milk or wool) and excretion of nitrogen and for the various manure-management systems. Pursuant to IPCC-GPG, detailed characterisation should be carried out in cases in which emissions represent a key source. Many countries refer to the methods they use as "Tier 1 and Tier 2". And yet Tier 2 always involves calculation with country-specific parameters. In general, N_2O emissions are determined via the following five steps:

- Animal-herd sizes, for each animal species and category
- Determination of the annual N excretion per animal of a relevant species / category
- Determination of the distribution of animals of a relevant species / category throughout the various relevant manure-management systems
- Determination of emission factors for each manure-management system
- Calculation of total emissions (addition of emissions of all sub-categories)

Pursuant to IPCC Good Practice Guidance, total emissions are determined via the following equation:

Equation 4: Determination of N_2O emissions from manure management

$$E_{N2O-N} = \sum_{i,j} n_i \cdot m_{ex,i} \cdot x_{i,j} \cdot EF_j$$

where
- E_{N2O-N} N_2O-N emissions from manure management
- n_i Number of animals of a species/category i
- $m_{ex,i}$ Mean annual N excretions of an animal species/category i
- $x_{i,j}$ Percentage of the annual excretions of a species / category i that is subject to a certain manure-management system j.
- EF_j N_2O emission factor for manure-management system j

Pursuant to IPCC-GPG (2000), the parameters for the above formula must be obtained through statistical surveys and through measurements. In the process, framework conditions such as the ventilation situation and temperature for manure storage must be taken into account. The entire data-collection, data-review and documentation process is, thus, considerably involved. IPCC-GPG (2000) also contains default values for emission factors, however (Tables 4-12 and 4–13). Nevertheless, three basic types of data are required for determination of N_2O emissions:

- Animal-herd data
- Frequency distribution for the various manure-management systems, by animal species / category
- N excretions, by animal species / category (including adjustment to take account for young animals)

N excretions also enter into calculation of soil-based N_2O emissions in CRF 4.D. The same calculation method and database should thus be used for both sources.

Pursuant to key-source analysis, category 4.B N_2O emissions are not a key source. For this reason, a simple method (Tier 1 approach) may be used for calculation.

In the substance-flow model, and for cattle, the duration of grazing (pasture) periods, the average grazing duration per day and the average time spent in milking stalls are used to divide excrement into pasture and stable portions. All of the stall categories commonly found in Germany are considered. Information on frequency distribution is provided by LÜTTICH et al. (2004: Tables AI1005CAT.05, AI1005CAT.06, AI1005CAT.15 and similar). The relevant data has been compiled in IPCC report tables 4.B(a) and 4.B(b) (IPCC et al., 1997).

The emission factors (liquid-manure-based systems: $EF_{N2O} = EF_{NO} = 0.001$ kg * kg^{-1} N, $EF_{N2} = 0.007$ kg * kg^{-1} N; straw-based systems: $EF_{N2O} = EF_{NO} = 0.02$ kg * kg^{-1} N, $EF_{N2} = 0.14$ kg * kg^{-1} N) have either been taken from IPCC or derived from that source (IPCC, 1996b: Table 4-22). The quantities of N_2 that form simultaneously with N_2O are estimated on the basis of literature data, with a view to calculation of indirect emissions. The figures are determined for each rural district, with the help of the RAUMIS agricultural sector model (1996). In principle, a different emission factor results each year for each animal category and each district (DÄMMGEN et al., 2004: Part 3, Chapter 4.4).

6.2.2.3 Relevant herd sizes

Normally, emissions of N-containing compounds for a given animal category are calculated using the numbers of animals in the entire relevant population. The *cattle* category is subdivided into dairy cows, calves, bulls, heifers and mother cows. In the *swine* category, fattened swine and sows are considered separately in calculation of emissions of N species, however. The emission factors for sows include emissions of piglets and boars. The procedure used to date for calculation of CH_4 emissions requires the total number of swine as an activity. In the category *sheep*, emissions of N species are calculated from figures for female sheep for breeding; the relevant emission factor includes lambs and castrated rams. CH_4 emissions, on the other hand, are determined from the size of the entire sheep population. Official animal censuses provide only incomplete head counts of horse populations.

In the new German Länder, ewes were not separately counted. As use of the same animal statistics continued, it was discovered that the number of ewes was considerably greater than the total number of sheep. The population of ewes was thus calculated for Mecklenburg - West Pomerania, Saxony, Saxony-Anhalt and Thuringia, for 1991, 1992 and 1993, on the basis of the assumption that population compositions remained constant.

6.2.2.4 Excrement

C species: No data on excretion of "volatile solids" is available for Germany . Relevant calculations are based on default values for excretions (IPCC, 1996b: Tables B-1 and B-7):

Dairy cows	5,08	[kg animal^{-1} d^{-1} C]
Male and female beef cattle	2,99	[kg animal^{-1} d^{-1} C]
Calves	1,46	[kg animal^{-1} d^{-1} C]
Mother cows	5,08	[kg animal^{-1} d^{-1} C]
Swine	0,50	[kg animal^{-1} d^{-1} C]
Sheep	0,40	[kg animal^{-1} d^{-1} C]
Horses	1,72	[kg animal^{-1} d^{-1} C]
Poultry	0,10	[kg animal^{-1} d^{-1} C]

NMVOC emissions are calculated via use of calculated quantities of NH_3 emissions, since the two substance groups are linked via their formation mechanism.

N species: N excretions for dairy cows are calculated as a function of milk yields:

$$m_{N_{excr}} = m_0 + a \cdot m_{milk}$$

where m_{Nexc} Mass of excreted N [kg animal^{-1} a^{-1} N]
m_0 48.5 kg animal^{-1} a^{-1} N
a 0.0095 kg N (kg milk)$^{-1}$
m_{milk} Milk yield [kg animal^{-1} a^{-1} milk]

An additional correction factor takes feed (percentage of grass / grass silage) into account. Milk yields are taken from statistics, for each district, and ration compositions are modelled, for each district, with RAUMIS (1996). For details regarding the methods, cf. DÄMMGEN et al. (2004: Part 3, Chapter 4.9.1.); regarding spatial and chronological breakdown of N excretions, cf. LÜTTICH et al. (2004).

For all other animals, N-excretion figures were taken from the German literature (DÄMMGEN et al., 2004: Part 3, Chapter 4.9.2 to 4.9.9). Specifically, the following figures were used:

Male beef cattle	42	[kg animal^{-1} a^{-1} N]
Female beef cattle	44	[kg animal^{-1} a^{-1} N]
Calves	16	[kg animal^{-1} a^{-1} N]
Mother cows	96	[kg animal^{-1} a^{-1} N]
Fattened swine	13	[kg animal^{-1} a^{-1} N]
phase-fed	11	[kg animal^{-1} a^{-1} N]
Sows	36	[kg animal^{-1} a^{-1} N]
phase-fed	29	[kg animal^{-1} a^{-1} N]
Sheep	13	[kg animal^{-1} a^{-1} N]
Horses	64	[kg animal^{-1} a^{-1} N]
Laying hens	0,74	[kg animal^{-1} a^{-1} N]
phase-fed	0,71	[kg animal^{-1} a^{-1} N]
Fattened cocks and chickens	0,29	[kg animal^{-1} a^{-1} N]
Young hens	0,28	[kg animal^{-1} a^{-1} N]
Geese	0,73	[kg animal^{-1} a^{-1} N]
Ducks	0,60	[kg animal^{-1} a^{-1} N]
Turkeys	1,50	[kg animal^{-1} a^{-1} N]
phase-fed	1,41	[kg animal^{-1} a^{-1} N]

For animals with lifetimes < 1 a, the figures for were calculated for keeping facilities with average rotation periods.

The percentage of total ammoniacal N (TAN) was calculated as follows:

Cattle	0,50	[kg kg^{-1} N]
Swine	0,66	[kg kg^{-1} N]
Sheep	0,40	[kg kg^{-1} N]
Horses	0,40	[kg kg^{-1} N]
Poultry	0,70	[kg kg^{-1} N]

6.2.2.5 Grazing periods, stable types and stabling periods

In the cattle category, the duration of grazing (pasture) periods, the average grazing duration per day and the average time spent in milking stalls are used to divide excrement into pasture and stable portions.

All of the stable categories commonly found in Germany are taken into account (Lüttich et al., 2004). The relevant data is compiled in the IPCC-CRF report tables 4 B(a) and 4 B(b) (additional information).

6.2.2.6 Processing of liquid and solid manure

A distinction must be made between processed and unprocessed manure (for example, liquid-manure separation, biogas collection, composting of solid manure). Due to a lack of background information regarding manure processing, as well as to a lack of frequency distributions for liquid manure and to a lack of relevant calculation procedures (solid manure), no figures can be provided in this area.

6.2.2.7 Storage

A distinction is made between solid and liquid manure. The storage forms commonly used in Germany are taken into account. Daily spreading is not commonly practiced in Germany; open lagoons are not used. CRF Table 4.B(b) lists the frequency distributions for the various forms of storage.

6.2.2.8 Spreading

The spreading method used, and the time of subsequent working of manure into the soil, play an important role in calculation of NH_3 emissions and in determination of the N quantities added to the soil via manure. For liquid manure, a distinction is made between broad distribution, towed tubes and towed "shoes"; for solid manure, only broad distribution is considered. Farmland (fallow and with vegetation) and grassland are differentiated. A graduated scale of periods required to work manure into the soil is used (< 1 h, < 4 h, < 6 h, < 12 h,< 24 h, no working into the soil).

6.2.3 Uncertainties and time-series consistency (4.B)

The uncertainties listed in the EMEP/CORINAIR manual (EMEP, 2003) also apply, for the time being, to Germany; i.e. 10 % for animal head counts and 30 % for emission factors for CH_4 and NH_3. The errors for the other emission factors are not known.

The time series is inconsistent with regard to herd populations, due to amendment of the Agricultural Statistics Act (Agrarstatistikgesetz) (for details, cf. 6.1.3.1), i.e. a break occurs between 1998 and 1999. The figures on manure management have been modelled on the basis of a database that is considered inadequate (transfer of survey data collected in model districts to other districts; cf. vergleiche UBA, 2002a). No information regarding uncertainties is available.

6.2.4 Source-specific quality assurance / control and verification (4.B)

The data is reviewed for transcription errors made between the original data and the calculation tables, and it is checked for errors with regard to units and orders of magnitude. Future QA/QC procedures pre-suppose the further development of methods and a better breakdown of activity data (cf. Chapter 6.1.4). In addition, better data is needed for description of manure management.

In particular, such data would include parameters for feeding, yields (slaughter weight, duration of fattening period, etc.), keeping method (with pasturing, type of stabling), type of storage, spreading methods, etc.. Such data must be obtained via surveys.

At present, Germany has no database for description of data quality and uncertainties. The possibilities for improving the database are currently being reviewed.

6.2.5 Source-specific recalculations (4.B)

In contrast to the procedure used in earlier calculations, calculation of all emissions included animals in the city-states of Bremen, Hamburg and Berlin.

The existing population figures for ewes were changed – for Mecklenburg - West Pomerania and Thuringia (for 1991-1993), and for Saxony and Saxony-Anhalt (for 1991). The recalculations for these years also affect figures for manure use, pasturing, etc., along with the relevant derived emissions, leaching, deposition, etc..

6.2.5.1 Source-specific recalculations (CH_4)

Due to transfer errors, recalculations had to be carried out for all cattle. In particular, the emission factor for pasturing of other cattle was wrong.

The relevant differences are considerable, depending on the animal category (cf. Table 67).

Table 67: Comparison of figures, in NIR 2004 and NIR 2005, for CH_4 emissions E_{CH4} from animal husbandry (manure management) [Tg a^{-1} CH_4].

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
NIR 2004	1,61	1,40	1,36	1,33	1,38	1,35	1,35	1,39	1,34	1,33	1,30	1,31	1,31	
NIR 2005	1,29	1,12	1,09	1,07	1,16	1,13	1,14	1,18	1,13	1,14	1,11	1,12	1,10	1,10

6.2.5.2 Source-specific recalculations (NMVOC)

The values for NMVOC emissions from agricultural crops were too high by a factor of 10^3. NMVOC emissions are calculated using the NH_3 emissions for the animal species in question. Since for sheep the emissions are calculated on the basis of ewes, slight changes result for the years 1991 to 1993. These changes are no longer apparent in the tables with rounded values, however.

6.2.5.3 Source-specific recalculations (N_2O, NO, N_2)

No recalculations were carried out for this source category. Official figures are available for 2002.

Table 68: Comparison of figures for N_2O emissions E_{N2O} from animal husbandry (manure management) used in the NIR 2004 and NIR 2005. Figures for Germany in [Gg a^{-1} N_2O].

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
NIR 2004	14,4	12,8	12,5	12,4	10,1	10,1	10,2	10,1	10,0	9,8	9,7	9,8	9,8	
NIR 2005	14,4	12,8	12,5	12,4	10,1	10,1	10,2	10,1	10,0	9,8	9,7	9,8	9,6	9,4

The following errors resulted from transfer into the CRF tables:

- Cultivation of histosols
  The listed emissions level was too low by a factor of 10^3; the formula for calculation of the implicit emission factor was erroneously linked.

- Calculation of N excretion with regard to animal species (Animal waste management system, AWMS)
  In the 2003 CRF tables, IPCC Default EF were reported under AWMS; in the 2004 CRF tables, the AWMS data referred to kg/Stk (kg/head). The pertinent entries were wrong. In the 2005 CRF tables, the AWMS data was calculated in keeping with the relevant IPCC procedure (IPCC, Workbook, 1996a: p. 4.9).

6.2.6 Planned improvements (source-specific) (4.B)

In the NIR 2006, Germany will report for the first time on emissions from keeping of goats. In addition, emissions from keeping of swine will be calculated in accordance with Tier 2.

Plans for NIR 2006 call for basing CH_4 emissions from keeping of cattle on German figures for *volatile solids*, figures derived from calculation of energy flows in enteric fermentation.

The mass-flow model used to calculate emissions of N species needs to be updated in the area of oxidised species. In particular, the emission factors need to be related to TAN.

For it to be possible to use the mass-flow model (cf. DÄMMGEN et al., 2004: Part 3, Chapter 4.9), the database for describing frequency distributions in dairy-cow rationing, and for describing stall types, storage procedures and spreading methods, must be determined via surveys. The mass-flow model is being expanded and updated via international co-operation.

6.3 Rice cultivation (4.C)

No rice is cultivated in Germany (NO).

6.4 Agricultural soils (4.D)

6.4.1 Source-category description (4.D)

CRF 4.D					
Key source by level (l) / trend (t)		**Gas (key source)**	**1990 – contribution to total emissions**	**2003 – contribution to total emissions**	**Trend**
Agricultural soils, direct soil emissions (CRF 4.D.1)	l / t	N_2O	2,22 %	2,32 %	rising
Agricultural soils, indirect emissions (CRF 4.D.3)	l / -	N_2O	1,10 %	1,10 %	stag-nating

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor[138] (EF)	IE	CS	NO	NO	NO	C/D	C/D	NO	C	NO
EF uncertainties in %		50				50				
Distribution of uncertainties[139]		-				-				
Method of EF determination[140]		CS				C/CS				

The source category Agricultural soils (4.D) is a key source for indirect emissions, in terms of emissions levels, and a key source for direct emissions, in terms of emissions levels and trend.

138 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
139 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
140 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model

Microbial reactions (nitrification and denitrification) with nitrogen compounds lead to emissions of nitrous oxide. The more nitrogen that enters the soil, the higher can be the rates of nitrification and denitrification. For this reason, N-inputs play a key role in determination of N_2O emissions. Only part of these emissions are natural. Anthropogenic nitrogen inputs into soils, both direct and indirect, increase such emissions, while soil tilling influences nitrous-oxide emissions.

Direct N-inputs leading to N_2O emissions include use of mineral and farm fertilisers, spreading of sewage sludge, legume cultivation, working of plant residues into the soil, animal excretions in pasture and N-mineralisation in cultivation of organic soils.

The inventory includes direct N_2O, NO and NH_3 emissions from nitrogen fertilisation with mineral N fertilisers, and with farm manure, from biological N fixing and from plant residues in the soil. N_2O emissions from cultivation of organic soils are likewise included as a direct emissions source.

Indirect N_2O emissions from agriculture occur via the following input pathways:

- Leaching and surface run-off from fertilised land,
- Atmospheric deposition of NH_3 and NO_x from agricultural sources;
- Leaching from spread sewage sludge, or from applied wastewater that reaches surface waters.

In every case, the nitrogen used by agriculture is lost, while reactive species reach other ecosystems as deposits (nitrate-N, ammonium-N). The entry pathways "formation of N_2O from NH_3 in the atmosphere, via anthropogenic NH_3 emissions", "discharges from wastewater and food-industry processing facilities" are also emissions sources, but they are not taken into account in the IPCC methods. Calculation of indirect N_2O emissions for purposes of the inventory includes the areas of atmospheric deposition of reactive N-species (NH_3 and NO) from agricultural sources, leached N and run-off of spread N. Germany does not yet report on emissions resulting from use of sewage sludges.

In principle, plant stocks are always sources of volatile organic compounds. A first estimate of surch emissions was carried out for important crops.

Agricultural soils are sinks for atmospheric methane that is oxidised by methanotrophic bacteria.

In each case, calculations are carried out for Länder. For the first time, fertiliser sales in the city-states are included.

The results of the calculations are shown in Table 69. As the table shows, emissions decreased from 1990 to 2003.

Table 69: N_2O and NO emissions E_{N2O} and E_{NO} from agricultural soils. Figures in [Gg a^{-1} N_2O] and [Gg a^{-1} NO].

Jahr	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
E_{N2O}	142	130	126	122	116	121	121	120	121	124	127	12	119	119
E_{NO}	66	60	57	56	52	55	55	54	55	56	57	55	54	53
E_{NH3}	122	111	105	109	99	110	111	112	115	122	126	131	129	127

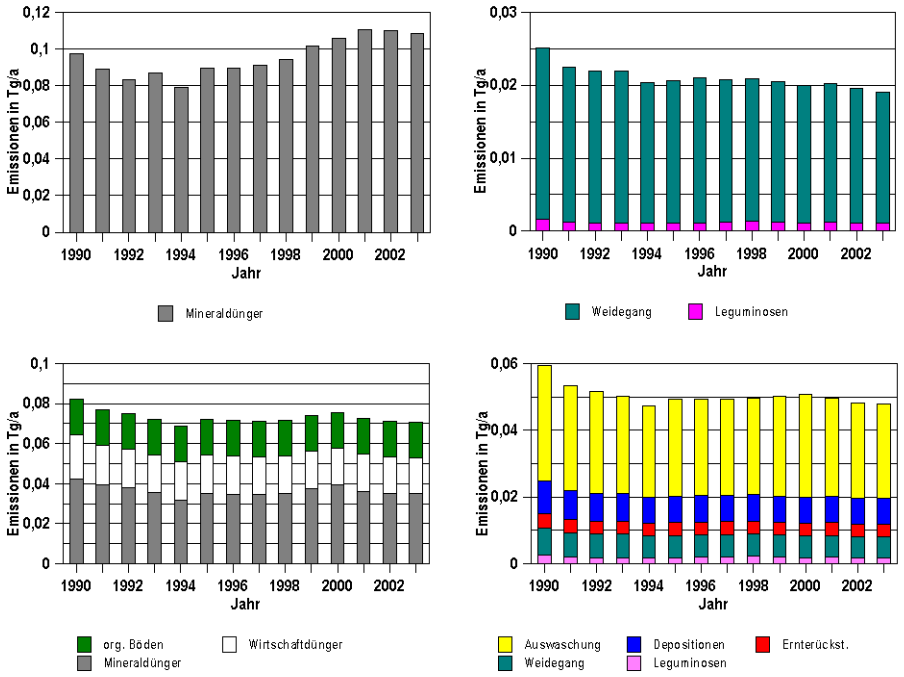

Figure 49: Time series for NH_3 emissions E_{NH3} from soils (above) and for N_2O emissions from soils (below). In each case, N-fertilised systems on the left, while unfertilised systems are on the right. Figures in [Tg a-1 NH_3 and N_2O].

The largest share of N_2O emissions (30 %) from soils can be attributed to use of mineral fertilisers in soils. Indirect emissions from leaching account for 25 % of N_2O emissions, while manure and organic soils each account for 15 % of N_2O emissions. The remaining emissions consist of emissions from grazing, legumes, harvest residues and indirect emissions from deposition.

Use of mineral fertilisers also accounts for the largest share of NH_3 emissions: a share of 80 % in 1990 and of 85 % in 2003 (provisional value).

In the CSE, source category 4.D Agricultural soils includes crop cultivation with and without fertiliser use.

Figure 50: Structural allocation, 4.D Agricultural soils

6.4.2 Methodological issues and requirements, (4.D)

The IPCC-GPG (2000) describe Tier 1a and Tier 1b procedures for determining **direct nitrous-oxide emissions** from agricultural soils. The Tier 1a procedure is somewhat older,

conforming to the 1996 IPCC Guidelines, while Tier 1b is a procedure pursuant to IPCC-GPG (2000). Tier 1b provides greater precision in development of individual terms. Where sufficiently precise activity data is not available, calculation may be carried out in accordance with Tier 1a. Where more detailed, country-specific methods are available, these should be used, and adequate relevant documentation should be provided. Various countries refer to these methods as "Tier 2" methods. In principle, both procedures use the following calculation steps:

1. Determination of N input from agriculture
2. Determination of emission factors for the various individual N inputs
3. Calculation of total emissions

The Tier 1a procedure differentiates between two different emission factors – one for emissions from N input and one for emissions from cultivation of organic soils (IPCC-GPG, 2000; p. 4-54):

Equation 5: Tier 1a for determination of direct N_2O emissions from agricultural soils

$$E_{N_2O,\,direkt} = \left[\left(m_{SN} + m_{AM} + m_{BN} + m_{CR}\right)\cdot EF_1 + \left(A_{OS}\cdot EF_2\right)\right]$$

where $E_{N2O,\,direct}$ N_2O emissions [kg a^{-1} N]
m_{SN} Annual input of synthetic fertiliser, adjusted for NH_3 and NO_X emissions [kg a^{-1} N]
m_{AM} Annual input of farm manure, adjusted for NH_3 and NO_X emissions [kg a^{-1} N]
m_{BN} Annual N fixing by legumes [kg a^{-1} N]
m_{CR} Annual N return from plant residues [kg a^{-1}]
EF_1 Emission factor for emissions from N inputs [kg * kg^{-1} N]
A_{OS} Area of cultivated organic soils [ha]
EF_2 Emission factor for emissions from cultivation of organic soils [kg ha^{-1} a^{-1} N]

The more detailed Tier 1b method, on the other hand, employs more strongly disaggregated emission factors for the various N inputs. The N fraction from fertiliser that is emitted as NH_3, following spreading of fertiliser, is deducted from the applied amounts, because this fraction is included in calculation of indirect emissions:

Equation 6: Tier 1b for determination of direct N_2O emissions from agricultural soils

$$E_{N2O,direkt} = \sum_i \left\{\left[\left(m_{SN} + m_{AM}\right)_i \cdot EF_i\right] + \left[\left(m_{BN} + m_{CR}\right)\cdot EF_1\right] + \left(A_{OS}\cdot EF_2\right)\right\}$$

where EF_i Emission factor for emissions from fertiliser application for various conditions i
EF_1 Emission factor for emissions from biological fixing and from returns of plant residues (see above)

A term for application of sewage sludges can be included in the equation. The IPCC regulations do not yet contain any default EF for application of sewage sludges, however.

N_2O emissions from animal excrements in pastures should also be reported with direct emissions from soils; the relevant methods description and default EF are presented in the IPCC Good Practice Guidance (2000), in the chapter on N_2O emissions from manure management.

The degrees of disaggregation for the various terms of the equation may be chosen in keeping with data availability. As a result, the two methods, Tier 1a and 1b, can be combined. More detailed equations for the various terms are described on pages 4.54 to 4.59 of IPCC-GPG (2000).

In principle, detailed, country-specific data should be used, especially in cases in which the emissions are a key source. Emission factors should be based on measurements, and measurements should be carried out for prolonged periods, to ensure that fluctuations in the relevant biogeochemical processes are adequately reflected. Where data is lacking, an option is to use emission factors of other countries that have comparable conditions. Yet another option is to use the simpler IPCC estimates.

Data on fertiliser use should be taken from official statistics and should be compared with international data (such as IFA or FAO). For the N fraction from fertiliser use that degases as NH_3 or NO_x, a loss rate of 10 % may be assumed, if no country-specific data is available. The database for determining N inputs from manure should be the same as that used for determining emissions from animal husbandry.

Where countries do not have any country-specific emission factors available, they should still determine activity data with the greatest possible degree of detail, in order to simplify future improvement.

In principle, calculation of **indirect emissions** proceeds according to the following steps:

1. Determination of indirect N inputs via determination of N losses from agriculture due to emissions, surface run-off, leaching and wastewater management
2. Determination of emission factors for the various N inputs
3. Calculation of total emissions

The IPCC Guidelines' general equation for determination of indirect N_2O emissions from agricultural soils is as follows:

$$E_{\mathrm{N2O,indirect}} = E_{\mathrm{N2O,ge}} + E_{\mathrm{N2O,l}} + E_{\mathrm{N2O,s}}$$

where
- $E_{\mathrm{N2O\ (indirect)}}$ Nitrous-oxide emissions as given [kg a^{-1} N]
- $E_{\mathrm{N2O,ge}}$ Nitrous oxide emissions from emissions of NO_x and NH_3 from fertiliser, manure and liquid manure and their subsequent atmospheric deposition [kg a^{-1} N]
- $E_{\mathrm{N2O,l}}$ Nitrous oxide emissions from surface run-off and leaching of spread fertilisers [kg a^{-1} N]
- $E_{\mathrm{N2O,s}}$ Nitrous oxide emissions from wastewater discharge into surface waters [kg a^{-1} N]

As with direct emissions, a differentiation is made between the Tier 1a method and the Tier 1b method. The two methods, Tier 1a and Tier 1b, differ in the number of N sources they take into account, for calculation of emissions from volatilisation/deposition and for calculation of emissions from leaching and surface run-off. The following description of calculation of N_2O emissions from atmospheric deposition serves to illustrate the Tier 1a and Tier 1b methods.

N_2O emissions from atmospheric deposition are calculated using the following equation (Tier 1a):

$$E_{N2O,ge} = \left[\left(m_{N,fert} \cdot x_{fert}\right) + \left(m_{N,ex} \cdot x_{ex}\right)\right] \cdot EF_4$$

where: $E_{N2O,ge}$ Nitrous oxide emissions from emissions of NO_x and NH_3 from fertiliser, and their subsequent atmospheric deposition [kg a^{-1} N]
$m_{N, fert}$ Amount of mineral fertiliser applied [kg a^{-1} N]
x_{fert} Fraction of mineral fertiliser that is emitted as NH_3 or NO_x [kg * kg^{-1} N] (IPCC: $Frac_{GASF}$)
$m_{N,ex}$ Total amount of excreted farm manure [kg a^{-1} N]
x_{ex} Fraction of farm manure that is emitted as NH_3, NO_X, N_2O or N_2 [kg * kg^{-1} N] (IPCC: $Frac_{GASM}$)
EF_4 Emission factor for N_2O emissions from atmospheric deposition [kg * kg^{-1} N]

The Tier 1b method takes account of other indirect N depositions, in addition to those from fertilisation. These include N emissions from spread sewage sludge, for example.

For each of the three sources in question (N deposition, leaching, N from wastewater), the IPCC-GPG (2000) provides a separate default emission factor (EF_4, EF_5, EF_6) for describing nitrous-oxide formation (IPCC-GPG, 2000: Table 4.18). It is explicitly stated that these default emission factors should be used in cases in which no thoroughly substantiated, checked national emission factors are available. All in all, the emission factors for calculation of indirect N_2O emissions are subject to large uncertainties.

In most cases, the calculation methods comply with specifications for the simpler method described in the CORINAIR manual (EMEP, 2003). Specific details are provided in the relevant sections. The data on land under cultivation is taken from the official statistics for each year. The emissions calculation for 2003 is based on provisional land-use data.

6.4.2.1 Methane consumption of agricultural soils (4.D)

Calculation of CH_4 deposition is based on a proposal of BOECKX & VAN CLEEMPUT (2001), who summarise the available results of European measurements. The proposal calls for differentiation between grassland (EF_{CH4} = -2.5 kg ha^{-1} a^{-1} CH_4) and farmland (EF_{CH4} = -1.5 kg ha^{-1} a^{-1} CH_4).

6.4.2.2 Emissions of non-methane volatile organic compounds from agricultural soils and crops (first estimate) (4.D)

Levels of NMVOC emissions from plants were estimated using the procedure set forth in the CORINAIR manual (EMEP, 2003). This source provides area-dependent emission factors for some of the main crops in question (for details, cf. DÄMMGEN et al, 2004: Part 3, Chapter 4.1.5).

6.4.2.3 Nitrous oxide and nitrogen monoxide emissions from agricultural soils (fertiliser use) (4.D)

For calculation, emissions of the two gases are assumed to be proportional, on the average, to N discharges into the system. N discharges from mineral fertilisers are taken from official statistics, while discharges from manure follow from calculations of N flows in manure management. Mineral fertiliser sales (for each German Land) serve as the activity data. (for details, cf. DÄMMGEN et al., 2004: Chapter 4.1.1).

N_2O emissions from agricultural use of sewage sludge are currently not reported, since relevant activity data is lacking. IPCC provides no emission factors for spreading of sewage

sludge on agricultural croplands. In the IPCC Guidelines (1996: p. 4.110) the emissions are considered negligible.

6.4.2.4 Nitrous oxide and nitrogen monoxide emissions from agricultural soils (legumes) (4.D)

The amounts of N fixed by legumes are calculated from the areas under cultivation (DÄMMGEN et al., 2004: Part 3, Chapter 4.2.1) and from the national mean values for area-specific N fixing.

Equation 7: Determination of emissions of N species from legume cultivation

$$E_N = b \cdot EF_1 \cdot \sum_i A_i \cdot m_{NF,i}$$

where E_N Emission of N species [Gg a^{-1} N]
b Conversion factor [10^6 kg Gg^{-1}]
EF_1 Emission factor for emissions from N inputs [kg ha^{-1} N] (see below)
A_i Cultivation area for a crop i [ha]
$m_{NF,i}$ Fixed N amounts [kg ha^{-1} a^{-1} N] (see below)

Different fixed amounts $m_{NF,i}$ are differentiated, for:

Legumes	250	[kg ha^{-1} N]
Clover, clover/grass, clover/lucerne	200	[kg ha^{-1} N]
Lucerne	300	[kg ha^{-1} N]

The following emission factors are used:

N_2O	0,0125	[kg kg^{-1} N]
NO	0,007	[kg kg^{-1} N]

Equation 8 is derived directly from Equation 4.21 of the Good Practice Guidance. While that source proposes estimating $m_{NF,i}$, for different crop types, via yields or above-ground biomass, the above-described German procedure draws amounts of fixed N from tables. The activity is $\Sigma(A_i\ m_{NF,i})$; the NIR 2004's use of one area was inaccurate.

6.4.2.5 Nitrous oxide and nitrogen monoxide emissions from agricultural soils (harvest residues) (4.D)

The N quantities remaining in the soil with harvest residues are calculated from the area under cultivation and the crop-specific N residues:

$$E_{N2O_{Crop}} = EF_{N2O} \cdot m_{N_{Crop}} \cdot A_{Crop}$$

where $E_{N2O,\ Crop}$ N_2O emissions from cultivation of a crop
EF_{N2O} Emission factor
$m_{N,\ Crop}$ Nitrogen quantity in harvest residues
A_{Crop} Area under cultivation with the relevant crop

The calculations make use of default emission factors for calculation of emissions from use of mineral and manure fertilisers (IPCC et al, 1996b, Table 4-19 and EMEP, 2003, B1010-15): EF_{N2O} = 0.0125 [kg * kg^{-1} N]; EF_{NO} = 0.007 [kg * kg^{-1} N]; EF_{N2} = 0.1 [kg * kg^{-1} N]. The same factors are also applied to the N quantities bound in harvest residues.

The following list indicates what N quantities are found in harvest residues:

Wheat	17	[kg ha^{-1} N]
Rye	14	[kg ha^{-1} N]

Winter barley	12	[kg ha^{-1} N]
Summer barley	9	[kg ha^{-1} N]
Oats	14	[kg ha^{-1} N]
Triticale	12	[kg ha^{-1} N]
Grain corn	60	[kg ha^{-1} N]
Silo corn	26,7	[kg ha^{-1} N]
Rape	15	[kg ha^{-1} N]
Sugar beets	22	[kg ha^{-1} N]
Fodder beets	0,11	[kg ha^{-1} N]
Clover, clover/grass, clover/lucerne	40	[kg ha^{-1} N]
Lucerne	158	[kg ha^{-1} N]
Grass	30	[kg ha^{-1} N]
Potatoes	10	[kg ha^{-1} N]

The areas under cultivation are listed in LÜTTICH et al. (2004: Part 1, Chapter 2.3.2.6).

The CRF tables (Version 14.06.04) list emissions, but not the activity rates or IEF. The relevant entries are "NA".

6.4.2.6 Nitrous oxide emissions from organic soils (4.D)

Nitrous oxide emissions from cultivation of *organic soils* are calculated in accordance with the simpler method. In this method, emissions are proportional to the area in question. Since no statistical data on use of such soils is available, the areas in question have been estimated via superpositioning of land-use maps and soil maps. (for details, cf. DÄMMGEN et al., 2004: Chapter 6.2). The emission factor used is the "new" default factor EF_2 (Good Practice Guidance: 8 kg ha^{-1} a^{-1} N_2O-N, Table 4.17). Last year, the "old" EF_2 (IPCC Guidelines, 1996: 5 kg ha^{-1} a^{-1} N_2O-N) was used.

6.4.2.7 Nitrous oxide emissions from excrement produced during grazing (4.D)

In treatment of manure via the mass-flow procedure, emissions of N species that result from grazing on pastures are calculated for each species and district, using the relative quantities of excretions occurring on pastures, and then summed for all German Länder (for details, cf. DÄMMGEN et al., 2004, Part 3, Chapter 4.9).

The emission factors used are as follows (EMEP, 2003, B1010-13 und IPCC et al., 1996b: Table 4-22):

NH_3	0,075	[kg kg^{-1} N]
N_2O	0,02	[kg kg^{-1} N]
NO	0,02	[kg kg^{-1} N]

6.4.2.8 Indirect nitrous oxide emissions resulting from atmospheric deposition (4.D)

These indirect emissions comprise N_2O emissions from atmospheric deposition and from leaching and surface run-off. The pertinent NH_3 and NO emissions data is based on use of mineral fertilisers and on manure management. The data on use of mineral fertilisers and on legume cultivation comes from official statistics. IPCC default emission factors are used (IPCC Reference Manual, 1996b: Table 4-23).

6.4.2.9 Indirect nitrous oxide emissions resulting from leaching and surface run-off (4.D)

Under a simple Tier 1 procedure, N_2O emissions from leaching and surface run-off are considered to be proportional to N inputs into the soil. The CRF calls for fugitive nitrogen releases from mineral fertilisers and farm manure to be listed as a source. IPCC default values are used for the leachable fraction and for the emission factor (IPCC Reference Manual, 1996b: Tab. 4-24 and Tab. 4-23).

Pursuant to the GAS-EM documentation (DÄMMGEN et al., 2002), N_2O emissions are calculated in accordance with the following formula:

$$E_{N2O,I} = (m_{man} + m_{fert}) \cdot x_{leach} \cdot EF_5$$

where: $E_{N2O,I}$ Emissions rate for N_2O from leaching and surface run-off [kg a^{-1} N]
m_{man} N input via manure [kg a^{-1} N]
m_{fert} N input via mineral fertilisers [kg a^{-1} N]
x_{leach} Leachable N fraction [kg kg^{-1} N]
EF_5 Emission factor for leached or run-off N [kg kg^{-1} N]

6.4.3 Uncertainties and time-series consistency (4.D)

The uncertainties are outlined in EMEP/CORINAIR (EMEP, 2003); they apply to Germany as well until further notice. The detailed discussion in this source indicates that the error for relevant areas is on the order of 10 % and that the error for emissions is on the order of 50 %. The time series is consistent.

6.4.4 Source-specific quality assurance / control and verification (4.D)

The data is reviewed for transcription errors made between the original data and the calculation tables, and it is checked for errors with regard to units and orders of magnitude. Future QA/QC procedures pre-suppose the further development of methods and a better breakdown of activity data (cf. 6.1.4). At present, Germany does not have any database for description of data quality and uncertainties.

6.4.5 Source-specific recalculations (4.D)

6.4.5.1 Methane consumption of agricultural soils (4.D)

No source-specific recalculations have been carried out.

6.4.5.2 Nitrous oxide and nitrogen monoxide emissions from agricultural soils (4.D)

Inclusion of the amounts of mineral fertilisers sold in Germany's city-states results in a noticeable increase of direct emissions of N_2O, NO and NH_3 and of indirect emissions of N_2O. This has very little impact on total emissions from soils, however.

Table 70: Comparison of figures used in the NIR 2004 and NIR 2005 for N_2O emissions from agricultural soils. [Tg a^{-1} N_2O].

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
NIR 2004	0,14	0,13	0,13	0,12	0,11	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,12	
NIR 2005	0,14	0,13	0,13	0,12	0,12	0,12	0,12	0,12	0,12	0,12	0,13	0,12	0,12	0,12

Table 71: Comparison of figures used in the NIR 2004 and NIR 2005 for NO emissions from agricultural soils. [Tg a^{-1} NO].

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
NIR 2004	0,065	0,059	0,057	0,055	0,051	0,054	0,054	0,054	0,055	0,056	0,057	0,055	0,054	
NIR 2005	0,066	0,060	0,057	0,056	0,052	0,055	0,055	0,054	0,055	0,056	0,057	0,055	0,054	0,053

The values for NMVOC emissions from agricultural crops were too high by a factor of 10^3.

6.4.6 Planned improvements (source-specific) (4.D)

A national workshop took place in November 2004. At this workshop, results from international inventory review, relative to determination of nitrous oxide from soils, were discussed (inter alia) and used to make improvements in the source category. The suitability of existing process-oriented models for calculating direct and indirect emissions, and the possibility of using such models in future, are to be reviewed. Plans also call for provision of more detailed explanations of methods used, especially methods for determination of emissions from harvest residues.

In the NIR 2006, Germany will report for the first time on emissions from keeping of goats.

In future, the statistics on which emissions calculation is based will have to be expanded to include error and scattering, to make it possible to calculate uncertainties as required by the IPCC. The Federal Environmental Agency has prepared a guide for execution of experts' estimates.

6.5 Prescribed burning of savannas (clearance of land by precribed burning) (4.E)

Land clearance by prescribed burning is not practiced in Germany (NO).

6.6 Field burning of agricultural residues (4.F)

Burning of agricultural residues is prohibited in Germany. It is not possible to collect data on permitted exceptions. Such exemptions are considered to be irrelevant (NO).

6.7 Other areas (4.G.)

No other sources of greenhouse-gas emissions are known.

7 LAND USE, LAND-USE CHANGES AND FORESTRY (5)

7.1 Forests (5.A)

The basis for reporting consists of the definition of "forest" used by the Federal Forest Inventory (Bundeswaldinventur - BWI)[141]. The BWI's survey instructions differentiate between the following sub-categories of forest:

- Productive forest, wooded ground[142]
- Unproductive forest[143], wooded ground[141]
- Forest, openings[144]
- Forest, non-wooded ground[145]

In calculations for greenhouse-gas inventories, the categories "unproductive forest" and openings were included with forest, while non-wooded ground, in keeping with the definition of "forest" used in decision 11/CP.7 of the 7th Conference of the Parties in Marrakesh (UNFCCC, 2002: p. 58) was excluded, as non-forest.

In the Good Practice Guidance for Land use, Land-use Change and Forestry (GPG-LULUCF, IPCC, 2003), in the official reporting tables for the greenhouse-gas inventories sent to the Climate Secretariat and in the "Common Reporting Format" (CRF), the category "forest" is divided into "Forest Land remaining Forest land" (forest that remains forest during the period covered by the report) and "Land converted to Forest Land" (new forest created, via afforestation or natural succession, on areas previously used for other purposes). Pursuant to IPCC GPG-LULUCF (2003), new forest remains for at least 20 years within this category, after which it is transferred to the "remaining forest land" category.

In Germany, with existing data, new forest additions in the old German Länder can be traced only back to 1987; for the new German Länder, it has been possible only to derive the net new forest since 1993.

[141] Forest within the meaning of the FFI is any area of ground covered by forest vegetation, irrespective of the information in the cadastral survey or similar records. The term forest also refers to cutover or thinned areas, forest tracks, firebreaks, openings and clearings, forest glades, feeding grounds for game, landings, rides located in the forest, further areas linked to and serving the forest including areas with recreation facilities, overgrown heaths and moorland, overgrown former pastures, alpine pastures and rough pastures, as well as areas of dwarf pines and green alders. Heaths, moorland, pastures, alpine pastures and rough pastures are considered to be overgrown if the natural forest cover has reached an average age of five years and if at least 50% of the area is covered by forest. Areas with forest cover in open pasture land or in built-up areas of under 1000 m², coppices under 10 m wide and the cultivation of Christmas trees and ornamental brushwood as well as parkland attached to country houses are not forest within the meaning of the FFI. Watercourses up to 5 m wide do not break the continuity of a forest area. The cultivation of Christmas trees and ornamental brushwood in the forest is forest within the meaning of the Federal Forest Inventory (BMELF, 1990).

[142] The wooded-ground area is that part of the forest that is covered with trees used in forestry and that is used for wood production.

[143] Unproductive forest areas are fields of dwarf pines and green alders, areas of shrubs (but not openings) and other forest areas which are sparsely covered or which have low productivity (≤1 m³ average total growth (dGZ)/hectare).

[144] Openings are areas of wooded ground temporarily without forest cover.

[145] Non-wooded ground includes forest tracks, rides and firebreaks over 5 m wide, landings, tree nurseries, seed and plant nurseries, wood-pastures and fields for game, the areas of yards and buildings used for forestry purposes, recreational facilities linked to the forest and rocks, boulders, gravel and water located in the forest. In addition, if they are not overgrown, swamps and moors located in the forest come under non-wooded ground.

7.1.1 Forest Land remaining Forest Land (5.A.1)

7.1.1.1 Source-category description (5.A.1)

CRF 5.A					
Key source by level (l) / trend (t)		**Gas (key source)**	**1990 – contribution to total emissions**	**2003 – contribution to total emissions**	**Trend**
	- / -				

Gas	CO_2	CH_4	HFCs	PFCs	SF_6	N_2O	NO_X	CO	NMVOC	SO_2
Emission factor[146] (EF)	CS									
EF uncertainties in %										
Distribution of uncertainties[147]										
Method of EF determination[148]	CS/T2 [149]									

The source category "forest land remaining forest land" has not yet been subjected to key-source analysis.

7.1.1.1.1 Changes in biomass

For the old German Länder, data is available from two federal forest inventories (key dates: 1 October 1987 and 1 October 2002) (BFH, 2004). Between the two forest inventories, C stocks in forests of the old German Länder underwent a net increase of 1.52 Mg/ha/a. The increase in stocks is a result of low use, in comparison to growth. For the new German Länder, data from the Federal Forest Inventory II (BWI II) was compared with forest-establishment data, given the lack of an initial inventory comparable to BWI I. The comparison showed a marked net C-stock increase of 3.01 Mg/ha/a.

It seems clear that the forest-establishment data underestimates stocks. If the initial value for total stocks is assumed to be 10 % higher (and evenly distributed among all tree species), a marked net C-stock increase of 2.32 Mg/ha/a results.

Overall, the forests of the Federal Republic of Germany are thus a net sink for C.

7.1.1.1.2 Dead wood, debris and soils

For greenhouse-gas inventories, it was assumed that stocks under existing forest do not change (corresponds to "Tier 1").

7.1.1.1.3 Other greenhouse-gas emissions from forests

Figures for CO_2 emissions from liming of forest soils are provided in category 5.G. (Other). They range between 130 and 210 Gg CO_2 per year, and are tending to decrease.

Forests in Germany are not normally given nitrogen fertilisers. In CRF Table 5(I), therefore, this activity has been marked "NO". No reliable data is available for reporting on N_2O emissions from draining of forest soils (CRF 5(II)).

146 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
147 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
148 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model
149 The figure CS/T2 refers to determination of changes in biomass stocks. Under Tier 1, changes in deadwood, debris and soil were estimated to be 0.

BUTTERBACH-BAHL (2003), using the PnET-N-DNDC model, estimated total nitrous oxide (N_2O) emissions from forest soils for the years 1990-1999 as amounting to about 14 Gg per year. This figure includes "indirect" N_2O emissions, however, which originate in sources outside of the forestry sector and thus are outside the scope of greenhouse-gas inventories for forest soils.

As a result of use of the "stock-change method", CO_2 from biomass combustion has already been taken into account in changes of biomass stocks; the entry for this category is thus "IE".

Emissions of other greenhouse gases from forest fires and from controlled biomass combustion have been classified as negligible and, in Table 5 (V) "Biomass burning", reported as "NO", since only small areas of Germany are affected by forest fires and since logging areas are burned only in exceptional cases – for example, in cases of bark-beetle infestation. Burning-off of vegetated areas is prohibited in Germany.

7.1.1.2 Methodological issues (5.A.1)

7.1.1.2.1 Data sources

The basis for the biomass and area calculations consists of the data from the two Federal Forest Inventories. Pursuant to provisions of the GPG-LULUCF (IPCC 2003), this data is processed in keeping with requirements pertaining to international reporting obligations.

The Federal Forest Inventory (Bundeswaldinventur – BWI) is a terrestrial random-sampling inventory with permanently marked sampling points in a 4 x 4 km basic grid whose resolution, at the request of the Länder, can be increased on a regional basis[150].

The first Federal Forest Inventory, BWI I, covered only the territory of the Federal Republic of Germany in its pre-1990 boundaries and West berlin. For the new German Länder, therefore, forest-establishment data has to be taken from another source – the publication "The Forest in the New German Länder" ("Der Wald in den neuen Bundesländern" (BML, 1994)).

Due to the differences in the data situations for the two areas, and to the resulting need to use different calculation methods, reporting in the CRF tables is broken down by old and new German Länder.

Now, with the Federal Forest Inventory II (BWI II) and Soil-Condition Survey (Bodenzustandserhebung - BZE), first inventories are available for the categories of deadwood, debris and soils. While this makes it possible to estimate the C stocks in these categories, it does not made it possible to determine the relevant changes.

The deadwood stocks of 11.5 m^3/ha found by the BWI II correspond to C stocks of some 2.6 Mg C /ha.

Finer debris fractions are part of the humus layer, which was surveyed by the BZE. The first BZE, which was carried out from 1987 to 1993, estimated the carbon stocks in the humus layer, and in the first 30 cm of mineral soil lying beneath the humus layer, as amounting to about 0.858 Pg C (BMELF, 1997).

Data on liming of forest soils was derived from fertiliser statistics (Düngemittelstatistik) published by the Federal Statistical Office (DESTATIS, 2003: Tab. 8.27.2, Domestic sales of

[150] Further information: http://www.bundeswaldinventur.de and http://www.bundeswaldinventur.de/Verdichtung.gif

fertilisers) and from statistics of the former GDR. From 1993/94 onwards, the results have been collected and published for unified Germany.

Data on areas on which forest fires have occurred, since 1992, is available in official forest-fire statistics pursuant to Council Regulation (EEC) No. 2158/92 of 23 July 1992 on protection of the Community's forests against fire; excerpts from the forest-fire statistics are published in BML 1992ff..

7.1.1.2.2 Forest land remaining as forest land

Forest-area data is not required for calculation of biomass stocks pursuant to the stock-change method, but it must be reported in the CRF. The area data for individual years is based on linear interpolation.

Pursuant to the results of the two Federal Forest Inventories, in the old German Länder, the total forest area (not including the non-timber area) increased by 54.12 kha, to 7,693.72 kha, between 1987 and 2002. Pursuant to IPCC GPG-LULUCF (2003), new forest must be classified as "new forest" for a period of 20 years, and thus each year the category "forest land remaining forest land" is reduced by that forest area converted to other land uses. The category "forest land remaining forest land" thus decreased from 7,626.14 kha (1990) to 7,572.27 kha (2002).

According to forest-establishment data, in the new German Länder, the forest area (not including non-wooded ground) in 1993 amounted to 2,852.5 kha; by BWI II it had increased to 3,027 kha. As a result, the first of these values can assigned to the category "forest land remaining forest land".

7.1.1.2.3 Derivation of stock changes pursuant to the "stock-change method" (difference method)

The Federal Forest Inventories provided such good data for calculation – measuring about 230,000 trees in key year 1987 (BWI I) and some 377,000 trees in key year 2002 (BWI II) – that it was possible to use the "stock-change method" instead of the "default method" (incremental extrapolation, as carried out for previous inventories) (IPCC, 2003: p. 3.24).

For use of the stock-change method, the relevant living biomass was divided into the following categories: standing-timber volume, branch wood volume and root mass. Above-ground volumes were converted into masses using specific volume densities for the various tree species in question. The basic equation (equation 1 and 2) for C-stock determination via the stock-change method was thus converted into a form pursuant to equation 3. The first part of equation 3 (standing timber, branch wood) was applied to each tree, while the second part was applied to stands. The total value was then extrapolated from the stand values.

Equation 9

$$\Delta C = \left(C_{t_2} - C_{t_1}\right) / \left(t_2 - t_1\right)$$

Equation 10

$$C = \left[V \bullet D \bullet BEF\right] \bullet \left(1 + R\right) \bullet CF$$

Equation 11

$$C = [V \bullet D_D + V \bullet D_A \bullet (VEF - 1)] \bullet (1 + R) \bullet CF$$

Standing timber | Branch wood | Root wood

where:
C = Carbon stocks
V = Volume of standing timber
D_D = Volume density of standing timber
D_A = Volume density of branches
BEF = Biomass-expansion factor
VEF = Volume-expansion factor[151]
R = Root / shoot ratio
CF = Carbon fraction

7.1.1.2.4 Procedure

For central European conditions, there are no generally valid biomass functions that could have been applied to the inventory's measured data (a function for spruce is one exception).

For this reason, a procedure was applied whereby the standing-timber volume, as determined in the inventory, is converted into the above-ground tree volume. The above-ground tree volume includes branches and, for evergreen trees, the leaf organs. Volume-expansion factors were used to estimate the tree-wood volume from the standing-timber volume (cf. Chapter 7.1.1.2.7).

For the new German Länder, forest-establishment data is available in aggregated form. For this reason, the C-balancing method pursuant to BURSCHEL et al. (1993), in conjunction with volume densities pursuant to KOLLMANN (1982), was used for C-stock determination.

7.1.1.2.5 Total stocks of remaining forest land

The results described here refer, in connection with individual-tree calculations for BWI I and BWI II, to volume densities pursuant to KOLLMANN (1982), whereas branch volumes, with their greater densities, were extrapolated pursuant to HAKKILA (1972). Regression equations were used to estimate above-ground tree volumes (cf. Annex). Root biomass was calculated using default values from IPCC GPG-LULUCF (2003). In the extrapolation for the new German Länder for 1993, the biomass-expansion factors of BURSCHEL et al. (1993) were separated into above-ground and below-ground components, and the above branch volume was estimated from the difference between above-ground volume and standing-timber volume. In the interest of comparability between the extrapolation of forest-establishment data and individual-tree calculation pursuant to BWI, the same volume densities were used throughout this process.

[151] The biomass-expansion factor (BEF) is used here in keeping with IPCC. In the literature, the term "BEF" is used in a variety of very different ways. For this reason, in the following, the term "volume-expansion factors" (VEF) is used, which describes the relationship above-ground volume / standing-timber volume.

Table 72: Total C stocks, forest land remaining as forest land, with estimate of the relative standard error

Gg C		1987 (BWI I)	1993 (BML)	2002 (BWI II)
Old German Länder	Below ground	174.670	-	212.849
	Above ground	604.474	-	740.481
	Total	**779.144 (± 8%)**	**-**	**953.330 (± 7,55%)**
New German Länder	Below ground.	-	34.723	63.690
	Above ground.	-	161.766	218.667
	Total	**-**	**196.489 (±12,71 %)**	**282.357 (± 10,02 %)**

7.1.1.2.6 Volume density of trunk wood and branches

The volume densities were derived from the figures provided by KOLLMANN (1982) for raw density and volume-loss measures (cf. Annex), using Equation 12:

Equation 12

$$R = r_0 * \left(1 - \frac{\beta_V}{100}\right)$$

where:
R= Volume density (g/cm^3)
r_0= Raw density (g/cm^3)
ß$_V$= Volume-loss measure

Pursuant to Equation 11, other volume densities are used for branches. Due to the stresses it is subject to, branch wood is denser than trunk wood. Separation into various categories makes it possible to use different densities. The relevant necessary data was derived by analogy to HAKKILA (1972).

Furthermore, figures for volume density of trunk wood vary widely. For this reason, calculations were carried out for a range of different scenarios (cf. Annex 14.5.1.1.1.2.7).

7.1.1.2.7 Volume-expansion factors

The volume-expansion factors (VEF) for conversion of standing timber into above-ground biomass are based on the tables of GRUNDNER & SCHWAPPACH (1952) for standing timber and tree wood; from these tables, a linear regression was derived. These factors provide a functional relationship between standing timber and tree wood. This makes it possible to estimate tree-wood amounts from the size of standing timber, which itself depends on the measurements diameter at a height of 1.3 m, diameter at a height of 7 m (BHD, D_7) and height. In addition, the tables call for separation, by age classes, for the tree species spruce, fir, beech and pine, since for these trees it was found that, for trunks with the same dimensions, older trunks have a greater volume than younger trunks; the older trunks have a greater wood fraction (Table 119). This separation was retained, since the tables on based on separate basic totalities.

The following relationship thus results for the various volume-expansion functions for specific species and tree ages:

Equation 13

$$VEF = \frac{B}{D} = \frac{a + bD}{D}$$

where:
B = Tree-wood volume
D = Standing-timber volume
a, b = Regression parameters
VEF = Volume-expansion function

7.1.1.2.8 Root biomass

Dry-root substance was estimated directly from above-ground mass, at the stand level, using the root/shoot ratio with values pursuant to IPCC 2003. To obtain stand values, the above-ground biomass, differentiated by tree-species groups, was extrapolated to the hectare level for each sampling point, and then the below-ground biomass was derived.

A comparative calculation, in keeping with the function published DIETER & ELSASSER (2002) for estimating root biomass, produced similar results (Annex, Chapter 14.5.1.1.1.2.10).

7.1.1.2.9 Derivation of CO_2 emissions from liming of forest soils

The liming data was derived from the total fertilisers calculation. It describes producers' and importers' deliveries to wholesalers and end users (DESTATIS, 2003). For the calculation, the amount of fertiliser spread was assumed to be the same as the amount sold. The relevant emissions were derived using equation 3.3.6 from IPCC GPG-LULUCF (2003: p. 3.80).

7.1.1.3 Uncertainties and time-series consistency (5.A.1)

The uncertainties were calculated for aggregated stocks, for the two Federal Forest Inventories and broken down by old and new German Länder.

For the old German Länder, stratification was carried out in accordance with tree-species groups pursuant to BWI (ALH[152], ALN[153], beech, douglas fir, oak, spruce, pine, larch, fir). To this end, the relative standard error is estimated or calculated for each input item (standing-timber volume, volume density, above-ground biomass expansion, root biomass and carbon fraction). This relative standard error is then extrapolated using the extrapolation procedure in question – additive error propagation or multiplicative error propagation. The calculation does not take account of every possible error source (divergence of allometry, model errors in standing-timber calculation, measurement errors). Errors are derived using practical approaches, and thus such derivation provides only an approximation of the actual errors at work. Correlations between individual terms were neglected.

As a result, one obtains an estimate of the relative standard error of the total stocks. The 95% confidence interval for this estimate corresponds to double the relative standard error.

[152] ALH = all other deciduous trees with high life expectancies
[153] ALN = all other deciduous trees with low life expectancies

For the new German Länder, errors for C stocks can be calculated only as estimates, based on aggregated values; this is accomplished pursuant to the publication "The forest in the new German Länder" ("Der Wald in den neuen Bundesländern" (BML 1994)).

Error propagation for the periods 1993 (BML, 1994: new German Länder), 1987 (BWI I: old German Länder) and 2002 (BWI II: new and old German Länder) is presented in the Annex (Table 128), while the relative standard error has been added as an overview in Table 72.

The greenhouse-gas inventory for 2005 presents newly calculated data for all years since 1990. Time-series consistency is thus assured. At the same time, reporting has been converted in keeping with the new CRF tables adopted at the 9th Conference of the Parties in Milan.

7.1.1.4 Source-specific quality assurance / control and verification (5.A.1)

The carbon-stocks estimates for the various periods are based on ACCESS queries of the data from the Federal forest inventories; with regard to the quality assurance developed for the Federal Forest Inventory, the reader's attention is called to the literature for the Federal Forest Inventory.

First, an estimate was carried out using the BURSCHEL et. al. (1993) method, to provide an indication of the orders of magnitude of the carbon-stock extrapolation. This estimate, which is based on aggregated values (average stocks, by tree-species groups), was carried out by two different persons, using two different methods (published BWI results and ACCESS queries). The results obtained with the two methods agreed.

In the individual-tree calculations, a "Burschel" scenario (cf. Annex Chapter 14.5.1.1.1.2.5) , using the same volume densities used for the estimate (using aggregated values), was calculated. The resulting values agreed with the calculations using the aggregated values. Consequently, it is clear that the ACCESS queries, in general, provide correct values; on the other hand, their results can deviate depending on what assumptions are made for volume densities and root-shoot ratios.

One systematic error persists, however: It was not possible to estimate rejuvenation below the standing-timber threshold, and the relevant figure is not found in the stock data, because the volume-expansion function is based on standing-timber volumes. The lack of rejuvenation stocks results in a systematic underestimation of total stocks.

7.1.1.5 Source-specific recalculations (5.A.1)

Pursuant to the above-described recalculation, stock increases are twice as high as listed in previous inventories. The main reason for this is the wood-stock increase determined in BWI II, an increase that far exceeds existing yield-table estimates. Other factors include inclusion, for the first time, of underground biomass, improved methods of calculation and underestimation of the outset stocks in the new German Länder (BML, 1994).

7.1.1.6 Planned improvements (source-specific) (5.A.1)

7.1.2 Land converted to Forest Land (5.A.2)

7.1.2.1 Source-category description (5.A.2)

Forest is created through succession, afforestation and reforestation; new forest areas begin storing C equivalents as soon as they are converted. In a rigorous approach, the C-stocks of previous land uses should be deducted. But no data is available on previous plant coverage (for example, individual trees, hedges or long-lived woody cultivations) and its biomass. Overall, such stocks are considered negligible, especially since the total area of new forest land is very small in comparison to the total forest area (old German Länder 2002: 121 kha to 7,694 kha).

7.1.2.2 Methodological issues (5.A.2)

7.1.2.2.1 New forest land

Pursuant to IPCC GPG-LULUCF (2003), new forest lands must remain in the category "new forest lands" for 20 years. No land-use-change data that could support comparisons is available prior to BWI I.

For the old German Länder, direct comparison between BWI I and BWI II makes it possible to separate new forest land and deforested land since 1987. The new forest lands occurring between BWI I (key year 1987) and BWI II (key year 2002), and amounting to 121.45 kha (not including the non-wooded ground) can be categorised as follows in keeping with their existing uses:

Table 73: New forest lands, old German Länder

Outset category	Area [kha]	Annual increase in area [kha/a]
Cropland and long-lived cultivations	30,57	2,04
Permanent grassland	45,46	3,03
Wetlands	15,67	1,04
Settled areas	29,75	1,98

To derive area data for individual years, a linear increase in the new forest lands in BWI I and II was assumed and included in the CRF tables. In comparison to the total forest area of the old German Länder in 2002, 7693.72 kha, these additional areas, totalling 1.58% in 15 years (both figures without non-wooded ground) are marginal.

For the new German Länder, only the net forest-land increase between 1993 and 2002 can be determined; it amounts to 174.56 kha. This difference is considered the new forest land. Its annual rate of increase is 17.46 kha/a; the data does not permit any allocation into outset categories. The area increases were assumed to progress linearly between 1993 and 2002.

7.1.2.2.2 Biomass stocks, new forest land

For the old German Länder, it was possible to carry out an individual-tree calculation for new forest land. First, the stocks were calculated for the entire new forest land. Then, the stocks were distributed throughout the entire new forest area and divided among the sub-categories in accordance with the relevant area shares (Table 74).

Table 74: Stocks, new forest lands, end of 2002

Outset category	Stocks [Gg C]
Cropland and long-lived cultivations	922
Permanent grassland	1.372
Wetlands	473
Settled areas	897

Since for the new German Länder wood stocks on new forest lands cannot be derived directly from comparison of two inventories, hectare values were derived from the standing-timber stocks of tree-species groups in the 1st age class (0-20 years, BWI II new German Länder) and converted into C stocks. In light of the young age of of the new forests that have developed since 1993, this value was then cut in half. This produces a value of 18.01 Mg/ha, or total stocks of 3,144 Gg C, for these areas at the end of the 2002 vegetation period.

The biomass stocks at the end of the 2002 vegetation period correspond to the biomass stock increases throughout the entire period under consideration since 1987 (old German Länder) and 1993 (new German Länder), as long as any possible previous plant cover is ignored. These stock increases were weighted with the new forest area produced in the relevant report years, and then they were linearly interpolated throughout the entire period under consideration.

7.1.2.2.3 Stocks in dead wood, debris and soils on new forest areas

Since in our latitudes it takes decades for typical forest stocks to develop in these categories, the annual increase was considered negligible and not taken into account in the greenhouse-gas inventory.

7.1.2.3 Uncertainties and time-series consistency (5.A.2)

7.1.2.4 Source-specific quality assurance / control and verification (5.A.2)

7.1.2.5 Source-specific recalculations (5.A.2)

7.1.2.6 Planned improvements (source-specific) (5.A.2)

7.2 Cropland (5.B)

For 2003, the total CO_2 emissions from cultivation of cropland were estimated at 25,078.18 Gg CO_2. Of this figure, 20,352 Gg CO_2 were releases from cultivated bogland, which account for only 4 % of Germany's total cropland. A total of 3,225 Gg CO_2 were release from mineral soils, as a result of usage changes on cropland or of conversion from perennial crops to

annual crops or vice-versa. As a result of such land-use changes, a total of 36 Gg CO_2 was stored in above-ground biomass. An additional 1,537 Gg CO_2 was released as a result of liming. While this total refers non-specifically to all agricultural lands, it was assigned wholly to cropland cultivation.

The estimate of CO_2 emissions resulting from land-use changes – emissions relative to biomass and mineral soils – is very conservative, since the approach used (consideration of net land-use change over long periods of time) fails to take account of the largest part of actual land-use changes (studies have indicated that actual land-use changes could be larger by a factor of 60 – 100).

7.2.1 Source-category description (5.B)

CRF 5.B					
Key source by level (l) / trend (t)		**Gas (key source)**	**1990 – contribution to total emissions**	**2003 – contribution to total emissions**	**Trend**
	- / -				

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor[154] (EF)	CS/D									
EF uncertainties in %										
Distribution of uncertainties[155]										
Method of EF determination[156]	CS/T2[157]									

The source category "Cropland" has not yet been subjected to key-source analysis.

Pursuant to IPCC GPG LULUCF (2003), carbon-stock changes in soil and biomass stocks are reported under the category "cropland". The land area subsumed under "cropland" consists of:

1. Cropland with annual crops
   - Wheat, rye, summer and winter barley, oats, triticale, fodder plants, silo corn, potatoes, sugar beets, non-food crops – especially winter rape (broken down by crop only for biomass determination)
2. Cropland with perennial crops
   - Fruit crops, osiers, poplars, Christmas tree farms, nurseries (long-lived crops)
   - Vineyards

Reporting under "cropland" is based on definitions for the usage-type key of the Working group of surveying administrations of the Länder of the Federal Republic of Germany (Arbeitsgemeinschaft der Vermessungsverwaltungen der Länder der Bundesrepublik Deutschland - AdV), in the "Directory of area-based usages in the property cadastre and their definitions" ("Verzeichnis der flächenbezogenen Nutzungsarten im Liegenschaftskataster und ihrer Begriffsbestimmungen" - AdV, 1991), and on the "Ground-cover nomenclature" ("Nomenklatur der Bodenbedeckungen") of the CORINE LAND COVER project (DESTATIS, 1989).

154 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
155 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
156 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model
157 The figure CS/T2 refers to determination of changes in biomass stocks. Under Tier 1, changes in dead wood, debris and soil were estimated to be 0.

7.2.2 Methodological issues (5.B)

7.2.2.1 Data sources

The following data sources were used for determination of cropland areas, for determination of any land-use changes, for allocation of natural and administrative parameters, for development of emission factors for soils and biomass and for calculation of carbon stocks in soils and biomass at various times (for literature details, cf. Chapter 14.5.2.1/14.5.2.2 in the Annex):

1. Digital soil map of Germany, drawn to a scale of 1: 1 000.000 (BUEK 1000)
2. CORINE LAND COVER
3. Data from the following official German statistics:
    - Main soil-use survey (Bodennutzungshaupterhebung) 1991, 1999, 2001
    - Area survey (Flächenerhebung) 1993, 1997, 2001
    - Data from the district reform of 1998
    - Data from the Federal Forest Inventory (Bundeswaldinventur)

For determination of emission factors

Soil:

- Literature

Biomass:

- Main soil-use survey (Bodennutzungshaupterhebung) 1999
- Statistical Yearbook (Statistisches Jahrbuch) (BMVEL 2003)
- Literature

The procedures for determining outset parameters, as well as land areas and usage changes, are described in detail in the Annex, Chapter 14.5.2.1/14.5.2.2. The net changes between 1991 – 1999 and 1999 – 2001 were determined. More recent data is not available. The data was normed using data from the 2001 area survey (Flächenerhebung). A model was applied to these net changes in order to estimate the area changes resulting from use changes (for a detailed description, cf. also Chapter 14.5.2.1 in the Annex). To the thusly determined areas, it was then possible to assign directionality for the use changes – and this, in turn, made it possible to use emission factors for soil and biomass, as derived from the literature, (cf. also Chapter 14.5.2.3 in the Annex) to estimate carbon-stock changes in soil and biomass. All land-use changes that did not lead to grassland or forest were then combined, in the category "Other land" (CRF 5.F), since it was not possible to classify the relevant follow-on uses. It was assumed that no CO_2 emissions or storage occur.

7.2.2.2 Mineral soils

The change in carbon stocks in mineral soils – changes which are expected only in connection with land-use changes – was calculated on the "rural district" aggregation level, via formation of the difference between the final carbon stock (following the usage change) and the initial carbon stock (prior to the usage change) for the relevant area. The final carbon stock was determined by multiplying the area affected by a usage change with the weighted carbon stock – corrected via an emission factor – for the relevant land-use class. The equation is as follows:

$$\Delta C = C_f - C_i = A * EF * C_{gew.} - A * C_{gew}$$

where:

ΔC: Change in the carbon stocks as a result of usage change in t/district*monitoring period
C_f: Final soil carbon stocks in t
C_i: Initial soil carbon stocks in t
A: Area on which land-use change has occurred, in ha
EF: Dimensionless emission factor
C_{gew}: Weighted district-specific and use-specific carbon stocks in t/ha (derived from BUEK 1000, CORINE, BOHE and FE)

This calculation yields new, weighted soil carbon stocks, broken down by usage category. These are obtained by dividing the the newly calculated district soil carbon stock, for each usage category, by the "new" area.

7.2.2.3 Organic soils

The carbon-stock differences for organic soils were estimated on the basis of values from the literature. MUNDEL (1976), GENSIOR und ZEITZ (1999), MEYER (1999) und AUGUSTIN (2001) report losses in grassland areas ranging from 2.46 – 7.63 t $ha^{-1}a^{-1}$, and HÖPER (2002) reports a range of 4.6 – 16.5 t $ha^{-1}a^{-1}$, with bogs used as cropland reaching 10.6 – 16.5 t $ha^{-1}a^{-1}$. For the report, a grassland emission factor of 5 t $ha^{-1}a^{-1}$, and a cropland emission factor of 11 t $ha^{-1}a^{-1}$, were defined from these sources. The uncertainty, and the minimal and maximal values, result from the range of the above-cited values.

7.2.2.4 Biomass

The carbon-stock changes in biomass are estimated by subtracting the biomass carbon stock before the use change from the stock after the use change, with reference to the area affected by the change:

$$\Delta C_{Bio} = C_{Bio}f - C_{Bio}i = A * EF_{final} - A * EF_{initial}$$

ΔC_{Bio}: Change in the biomass carbon stocks in t/district*monitoring period
$C_{Bio}f$: Final biomass carbon stocks in t
$C_{Bio}i$: Initial biomass carbon stocks in t
A: Area on which land-use change has occurred, in ha
EF_{final}: Plant-specific biomass carbon stocks in t/ha (after use change)
$EF_{initial}$: Plant-specific biomass carbon stocks in t/ha (before use change)

Biomass carbon stocks were mathematically combined pursuant to GPG-LULUCF (IPCC, 2003) (cf. Chapter 14.5.2.3.2) in the Annex).

The values for 1990, 2002 and 2003 were linearly extrapolated, under the assumption that land-use changes and area changes would be in keeping with those of neighbouring years.

7.2.3 Uncertainties and time-series consistency (5.B)

The largest uncertainties are caused by the procedure for determining land-use changes on the basis of net area changes for individual land-use categories, over long periods of time. A preliminary review showed that the actual usage changes were clearly underestimated; in the case studied, the changes were actually greater by a factor of 60 – 100.

The potential error in estimation of carbon losses from the soil is about 70% of the mean value. The curve adjustments for determination of emission factors are highly significant; they explain 93.6 % (grassland/forest/untilled land to cropland) and 68.2 % (cropland to grassland/forest/untilled land) of the variation (cf. Chapter 14.5.2.5.2).

Although the statistical surveys for determination of land-use categories and their relevant areas are carried out regularly (complete surveys every four years), the time series are not unequivocally consistent. The reasons for this are as follows:

- German reunification in 1990; as a result, surveys for Germany as a whole do not begin until 1991 (BOHE) and 1993 (FE).
- Repartitioning of areas / district reform (1993/1998).
- Not all German Länder survey all parameters at all survey dates.
- The survey frequencies of some German Länder deviate from the basic relevant principle.

As a result of these factors, some of the data in published tables does not support comparisons (examples include combination of data from different years, and use of non-comparable reference areas (such as the administrative unit in a case in point)). Furthermore, the parameters presented throughout the various relevant formats vary; in particular, phasing-in of electronic data provision has led to a reduction of parameters and to form changes in them. As a result, unless certain Länder provide additional information, and unless certain data is modified and normed, a number of surveys will not lend themselves to comparisons.

A standard algorithm has been used to adjust and norm the data sources, for all report years; this has ensured that the values entered into the CRF tables are consistent. Since no data is available for 1990 for the new German Länder, the reconstruction for 1990 is based on the assumption that the conditions prevailing in 1991 also prevailed in that year. As the land-use categories for 2002 and 2003 were being identified, the BOHE 2003 survey data was not available; consequently, it was assumed that the relevant changes were similar to those of 2001 (cf. also Chapter 14.5.2.5 in the Annex).

7.2.4 Source-specific quality assurance / control and verification (5.B)

With the exception of "Institutionalisierung der Datenbereitstellung" ("Institutionalisation of Data Provision"), the data sources used to prepare this inventory fulfill the checking criteria of the QSE manual for data sources (and yet are still inadequate; cf. Chapter 14.5.2.6). No special third-party QA/QC checking is carried. The activity and liming data were taken from statistics based on federal laws that, as a rule, feature high-quality specification. The general relevant principles include neutrality, objectivity and scientific independence. The affected parties are required by law to provide truthful, complete information.

7.2.5 Source-specific recalculations (5.B)

This year's report presents newly calculated values for all years since 1990:

- For the first time, the carbon-stock changes resulting from land-use changes were estimated for mineral soils and biomass
- Administrative boundaries were adjusted in accordance with the current district-reform key (1998)

- Reporting was adapted to the new CRF tables
- The data has been completely recalculated; as a result, the tables are consistent.

7.2.6 Planned improvements (source-specific) (5.B)

The following specific steps will be taken to improve carbon inventories in the coming year:

1. Improvements that will make it possible to identify all land-use changes and to reconstruct the conditions prevailing in 1990:
   - Use of all potentially available BOHE and FE data at the municipal level (1989 – 2003)
   - Use of CORINE 2000 data
   - Ongoing transition to use of area-referenced data – InVeKoS, and supplementary ATKIS data
2. Improvements aimed at enhancing estimates of carbon stocks:
   - Use of an improved soil map (map of the humus concentrations in Germany's soils)
   - Improvement in the E factors used for soils
   - Review of models used to calculate carbon-stock changes in soils
   - Use of more precise values for carbon stocks in perennials (fruit trees, grapevines).
   - Use of more precise values for carbon stocks in underground biomass

For further remarks, cf. Chapter 14.5.2.6 in the Annex.

7.3 Grassland (5.C)

The anthropogenic CO_2 emissions from grassland were placed at 16,737 Gg for the year 2003. A total of 16,876 Gg of CO_2 emissions were released from drainage of organic grassland soils, and 998 Gg were stored through conversion of cropland into grassland. The loss of above-ground biomass corresponded to 859 Gg of CO_2 equivalents. With regard to the relevant uncertainties and liming, cf. Chapter 7.2 (CRF 5.B) and Chapters 14.5.2.4 and 14.5.2.5 in the Annex.

7.3.1 Source-category description (5. C)

CRF 5.B					
Key source by level (l) / trend (t)		**Gas (key source)**	**1990 – contribution to total emissions**	**2003 – contribution to total emissions**	**Trend**
	- / -				

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor[158] (EF)	CS/D									
EF uncertainties in %										
Distribution of uncertainties[159]										
Method of EF determination[160]	CS/T2[161]									

The source category "Grassland" has not yet been subjected to key-source analysis.

158 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
159 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
160 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model
161 The figure CS/T2 refers to determination of changes in biomass stocks. Under Tier 1, changes in dead wood, debris and soil were estimated to be 0.

Pursuant to GPG LULUCF (IPCC, 2003), reporting under the category "grassland" includes reporting on carbon-stock changes in soil and biomass stocks. The land area subsumed under "grassland" consists of:

Permanent grassland
Untilled land

Reporting under "grassland" is based on definitions for the usage-type key of the Working group of surveying administrations of the Länder of the Federal Republic of Germany (Arbeitsgemeinschaft der Vermessungsverwaltungen der Länder der Bundesrepublik Deutschland - AdV), in the "Directory of area-based usages in the property cadastre and their definitions" ("Verzeichnis der flächenbezogenen Nutzungsarten im Liegenschaftskataster und ihrer Begriffsbestimmungen" - AdV, 1991), and on the "Ground-cover nomenclature" ("Nomenklatur der Bodenbedeckungen") of the CORINE LAND COVER project (DESTATIS, 1989).

7.3.2 Methodological issues (5. C)

Cf. Chapter 7.2.2

7.3.3 Uncertainties and time-series consistency (5. C)

Cf. Chapter 7.2.3

7.3.4 Source-specific quality assurance / control and verification (5. C)

Cf. Chapter 7.2.4

7.3.5 Source-specific recalculations (5. C)

Cf. Chapter 7.2.5

7.3.6 Planned improvements (source-specific) (5. C)

Cf. Chapter 7.2.6

7.4 Wetland (5.D)

Emissions from this source category are currently not being reported.

7.4.1 Source-category description (5. D)

7.4.2 Methodological issues (5. D)

7.4.3 Uncertainties and time-series consistency (5. D)

7.4.4 Source-specific quality assurance / control and verification (5. D)

7.4.5 Source-specific recalculations (5. D)

7.4.6 Planned improvements (source-specific) (5. D)

7.5 Settlements (5.E)

Emissions from this source category are currently not being reported.

7.5.1 Source-category description (5. E)

7.5.2 Methodological issues (5. E)

7.5.3 Uncertainties and time-series consistency (5. E)

7.5.4 Source-specific quality assurance / control and verification (5. E)

7.5.5 Source-specific recalculations (5. E)

7.5.6 Planned improvements (source-specific) (5. E)

7.6 Other land (5.F)

7.6.1 Source-category description (5. F)

To source category 5.F, all those areas have been assigned that do not belong in the categories forest, cropland or grassland; pursuant to GPG LULUCF (IPCC, 2003), therefore, this includes settlement areas, wetlands and other lands (cf. Chapter 7.2.2.1).

In the case of agricultural reporting, it is assumed that land-use changes to and from source category 5.F are CO_2-neutral overall (cf. Chapters 14.5.2.1 & 14.5.2.2).

In CRF category 5.F.2.1 "Forest land converted to other land", all conversions of forest to (any) other land uses are reported as an aggregated value, without any differentiation. Estimates on the basis of results of the Federal Forest Inventory (Bundeswaldinventur) were possible only for the old German Länder; the actual area and stock changes are thus underestimated.

The areas in question have been cumulated since the key year for the first Federal Forest Inventory (1987). With the available data, it is not possible to list the cumulated area from the relevant last 20 years, as called for by the IPCC Good Practice Guidance for Land use,

Land-use change and Forestry (IPCC, 2003). The stock loss from biomass has been interpolated between 1987 and 2002 and refers, in each case, only to the report year. The reduction in the "implied emission factor" thus does not represent a real trend; it results from the fact that the reference area has increased from year to year.

Annual conversions to cropland and grassland, reported in categories 5.B and 5.C, were deducted in order to prevent double counting.

With the available data from the two Federal Forest Inventories, it was possible to derive data on deforested areas, and the relevant biomass losses, only for the old German Länder since 1987, the key year for Federal Forest Inventory I (BWI I). For the new German Länder, only estimates on net increases of forest area are available (cf. Chapter 7.1.2.2.1).

Forest areas converted to other forms of land use are smaller overall than the new forest areas. At the same time, they had higher average biomass stocks prior to conversion. In conversion, such stocks are normally removed, and thus they are considered C emissions.

The C-stock losses from dead wood, debris and soil, and relevant emissions of other greenhouse gases, cannot be precisely determined. The CRF tables thus contain only the C losses from tree biomass.

7.6.2 Methodological issues (5. F)

7.6.2.1.1 Deforested land

The total deforested area in the old German Länder (not including the non-wooded ground) is about half as large (67.33 kha and 4.49 kha/a) as the new forest area. The corresponding figures for the new German Länder cannot be derived from the available data.

7.6.2.1.2 Stock losses, deforestation areas

In the old German Länder, individual-tree-based extrapolation was carried out for this category (cf. 7.1.1.2.3). The C emissions that must be assigned to these areas are higher, as a result of their stock accumulations, than C binding by new forest lands. All in all, total stocks of 4,035 Gg C were lost from biomass in this category. Applying linear interpolation, this corresponds to an annual loss of 269 Gg C. For the sake of simplicity, it was assumed that these C stocks are emitted into the atmosphere in the year in which they are converted. Carbon binding by vegetation that succeeds the forest was estimated only for one follow-on use – "cropland" (cf. CRF 5.B). Such binding is nearly negligible and is not included in the net emissions from forest conversion reported as memo items in CRF5.

As to C-stock losses from dead wood, debris and soil, only a first, very rough estimate, based on average stocks identified by the Federal Forest Inventory (BWI) and the soil-condition survey (BZE), can be provided. The results (cf. Annex, Table 131) are reported as a memo item, but they have not been included in the CRF tables.

The total emissions from these areas could be more precisely estimated by linking the relevant BWI points with soil maps or with the nearest BZE points.

Stock losses from deforestation cannot be calculated for the new German Länder.

7.6.3 Uncertainties and time-series consistency (5. F)

7.6.4 Source-specific quality assurance / control and verification (5. F)

7.6.5 Source-specific recalculations (5. F)

7.6.6 Planned improvements (source-specific) (5. F)

7.7 Other areas (5.G)

Emissions from this source category are currently not being reported.

7.7.1 Source-category description (5. G)

7.7.2 Methodological issues (5. G)

7.7.3 Uncertainties and time-series consistency (5. G)

7.7.4 Source-specific quality assurance / control and verification (5. G)

7.7.5 Source-specific recalculations (5. G)

7.7.6 Planned improvements (source-specific) (5. G)

8 WASTE AND WASTEWATER (CRF SECTOR 6)

8.1 Solid waste disposal on land (6.A)

CRF 6.A					
Key source by level (l) / trend (t)		**Gas (key source)**	**1990 – contribution to total emissions**	**2003 – contribution to total emissions**	**Trend**
Solid waste diposal on land	l / t	CH_4	2,53 %	1,14 %	falling

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor[162] (EF)		CS								
EF uncertainties in %										
Distribution of uncertainties[163]										
Method of EF determination[164]		T2								

The source category "Solid waste disposal on land" (6.A) is a key source in terms of both emissions level and trend.

Only managed disposal in landfills (6.A.1) is relevant for purposes of German emissions reporting under CRF 6.A. "Wild" or illegal dumping of solid waste (CRF 6.A.2) is prohibited by law in Germany. In the framework of reporting, "other sources" (6.A.3) are included in reporting under CRF 6.A.1 (cf. Chapter 8.1.2).

In the CSE, source category 6.A Solid waste disposal on land includes landfilled household waste and sewage sludge.

Figure 51: Structural allocation, 6A Solid waste disposal on land

8.1.1 Managed disposal in landfills – landfilling of settlement waste (6.A.1)

8.1.1.1 Source-category description (6.A.1)

At present, some 330 landfills for municipal waste (household-waste landfills) are operated in the Federal Republic of Germany. Strict legal regulations are in place that require such landfills to have equipment for collecting and treating landfill gas; these regulations have extensively reduced methane emissions from such facilities. As a result of legal and waste-management requirements, the amounts of municipal waste stored in landfills have decreased by about ⅔ since 1990. This reduction is the result of separate collection and recycling of waste fractions ("bio"-waste, packaging, paper, etc.) and of increasing waste management in waste-incineration systems. As a result of these measures (landfill-gas collection, separate collection for recycling and waste management), methane emissions from landfills decreased by more than 60 % in comparison to their level in the reference, year, 1990.

162 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
163 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
164 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model

As a result of new, more extensive requirements imposed by the Ordinance on waste disposal and on landfills (Abfallablagerungs- und der Deponieverordnung), about ⅔ of these landfills will close by June 2005. As of that time, landfills that remain in operation may store only waste that conforms to strict categorisation criteria, and they must reduce landfill-gas formation from such waste by much more than 90 % with respect to gas from untreated waste. For conformance with the categorisation criteria, municipal waste must be pre-treated via thermal or mechanical-biological processes.

Pre-treatment will reduce stored waste amounts, in comparison to their 2003 levels, by an additional 60 - 70 %. As landfill-gas formation from older landfill storage layers tapers off, landfill methane emissions will again decrease extensively, and thus methane emissions in 2012 are expected to be less than 10 % of the methane emissions of 1990.

8.1.1.2 Methodological issues (6.A.1)

The *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC et al, 1997) specify two methods for determining methane emissions from landfills, a default method (Tier 1) and the "first order decay method" (short name: "FOD method" or "Tier 2"). Whereas the default method functions under the assumption that methane from waste forms completely in the year in which the waste is placed in a landfill, the FOD method uses a kinetic approach that describes methane formation, more realistically, as taking place over several years.

To date, the default method has been used to determine landfill methane emissions in Germany. There are several reasons why this method is inadequate for determining emissions in Germany:

- IPCC *Good Practice Guidance* (IPCC, 2000) specifies that the first order decay method should be used when source category 6A is a key source. At present, this source category is a key source in German in terms of emissions levels and trend.
- The default method tends to underestimate emissions especially when quantities of waste being placed in landfills are decreasing, and this is occurring in Germany. This problem is going to worsen in Germany, especially as of 1 June 2005, when the the waste-storage ordinance's transition periods expire. As of that date, no waste may be landfilled that has a loss due to burning of greater than 5% by weight.[165] In other words, landfilling of waste that forms significant amounts of methane will no longer be possible. As a result, as of 2005, the default method would identify virtually no methane emissions; if it were used, virtually no emissions would be reported. And yet a close look at the actual course of methane formation over time shows that landfills tend to emit methane for years. The FOD method's kinetic approach takes such behaviour into account.

For this reason, in the following section, CH_4 emissions were calculated with the FOD method (Tier 2).

165 As of 2005: Landfill class I: little or no gas formation; landfill class II: moderate gas formation, except for formation in mechanical-biological landfill facilities, of which only a few are in operation to date (sub-report waste / waste water F+ E 299 42 245).

The following section describes the FOD method, and the relevant parameters used, for determining methane formation in landfills. The FOD method calculates in accordance with Equation 1:[166]

Equation 14

$$CH_4 \ produced \ in \ year \ t \ (Gg / year) = \sum_x [(A * k * MSW_T(x) * MSW_F(x) * L_0(x) * e^{-k(t-x)}]$$

$$mit: L_0(GgCH_4 / kg \ waste) = MCF * DOC * DOC_F * F * 16/12$$

$$for \ x = first \ year \ to \ t$$

where:
t = Inventory year
x = Year in which consideration begins and quantity data is collected
MSWT (x) = Total amount of settlement waste
MSWF (x) = Percentage of municipal waste that is landfilled
A = (1-e-k)/k = Normalisation factor for sum correction
k = Constant methane-formation rate (1/year)
L_0 = Potential methane formation
MCF (x) = Methane-correction factor for year x
DOC (x) = Degradable organic carbon in year x (percentage)
DOC_F = Proportion of DOC converted into landfill gas
F = Proportion of CH_4 in landfill gas
16/12 =Ffactor for conversion from C to CH_4

No individual measurements of k are available; for this reason, the IPCC default value of 0.05 (corresponds to a half-life of about 14 years) was used for k in calculation.

To obtain the final CH_4-emissions result, methane that is collected and 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 15:

Equation 15

$$CH_4 \text{ emitted in year t (Gg/year)} = (CH_4 \text{ produced in year t} - R(t)) \bullet (1 - OX)$$

Where
R(t) = CH_4 collection in year t
OX = Oxidation factor (proportion)

For both Tier 1 and Tier 2, the relevant quantities of municipal waste (MSW_T), and the proportion of settlement waste that is landfilled (MSW_F), must be determined; for Tier 2, production of municipal waste over the previous decades must also be determined. Pursuant to IPCC Good Practice Guidance (2000), landfilled settlement waste should be broken down – via estimation – into waste types, since the further procedure takes account of the fact that different waste types have different DOCs.

Produced quantities of municipal waste (household and commercial waste), and the relevant landfilled proportions, are taken from relevant statistics of the Federal Statistical Office (DESTATIS, 1991-2004), 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 (cf. Chapter 14.6.1). The surveys of waste

166 A detailed description of the FOD method and its parameters is presented in the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, in the Greenhouse Gas Inventory Reference Manual, known as the "IPCC Guidelines" (IPCC et al 1997), and in the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, known as the "Good Practice Guidance" (IPCC 2001).

quantities commenced in 1975, on the basis of the Environmental Statistics Act of 1975. Waste quantities for the period from 1970 to 1975 were extrapolated on the basis of population data. The most recent year for which suitably differentiated data is available is 2000. For 2001 and 2002, quantities were assumed to remain constant in comparison to 2000. This data will be recalculated as soon as the relevant specialised series of the Federal Statistical Office become available.

For the period 1970 to 1990, there was no standardised statistical basis for waste-production and waste-disposal data throughout all of Germany, and this creates a problem with regard to data on waste quantities and landfilled proportions of waste during that period. Data for the former GDR cannot simply be derived from average data of the old German Länder, since marked differences applied: The average per-capita waste production (municipal waste), at about 175 kg/a, was considerably lower than that of the Federal Republic of Germany, where the corresponding figure was about 365 kg/a of household waste (BMU, 1990: p. 27). From the former GDR's Ministry for Nature Conservation, Environmental Protection and Water-Resources Management (MNUW), statistical data on municipal-waste production for the territory of the former GDR is available for four different years in the period leading up to reunification (1983, 1985, 1988, 1989) (MNUW, 1990); from this data, in connection with population data, the applicable municipal-waste quantities for the former GDR were derived for the period 1970-1990. Another reason why it is difficult to compare the data is that in the former GDR most sources recorded waste-quantity data in m^3, and the waste-composition information necessary for conversion into tonnes is lacking.

For the years 1990 and 1993, and for the period since 1996, differentiated data is available on landfilled quantities of individual fractions of municipal waste (such as household waste, bulky waste, compostable waste, garden and park waste). For the years prior to 1990, the landfilled proportions from 1990 were used, with no changes. For years after 1990 for which data was lacking, data from framing years with data was interpolated. In general, all waste was landfilled in the former GDR, and thus 100% landfilling of municipal waste was assumed for the period 1970-1990.

8.1.1.2.1 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 is available from a 1989 survey of the territory of the former GDR that covered 120 managed landfills, some 1000 controlled storage sites and some 10,000 uncontrolled dump sites (MNUW, 1990). 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 1970 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.

8.1.1.2.2 DOC

Both national data and IPCC default factors were used for DOC, the proportion of degradable organic carbon in waste. Table 75 provides an overview of the DOC values used. The fractions in Table 75 are based on the waste fractions for which data on landfilled waste quantities is available via the 1990–2002 time series. While national studies of individual DOC fractions of household waste (paper, glass, textiles, etc.) are available, no reliable data on landfilled quantities of these waste fractions is available, and thus DOC values from a more highly aggregated level had to be used.

Table 75: DOC values used

Fraction	DOC	Source
Household waste, commercial waste similar to household waste	18%	WALLMANN, 1999, p.118/119
Municipal waste of former GDR	15%	Assumption: smaller DOC than for household waste of old German Länder; larger mineral component
Compostable waste from "bio" bins (Biotonnen)	15%	IPCC default for food
Bulky waste	31%	ÖKO-INSTITUT 2002, p. 12ff
Road sweepings	18%	WALLMANN, 1999, p.118/119
Market waste	15%	IPCC default for food
Garden and park waste	17%	IPCC default
Sewage sludge	30%	MUNLV 2001, p. 205ff

For the fractions shown in Table 75, time series are available or can be derived from existing data. For the listed fractions, constant DOC values were assumed for all years, since no data is available for chronological adaptation of DOC values for household waste or bulky waste. Overall, waste-management measures carried out in the 1990s (including increasing separate collection of biological waste, paper and packaging waste) had various, often opposing effects, and experts consider it realistic to assume constancy in the aformentioned terms in the final result.

8.1.1.2.3 DOC_F

DOC_F, the DOC proportion that can be converted into landfill gas, is put at 50% for municipal waste, on the basis of a national study (RETTENBERGER et al, 1997: p. 277). This value lies within the IPCC default range of 0.5-0.6.

The proportion of carbon that is actually converted into gas is likely to be significantly lower for sewage sludge than for municipal waste, since sewage sludge is generally an extensively putrefied product resulting from sludge treatment in sewage plants. Consequently, the level of biological activity is likely to be comparatively low. Furthermore, sewage sludge is often limed prior to landfilling. In such cases, the resultant pH value is significantly above the neutral range favoured by methanogens. In the absence of sewage-sludge-specific data, the

10 % carbon-degradation rate cited in the literature, based on output of mechanical-biological waste treatment, is used as an approximation (WALLMANN, 1999).

In eastern Germany in 1998, 29% of sewage sludge was landfilled. The landfilled sewage sludge was first dehydrated and then subjected to sludge digestion in open basins. It is not thought that the sewage sludge was limed. In such cases, a relevant methane-emissions potential of methane would be assumed even during the landfilling process. In (UBA, 1993) a factor DOC_F = 40% is assumed, i.e. a higher portion of organic carbon in the portion converted into landfill gas. This factor is also consistent with the data in (ATV 1996) and, in the time series, is used on the portion of sewage sludge generated in eastern Germany until 1994.

8.1.1.2.4 F = proportion of CH_4 in landfill gas

A value of 50%, the mean value in the IPCC default-value range, is assumed for F. This value was confirmed by a national research project (UBA, 1993).

8.1.1.2.5 Half-life

A half-life of 5 years was assumed; this yields a value of 0.14 for k (constant for the methane-formation rate). The half-life is considerably less than the IPCC default value of 14 years. The small national half-life figure was derived from various literature sources and from information of national experts. For example, EHRIG (1997) gives a half-life of 3.5 to 6 years, while RETTENBERGER (1998) gives a half-life of 4 to 6 years for domestic landfills. The lower half-life could have to do with the composition of landfilled waste, as well as with specific technologies for placing waste in landfills, technologies that were specially developed early on in Germany and that are designed to create optimal conditions for decomposition.

8.1.1.2.6 Landfill-gas use

At present, a total of 75% of the filled landfill capacity in Germany, by volume, is connected to a system for collecting landfill gas (FHG ISI, 2003: p. 3). Gas-collection systems collect some 50% of the landfill gas produced. In 1993, only 35% of landfills were connected to gas-collection systems (UBA, 1994), and collection, basically, did not begin until the 1980s. These basic figures were used as a basis for calculating the amounts of CH_4 that must be deducted as a result of use of generated methane gas. In 2002, such calculation showed that some 63% of the generated methane is actually emitted.

Use of landfill gas for energy recovery is recorded and reported by the energy sector. Rough conversion, into energy data, of the assumptions made in this area, and comparison with other sources of data on use of landfill gas for energy recovery, show that the selected method leads to conservative results and tends to underestimate landfill-gas use and is thus a conservative procedure.

8.1.1.2.7 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 accepted for the entire time series. On the one hand, a larger proportion of uncontrolled landfills can be expected in the former GDR in the early

1990s; on the other hand, a research project found only a low CH_4-formation potential for landfills of the former GDR, and thus the factor 0.1 was also used for this period (BMBF, 1997).

8.1.1.3 Uncertainties and time-series consistency (6.A.1)

The method's uncertainties have been estimated for the first time. The results of this experts' judgement are presented in the Annex, Chapter 14.6.1.2.

Over the long activity-data period involved, thirty years, time-series inconsistencies have to be expected. In Germany, such inconsistencies must be expected primarily as a result of German reunification and its fusion of two different economic and statistical systems; furthermore, they must be expected as a result of improvements of laws and statistics for the waste sector.

Since 1996, procedures for recording quantities of waste produced, and quantities of waste disposed of by the manufacturing sector, have been considerably modified, and statistics have taken greater account of waste recycling. Pursuant to the new Environmental Statistics Act (Umweltstatistikgesetz), waste production and waste origins are determined solely via the waste actually delivered to waste-management facilities. As a result, findings from statistical waste surveys carried out as of 1996 are only partly comparable with published figures for 1993 and earlier (especially with regard to listed waste fractions). These changes were taken into account in the structure of the calculation model.

Section 8.1.1.2 explained the methods that were used to achieve consistent time series, in spite of these difficulties.

8.1.1.4 Source-specific quality assurance / control and verification (6.A.1)

The selected parameters were compared with relevant data for other countries. In particular, the Länder-specific DOC figures for municipal waste tend to be high compared to those for other European countries, which indicates that the underlying estimates tend to be conservative.

In the area of landfill-gas use, various data sources were compared and a consistent, conservative approach was selected.

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.

8.1.1.5 Source-specific recalculations (6.A.1)

The entire time series for CH_4 emissions from landfilling of municipal waste, for the period 1990 to 2002, was recalculated using a Tier 2 method.

8.1.1.6 Planned improvements (6.A.1)

Statistics and reporting on use of renewable energies are being improved within the framework of promotion of use of renewable energies. At the same time, efforts are being made in this context to improve the data on landfill-gas use. At present, the various available data sources exhibit considerable disagreement. A conservative estimate was used for CH_4 emissions from waste landfilling. Further efforts should be carried out in this area, aimed at

improving the precision of inventory calculations and at enhancing comparability of data from statistics on renewable energies (biomass use).

Commercial waste is included in the estimates for municipal waste. At present, emissions from industrial waste are not calculated. Data is available on the waste quantities produced by various sectors, but no data is available on the composition of such waste (paper, wood or biological waste fractions); consequently, no default DOC values can be used in this area, and no data on DOC values for waste of various sectors is available. No further calculations can be carried out on this basis.

8.1.2 Other sources – landfilling of residues from mechanical-biological waste treatment (MB waste treatment) (6.A.3)

MB-waste landfills are landfills on which residual waste is deposited following mechanical/biological treatment. Use of mechanical/biological treatment technology has been growing since the mid-1990s. From the year 2005 onwards, a growing volume of MB-waste residues is anticipated due to the obligation for compulsory pre-treatment of municipal wastes prior to landfilling. The criteria applying to MB-waste residue are outlined in the Ordinance on Environmentally Compatible Storage of Waste from Human Settlements and on Biological Waste Treatment Facilities (AbfAblV). Future requirements for MB-waste landfilling of waste stipulate that this must be done in such a way as to eliminate the need for after-care. This is defined more precisely, *inter alia*, with the formulation “virtually no landfill gas”. On the whole, because residual wastes will be extensively stabilised via pre-treatment, and since regulations require that TOC content not exceed 18% of the dry mass in MB-waste residue, MB-waste landfills can be expected to have only minimal CH_4 formation. Currently, statistics record what quantities of waste are treated in facilities for mechanical/biological treatment, but they do not show what quantities of MB-waste residues are landfilled. For this reason, waste treated in MB-waste facilities is still reported as part of the entire quantity of municipal waste, under category 6.A "Solid waste disposal on land", and methane emissions are calculated without regard for the very low rates of CH_4 formation in this sub-category of municipal waste; as a result, calculation of CH_4 emissions in category 6.A is conservative. Plans call for CH_4 emissions from landfilling of MB-waste residues to be calculated separately as soon as more reliable activity data is available for this sub-category.

8.2 Wastewater treatment (6.B)

Under source category 6.B Wastewater handling (treatment), the CSE lists wastewater quantities, treatment of sewage sludge and sewage-sludge production in wastewater treatment.

Figure 52: Structural allocation, 6B Wastewater handling (treatment)

8.2.1 Methane emissions from industrial wastewater and sludge treatment (6.B.1)

8.2.1.1 Source-category description (6.B.1)

CRF 6.B.1					
Key source by level (l) / trend (t)		**Gas (key source)**	**1990 – contribution to total emissions**	**2003 – contribution to total emissions**	**Trend**
	- / -				

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor[167] (EF)	NE	D/CS	NO	NO	NO	D	NO	NO	NO	NO
EF uncertainties in %										
Distribution of uncertainties[168]										
Method of EF determination[169]										

The source category "methane emissions from industrial wastewater and sludge treatment" (6.B.1) is not a key source.

The composition of industrial wastewater, in contrast to that of household wastewater, varies greatly, by industrial sector. In Germany, the biological stage of industrial wastewater treatment is partly aerobic and partly anaerobic. Anaerobic wastewater treatment is especially useful for industries whose wastewater has high levels of organic loads. This treatment method has the advantages that it does not require large amounts of oxygen, produces considerably smaller amounts of sludge requiring disposal and generates methane that can be used for energy recovery. As in treatment of municipal wastewater, treatment of industrial wastewater releases no methane emissions into the environment. The procedures used include aerobic treatment and anaerobic putrification; gas formed in the latter procedure is either used for energy recovery or is flared off.

Industrial sludge treatment and stabilisation, like industrial wastewater treatment, is carried out either aerobically or anaerobically with methane-gas use.

167 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
168 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
169 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model

8.2.2 Municipal wastewater treatment (6.B.2)

8.2.2.1 Methane emissions from municipal wastewater treatment (6.B.2)

8.2.2.1.1 Source-category description (6.B.2)

CRF 6.B.2					
Key source by level (l) / trend (t)		**Gas (key source)**	**1990 – contribution to total emissions**	**2003 – contribution to total emissions**	**Trend**
Wastewater handling (treatment), domestic and commercial	- / t	CH_4	0,18 %	0,01 %	falling

Gas	**CO_2**	**CH_4**	**HFCs**	**PFCs**	**SF_6**	**N_2O**	**NO_X**	**CO**	**NMVOC**	**SO_2**
Emission factor[170] (EF)	NE	D/CS	NO	NO	NO	D	NO	NO	NO	NO
EF uncertainties in %										
Distribution of uncertainties[171]										
Method of EF determination[172]										

In terms of its trend, the source category "wastewater handling, domestic and commercial" is a key source.

Municipal *wastewater treatment* in Deutschland – like that in Sweden and Denmark – uses aerobic procedures (municipal wastewater-treatment facilities, small wastewater-treatment facilities), i.e. it produces no methane emissions (default value for MCF = 0), since such emissions occur only under anaerobic conditions.

Treatment of human sewage from persons not connected to sewage networks or small wastewater-treatment facilities represents an exception: in cesspools and septic tanks, uncontrolled processes (partly aerobic, partly anaerobic) can occur that lead to methane formation. Since 1990, organic loads discharged into cesspools and septic tanks have been drastically reduced; the percentage of inhabitants connected to small wastewater-treatment facilities has continually increased, especially in eastern Germany.

8.2.2.1.2 Methodological issues (6.B.2)

Organic loads from cesspools and septic tanks are calculated pursuant to the IPCC method, in which the relevant population is multiplied by the average organic load per person; cf. Table 76. The average organic load is assumed as 60 g BOB_5 per inhabitant. This value, the IPCC default value, is used for Germany.

170 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
171 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
172 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model

Table 76: Organic wastewater load in cesspools and septic tanks (1990-2003)

Organic loads in:	BOB_5 [kt/a]													
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Cesspools and septic tanks	*180,33*	172,45	*164,57*	*156,69*	*148,80*	140,92	*105,41*	*69,90*	34,38	*31,06*	*27,74*	24,42	*21,10*	*17,78*
of these, in western Germany	*91,69*	87,45	*83,21*	*78,97*	*74,74*	70,50								
of these, in eastern Germany	*88,65*	85,01	*81,37*	*77,72*	*74,08*	70,43								

Numbers in italics: Interpolated and extrapoled values

(DESTATIS, Fachserie 19 Reihe 2.1, 2003; Calculations ÖKO-INSTITUT, 2004b)

Methane emissions from cesspools and septic tanks are determined in keeping with the IPCC method. The IPCC default value for potential methane formation, and an MCF of 0.5 for cesspools and septic tanks, are assumed. The MCF for cesspools and septic tanks has been estimated on the basis of experience gained other in countries (septic tanks in the U.S., anaerobically treated municipal wastewater in the Czech Republic (cf. Chapter 14.6.2). The emissions are determined as follows:

$$CH_4(cesspools\ and\ septic\ t.) = 24\,419\,000\ kg\ BOB_5\ x\ 0{,}6\ kg\ CH_4\ /\ kg\ BOB_5\ x\ 0{,}5$$

Table 77: Methane emissions from cesspools and septic tanks (1990-2003)

Methane emissions fromaus:	[kt CH_4]													
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Cesspools and septic tanks	54,10	51,74	49,37	47,01	44,64	42,28	31,62	20,97	10,31	9,32	8,32	7,33	6,33	5,33

(DESTATIS, Fachserie 19 Reihe 2.1, 2003; IPCC default value; calculations ÖKO-INSTITUT 2004b)

8.2.2.1.3 Uncertainties and time-series consistency (6.B.2)

The method's uncertainties have not yet been estimated.

The activity rates for organic loads in cesspools and septic tanks are based on data from the Federal Statistical Office's Fachserie 19 Reihe 2.1, which was published in 1991, 1995, 1998 and 2001 (DESTATIS, Fachserie 19 Reihe 2.1, 2003) veröffentlicht wurde. For production of a consistent time series, the activity rates were linearly interpolated between 1991 and 1995, between 1995 and 1998 and between 1998 and 2001. The activity rates for 1990, on the other hand, were extrapolated from the 1991 to 1995 time series. The activity rates for 2002 and 2003, on the other hand, were extrapolated from the 1991 to 1998 time series.

Until 1995, data for the old and new Federal Länder was determined separately; since then, a single value for all of Germany has been determined in each case. This does not affect time-series consistency, however.

8.2.2.1.4 Source-specific quality assurance / control and verification

The MCF for cesspools and septic tanks in Germany was derived on the basis of an evaluation of national inventory reports of other countries (cf. Chapter 14.6.2).

The fact that aerobic wastewater treatment in relevant facilities produces no significant methane emissions can be confirmed in other countries (Sweden, Denmark).

8.2.2.1.5 Source-specific recalculations (6.B.2)

Extensive recalculations were reported in the NIR 2004 (UBA, 2004a). No recalculations were carried out for the present report.

8.2.2.1.6 Planned improvements (6.B.2)

Consideration is being given to carrying out a research project that would explore whether methane could indeed form in aerobic wastewater treatment, under certain conditions and in certain process steps.

8.2.2.2 Methane emissions from municipal wastewater treatment (6.B.2)

8.2.2.2.1 Source-category description (6.B.2)

As a general rule, the treatment of sewage sludge comprises two treatment stages:

- Dehydration using
  Mechanical processes (chamber-filter press, cyclone)
  Evaporation in a sludge lagoon or drying beds
- Stabilisation:
  Aerobic stabilisation (open pool with oxygen input)
  Stabilisation in digestion tower (anaerobic)
  Formerly: Open sludge digestion

With respect to population figures, mechanical *dehydration* before and after treatment in the digestion tower currently represents the main treatment method (exception: small sewage-treatment plants in rural areas). Moreover, sewage sludge is generally limed prior to subsequent use, which stabilises it still further.

Sludge stabilisation is carried out in order to prevent uncontrolled putrefaction. In facilities < 10,000 inhabitants, such stabilisation is usually carried out aerobically, with energy consumption, while for facilities > 30,000 inhabitants it it normally carried out anaerobically, with production of methane gas. The amount of methane gas produced depends especially on the composition of the sewage sludge, the temperature and the reaction conditions. Gas so produced is usually used for energy recovery in combined heat/power generating systems (CHP). Where facilities are unable to use the methane gas cost-effectively in this manner, or when technical disruptions or overloads of attached CHPs occur, the methane gas may be flared off. In both treatment methods, no significant amounts of methane emissions are released into the environment.

In the early 1990s in eastern Germany, open sludge digestion was used for sludge stabilisation, a process that produced methane emissions. Open sludge digestion is now no longer used, however.

In Germany, sewage sludge from biological wastewater treatment is managed in the following three ways (where applicable, after dehydration and stabilisation):

- Landfill storage: resulting methane emissions are reported in the waste sector.

- Thermal disposal: no methane emissions occur. Thermal disposal 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, and use in recultivation measures and in composting. Emissions from recycling for substance recovery are also not reported under wastewater and sludge treatment.

8.2.2.2.2 Methodological issues (6.B.2)

Table 78 the emission factors for open sludge digestion and the methane emissions determined for that process.

Table 78: Methane emissions from open sludge digestion, in the new German Länder

	Unit	1990	1991	1992	1993	1994
Emission factor	[kg CH_4/t TS]	210	210	210	210	210
Sewage-sludge production	[t TS]	247.190	140.952	72.762	37.524	0
Methane emissions	[t]	51.910	29.600	15.280	7.880	0

Emission factors derived from (UBA 1993)

An emission factor of 210 kg CH_4/t TS is used for open sludge digestion in eastern Germany, in keeping with the results of the study FHG ISI (UBA, 1993: p.15)[173]. The activity rates for the years 1990 to 1992 were communicated personally to the Federal Environmental Agency by the Chief Inspector of the former GDR's water-processing plants.

In light of the fact that open sludge digestion is prohibited in the Federal Republic of Germany, it was assumed that use of this treatment method was gradually reduced in the new German Länder until 1994 and was no longer used at all as of 1994. On the basis of this assumption, the Federal Environmental Agency used the same activity rates – i.e. quantities of sewage sludge produced – for the years 1992 to 1994.

8.2.2.2.3 Uncertainties and time-series consistency (6.B.2)

The uncertainties for calculation of emissions from open sludge digestion in eastern Germany have not been estimated to date.

The activity rates between 1990 and 1992 are based on a personal communication; those for 1993 and 1994, are based on estimates of the Federal Environmental Agency. As a result, a high degree of time-series consistency is not assured.

8.2.2.2.4 Source-specific quality assurance / control and verification (6.B.2)

Measures for standardisation of QC and QA are currently being prepared.

8.2.2.2.5 Source-specific recalculations (6.B.2)

Extensive recalculations were reported in the NIR 2004 (UBA, 2004a). No recalculations were carried out for the present report.

173 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.

8.2.2.2.6 Planned improvements (6.B.2)

At present, improvements seem neither necessary nor possible, since no further activity data can be obtained.

8.2.2.3 Nitrous oxide emissions from municipal wastewater (6.B.2)

8.2.2.3.1 Source-category description (6.B.2)

Nitrous oxide (laughing-gas) emissions can occur as an auxiliary product of municipal wastewater treatment, especially in connection with denitrification, in which gaseous end products – mainly molecular nitrogen – are formed from nitrate (AUST, no year).

8.2.2.3.2 Methodological issues (6.B.2)

Pursuant to the IPCC method, nitrous oxide emissions from household wastewater can be roughly determined via the average per-capita protein intake. The IPCC default values are used in each case for the nitrous-oxide emission factor per kg of nitrogen in wastewater, and for the nitrogen fraction in protein; the average per-capita protein intake and relevant population figures for Germany have to be determined on a Länder-specific basis.

Average protein intake per person and day:

- The 1991 food table for practical applications (SENSER et al, 1991) lists an average protein intake of 94 g/inhabitant and day.
- The nutrition report of the German Nutrition Association (Deutsche Gesellschaft für Ernährung - DGE, 2000)[174] used estimated food-consumption data for 1993 to estimate average daily protein intake (among other figures). From this data, an average value of about 76.5 g protein/person and day[175] was derived.
- The FAO determined the average protein intake in Germany, per person and day, to be between 91g and 98 g (cf. Table 79).[176]

The FAO database is used for determination of the N_2O emissions from wastewater, since that database is a consistent, internationally comparable time series. The Federal Environmental Agency has no information to the effect that the Länder-specific values in the food table and in the 2000 nutrition report are more precise or enjoy greater national acceptance.

174 The nutrition report is published every four years.
175 This value was obtained with the help of the rough estimate that each population group in Germany consists of 50% men (81.5 g/day) and 50% women (71.6 g/day).
176 http://apps.fao.org/page/collections; e-mail correspondence with FAO (27 October 2003).

Table 79: Daily protein intake per person in Germany

	[g/inhabitant and dat]													
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Protein intake	98	97	96	92	95	94	96	91	96	96	96	98	98	*97*

Number in italics: Extrapolated value

(FAO, no year)

Table 80: Population of Germany (1990-2002)

	[in 1000]													
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Inhabitants	79.36	79.98	80.59	81.17	81.42	81.66	81.89	82.05	82.02	82.08	82.18	82.44	82.53	82.53

(DESTATIS, 1991-2004)

The nitrous oxide emissions can be determined with the aid of Table 79 and Table 80 and the IPCC method; cf. Table 81.

$$N_2O_{(s)} = \mathrm{Pr}otein\ x\ Frac_{NPR} x\ NR_{PEOPLE} x\ EF_6$$ dabei:

$N_2O_{(s)} = N_2O\ Emissions\ in\ human\ wastewater\ (kg\ N_2O-N/a)$

$\mathrm{Pr}otein = annual\ \ protein\ cons.\ (kg/person/a)$

$NR_{PEOPLE} = \ \ population\ of\ \ the\ country$

$EF_6 = emission\ \ factor\ (Default\ 0.01\ (0.002-0.12)\ kg\ N_2O-N/kg\ \ produced\ \ wastewater-N)$

$Frac_{NPR} = nitrogen\ \ fraction\ in\ \ protein\ (default = 0.16\ kg\ N/kg\ \ protein)$

Table 81: Nitrous oxide emissions in Germany pursuant to IPCC method, 1990-2003

	[t N_2O]													
N_2O emissions	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
	7.138	7.120	7.100	6.854	7.099	7.044	7.215	6.852	7.227	7.232	7.241	7.414	7.423	7.347

(ÖKO-INSTITUT, 2004b)

8.2.2.3.3 Uncertainties and time-series consistency (6.B.2)

The uncertainties in emissions determination have not yet been estimated. The activity rate for 2003 was extrapolated from the 1999 to 2002 time series.

Calculations were based on the average daily protein requirements listed by the FAO database, to ensure that the time series is consistent and to prevent any need for extrapolation of individual values.

8.2.2.3.4 Source-category-specific quality assurance / control and verification (6.B.2)

Analysis of the national inventory reports of other countries shows that most Annex I countries, like Germany, use the IPCC method for determining N_2O emissions. In addition, many countries use the FAO database; as a result, the emissions-determination process used by Germany is internationally comparable. An international comparison shows that the daily protein intake assumed for Germany lies within the middle of the overall range (cf. Annex, Table 134).

Plans within the framework of quality assurance call for checking the Länder-specific N_2O emission factor used to date for wastewater treatment; this factor was determined in a national research project (Krauth et al, 1994) and in UBA (1993). The factor is 0.07 – 0.08 g N_2O/m^3 for wastewater treated in facilities with N elimination. While relevant research projects show that this factor applies to both municipal and industrial wastewater-treatment plants, it has not yet been scientifically confirmed.

Measures for standardisation of QC and QA are currently being prepared.

8.2.2.3.5 Source-specific recalculations (6.B.2)

Extensive recalculations were reported in the NIR 2004 (UBA, 2004a). No recalculations were carried out for the present report.

8.2.2.3.6 Planned improvements (6.B.2)

Review is currently underway to determine whether the FAO database (FAO, n.y.) for daily protein intake should be replaced with data from the nutrition report (DGE, 2000), since the latter is based on studies of eating habits and thus probably reflects actual protein intake more precisely.

In addition, as described under 8.2.2.3.4, the N_2O emission factor used to date, 0.07 – 0.08 g N_2O/m^3 of wastewater, is to be reviewed. If this emission factor can be confirmed – i.e. if it proves to be accurate for Germany – it will again be used in future.

8.2.3 Waste incineration (6.C.)

All waste incineration in Germany is carried out with energy inputs; for this reason, and in order to avoid double counting, the resulting emissions are reported in the energy section (CRF 1). No emissions (NO) from this energy use, therefore, are reported under 6.C.

8.2.4 Other areas (6.D.)

No other sources of greenhouse-gas emissions are known.

9 OTHER (CRF SECTOR 7)

At present, no greenhouse-gas emissions are calculated for Germany which cannot be allocated to one of the envisaged source categories.

10 RECALCULATIONS AND IMPROVEMENTS

In the following section, recalculations and inventory improvements are documented – for the first time – that occurred between between the CRF coverage of the 2004 report year and that of the 2005 report year. Further information regarding the recalculations is provided in CRF tables Table 8(a) and Table 8(b) and in the present report's chapters on source-specific recalculations.

Pursuant to the aims of the *Good Practice Guidance*, emissions calculations should be based on the best available data, and efforts should be made to improve the inventories continuously. Consequently, each year quality control and assurance measures lead to recalculations. Recalculations become necessary when statistics are updated retroactively and the relevant changes are also adopted in the inventories. The need for recalculation also arises when more precise data is provided and when manual transfer errors are revised. In addition, a range of various specialised factors can necessitate recalculations (cf. Chapter 10.1.1).

This chapter does not consider recalculation of F gases separately, since that area is currently being completely revised.

10.1 Recalculations: explanation and justification

10.1.1 General procedure

Apart from routine corrections of inventory data, a number of specialised factors can necessitate recalculations and improvements:

- new data and new time series become available
- the availability of the existing data source has changed
- the method previously used for the relevant source category was not consistent with the *Good Practice Guidance*
- the source category has become a key source, thus making a change of methods necessary
- new country-specific methods are available
- the relevant data has been re-processed in keeping with review results

In good practice, when methods change, the entire relevant time series should be recalculated with the same method, to ensure that the same method is used each year and old values can be suitably replaced. Where it is not possible to use the same method every year, alternative recalculation methods should be used. The following four recalculation methods are available for this purpose (IPCC Good Practice Guidance, Chapter 7) :

- overlapping method: For it to be possible to use this method, the data for calculation pursuant to the old and new method should be jointly available for at least one year.
- replacement method: For it to be possible to use this method, the EF and/or AR used to data should be highly similar to the newly available data.
- interpolation method: The data previously used for recalculation are available only for a few years of the time series, and the lacking data is interpolated.
- trend extrapolation or continued-use method: The data for the new method is not available for the beginning and/or end of the time series.

The QSE manual contains a guide to applying the above-outlined recalculation reasons. It also presents relevant examples.

10.1.2 Recalculations in the 2005 report year, by source categories

The inventories contain improvements in the following areas (Figure 53):

Energy:

- Changed N_2O emission factors as a result of changes in interpolation for large combustion systems (1.A.1)
- Changed emissions in the *Manufacturing industry sector* (1.A.2)
- New emission factors as a result of considerable improvements of fuel efficiency of aircraft engines in the years 2000 to 2002 (1.A.3a and international aviation)
- New activity rates as a result of new consumption data for road transportation (1.A.3b)
- Changed emission factors for stationary sources as a result of methods standardisation, especially for the years 1990 to 1994 (1.A.4 and 1.A.5)
- New CH_4 activity rates following technological changes in the areas of fugitive emissions from fuels (1.B)

Industrial processes:

- New activity rates in cement production (2.A.1)
- New activity rates in lime production (2.A.2)
- Changes in aggregation (2.A.5 and 2.A.6)
- New activity rates in glass production, (2.A.7) as a result of current statistics
- Use of unrounded activity rates (2.B.1 und 2.B.2)
- New emissions figures for adipic acid production (2.B.3)
- Initial survey of calcium-carbid production (2.B.4)
- Initial survey of methanol and ethylene dichloride under methane emissions from other production processes (2.B.5)

Agriculture:

- Changed CH_4 emission factors (4.A.1a)
- New activity rates for dairy cows and other cattle (new survey 4.A.1, 4.B.1)
- Changed CH_4 emission factors for other cattle, as a result of error correction (4.B.1b)
- New activity rates for N_2O in soils, as a result of changes in herd sizes for dairy cows and other cattle (4.D)

Land-use changes and forestry:

- The data was calculated in keeping with the new CRF structure, for the entire time series, and entered here as a sum value.
- New data; the increase in stocks (increase of timber) is higher than in earlier estimates (5)
- Inclusion of belowground biomass, improved methods of calculation, and changed estimates of the original stocks (5)
- Initial survey of carbon storage in mineral soils (5)

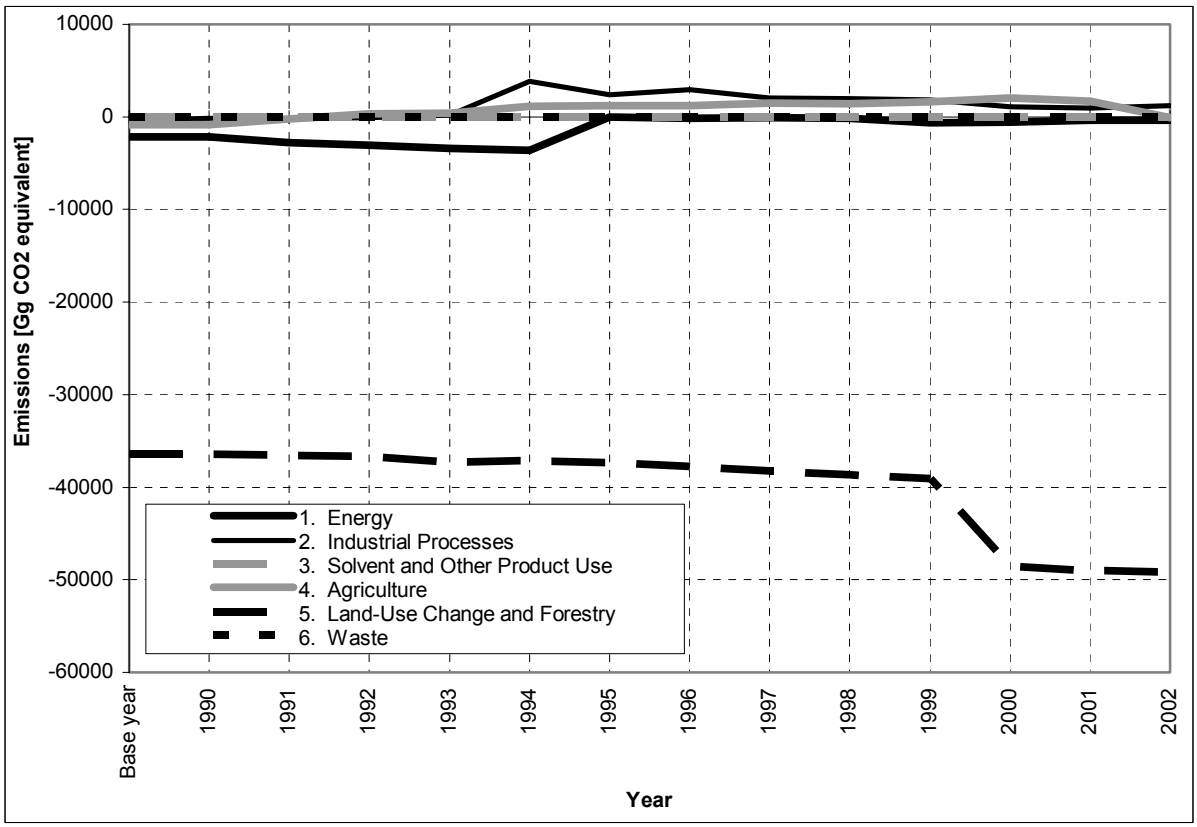

Figure 53: Change in source-category-specific total emissions, for all gases, and for the entire time series, in comparison to the relevant figures in the 2004 report

10.1.3 Recalculations in the 2005 report year, by gases

CO_2 recalculations were carried out in the following source categories (Figure 54):

- Civil aviation (1.A.3a)
- Road transportation (1.A.3b)
- Cement production (2.A.1)
- Lime production (2.A.2)
- Glass production (2.A.7)
- Use of unrounded activity rates (2.B.1 und 2.B.2)
- Initial survey of calcium-carbide production (2.B.4)
- Initial survey of methanol and ethylene dichloride under methane emissions from other production processes (2.B.5)
- Emissions and storage in soils (5)

N_2O /CH_4 recalculations were carried out in the following source categories (Figure 54):

- Changed N_2O emission factors as a result of changes in interpolation for large combustion systems (1.A.1)
- Civil aviation (1.A.3a)
- Stationary sources (1.A.4)
- Stationary sources (1.A.5)
- New CH_4 activity rates following technological changes in the areas of fugitive emissions from fuels (1.B)
- International navigation (1.BU.2)

- Use of unrounded activity rates (2.B.1 und 2.B.2)
- Adipic acid production (2.B.3) N_2O
- Initial survey of calcium-carbide production (2.B.4)
- Other chemical production (2.B.5)
- Manure management (4.B.1)
- Agricultural soils (4.D)

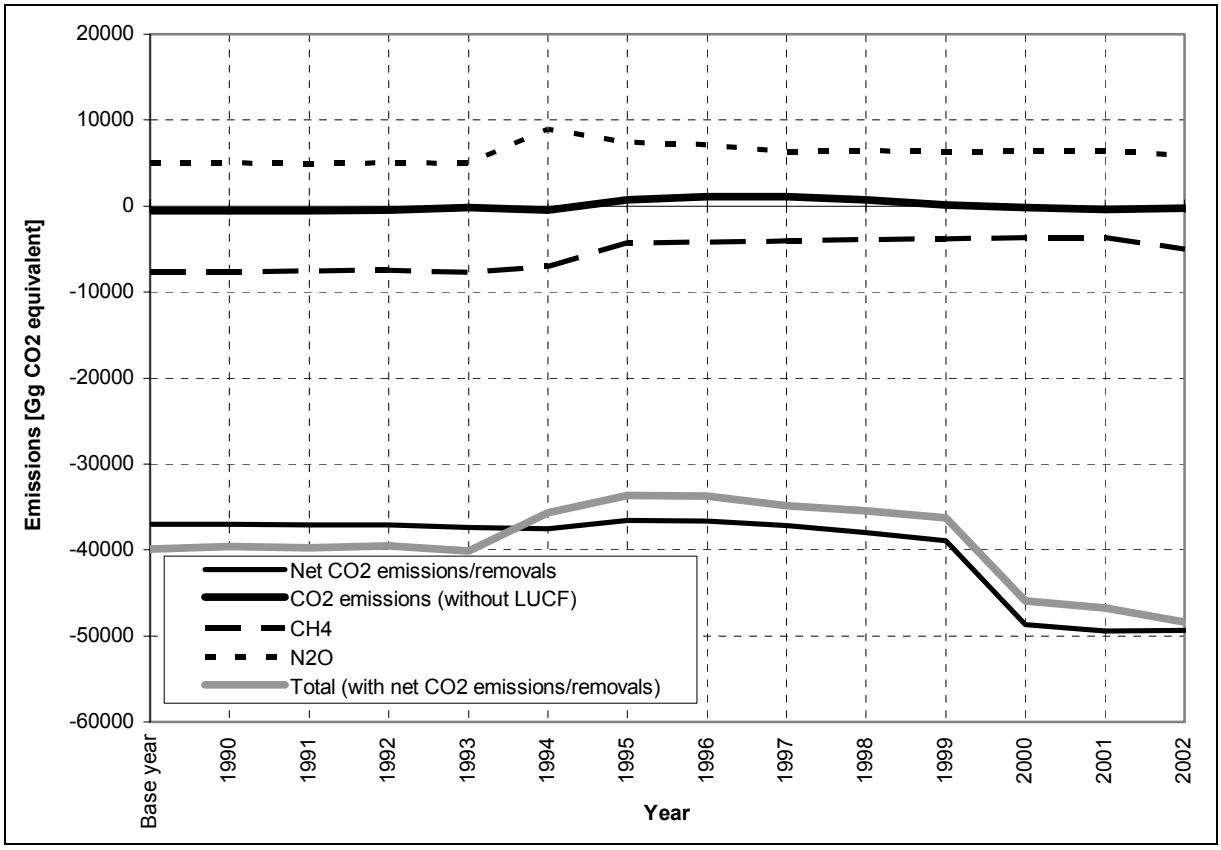

Figure 54: Recalculation of pollutant-specific total emissions, for all source categories, and for the entire time series, in comparison to the relevant figures in the 2004 report

10.2 Impacts on emissions levels

10.2.1 Impacts on the emissions levels of base year

Via recalculations, total emissions in the **base year**, for all source categories and pollutants, and in comparison to the figures calculated for the 2004 report year, decreased by 39912 CO_2 equivalents (Gg) (Table 82). This corresponds to a change of -3.3%. The largest change, for all pollutants, occurred in the source category land-use changes and forestry (LUCF 5A, 5B, 5C); it amounted to 36459 Gg (CO_2 equivalents). This corresponds to a change of -485%. Additional significant recalculations were carried out in 1.A.5 Others (CH_4). Energy-related CO_2 emissions are not affected by the changes (Figure 55).

Table 82: Recalculation of report years 2004 and 2005: Impacts on the base year

	Recalculation of the base year	
	CO_2 equivalents [Gg]	**In percent**
Total emissions, for all pollutants (gases) and source categories (including LUCF)	39912	-3,3
Total emissions, for all pollutants (gases) and source categories (not including LUCF)	3453	-0,3
Region in which the largest base-year recalculation occurred (including LUCF): LUCF	36459	-485,1
Region in which the largest base-year recalculation occurred (not including LUCF): Energy	2144	-0,2
Pollutant (gas) for which the largest base-year recalculation occurred (not including LUCF): CH_4	7668	-5,8

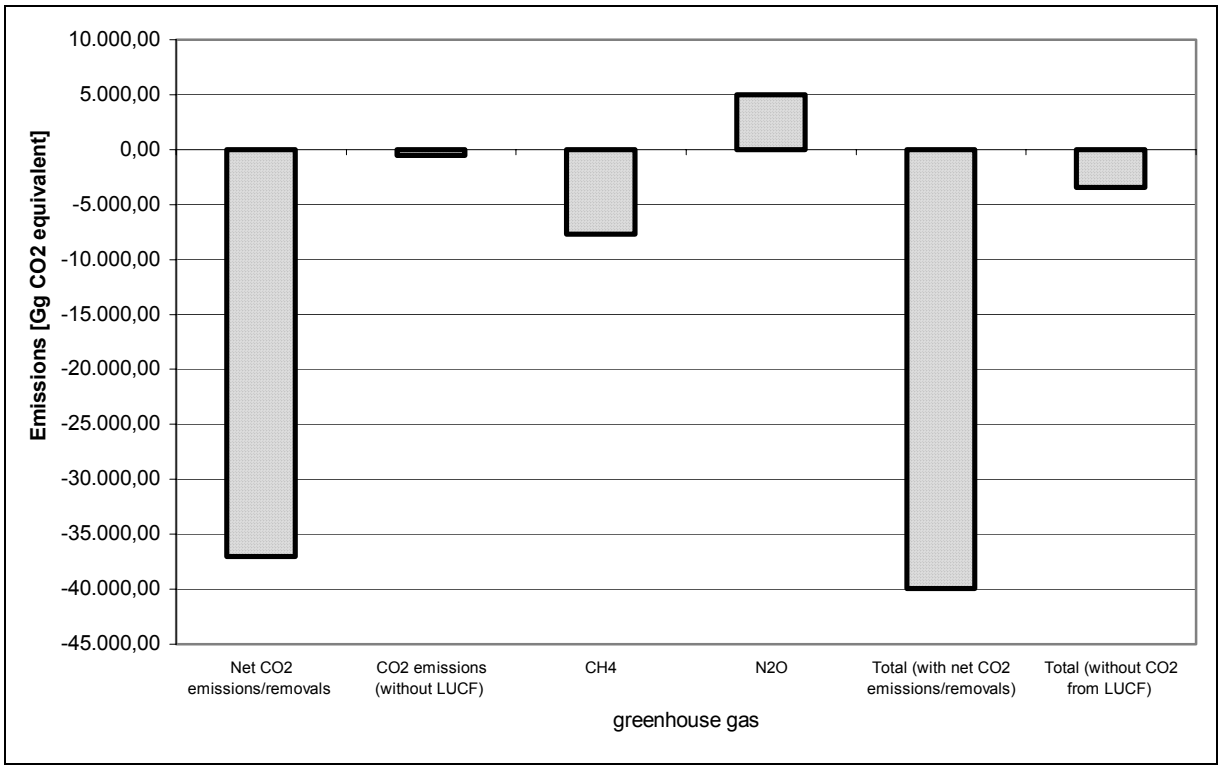

Figure 55: Recalculation of pollutant-specific total emissions, for all source categories, for the base year, ,in comparison to the relevant figures in the 2004 report.

10.2.2 Impacts on 1990 emissions levels

The largest recalculation for 1990 was carried out in the area of land-use changes and forestry (Table 84, Figure 56). Additional significant changes were made especially in the area of energy (Table 83, Figure 56).

Table 83: Largest emissions changes, for the various areas, for the year 1990, by gases

Area	Gas with highest absolute change	Amount [Gg]	Change in comparison to previous submission [%]
Energy	CH_4	1387	-3,6
Industrial processes	CO_2	540	-2,0
Solvent and other product use	No change	0	0
Agriculture	CH_4	6613	-9,8
Land-use changes and forestry	CO_2	36459	-485,1
Waste	No change	0	0

Table 84: Recalculation of source-category-specific total emissions, for all gases

	Change, in CO2 equivalents [Gg]	Change [%]	Reported 2004	Reported 2005
Total national emissions (not including LUCF)	**-3123**	**-0,3**	**1246815**	**1243692**
1. Energy	-2144		1038761	1036617
2. Industrial processes	-132	-0,2	60296	60165
3. Solvent and other product use	0	0,0	1922	1922
4. Agriculture	-847	-0,8	109917	109070
5. Land-use changes and forestry	-36459	-485,1	7515	-28944
6. Waste	0	0,0	35918	35918

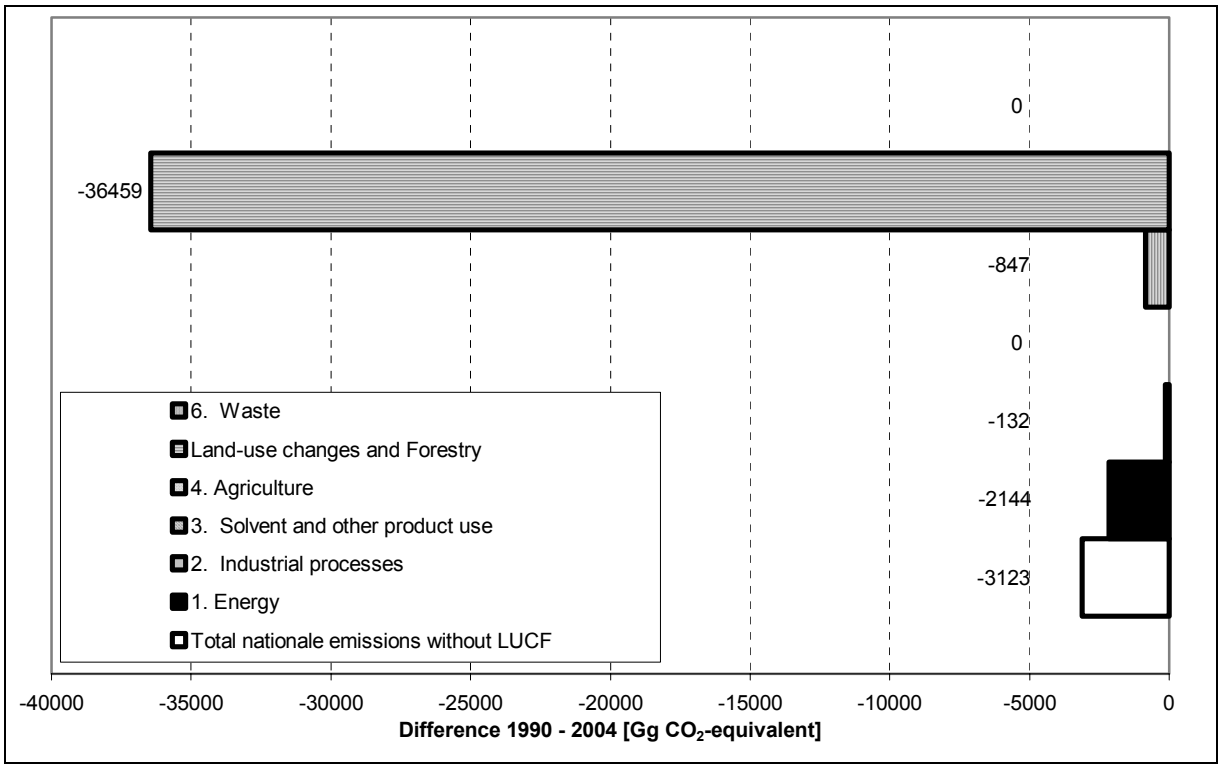

Figure 56: Changes in GG CO_2 equivalents for 1990, with respect to reporting for 2004 [Gg]

10.2.3 Impacts on 2002 emissions levels

Via recalculations, **total emissions in 2002**, **for all source categories and pollutants**, and in comparison to the figures calculated for the 2004 report year, decreased by 48399 CO_2 equivalents (Gg) (Table 85). This corresponds to a change of -4.9%. The largest change, for all pollutants, occurred in the source category land-use changes and forestry (LUCF 5A, 5B, 5C); it amounted to 49123 Gg (CO_2 equivalents) (Table 85, Figure 57, Figure 58) This corresponds to a change of -353.2% (Table 85).

Table 85. Recalculation of report years 2004 and 2005: Impacts on the year 2002

	Recalculation of 2002	
	CO_2 equivalents [Gg]	**In percent**
Total emissions, for all pollutants (gases) and source categories (including LUCF)	48399	-4,9
Total emissions, for all pollutants (gases) and source categories (not including LUCF)	726	+0,1
Area in which the largest recalculation for 2002 was carried out (including LUCF): LUCF	49123	-353,2
Area in which the largest recalculation for 2002 was carried out (not including LUCF): Industrial processes	1207	+2,8
Gas with the largest recalculation for 2002 (not including LUCF): N_2O	5934	+9,6

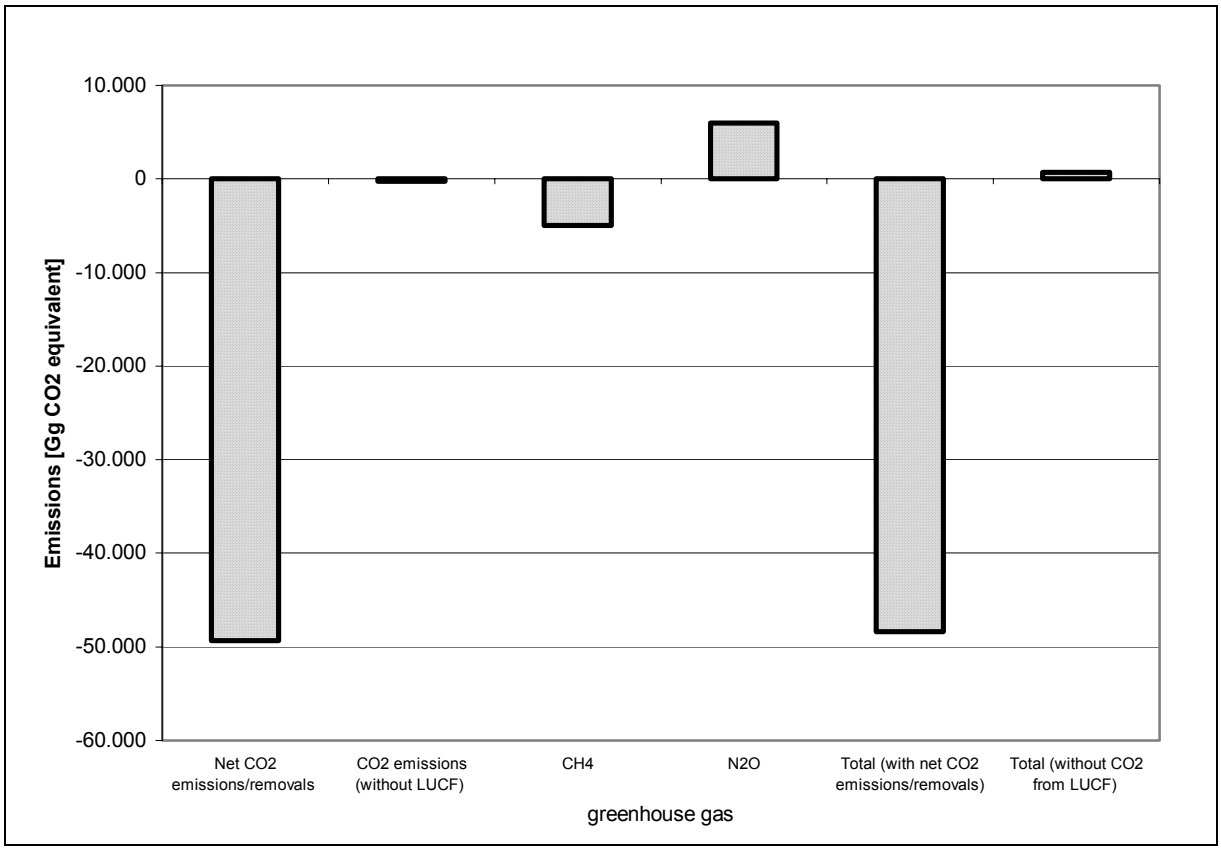

Figure 57: Recalculation of pollutant-specific total emissions, for all source categories, in comparison to the relevant 2002 figures in the 2004 report

Table 86: Largest emissions changes, for the various areas, for the year 2002, by gases

Area	Gas with highest absolute change	Amount [Gg]	Change in comparison to previous submission [%]
Energy	CO_2	311	-0,04
Industrial processes	N_2O	780	+11,0
Solvent and other product use	No change	0	0
Agriculture	CH_4	5377	-10,0
	N_2O	5293	+15,2
Land-use changes and forestry	CO_2	49123	-353,2
Waste	No change	0	0

Table 87: Recalculation of source-category-specific total emissions, for all gases in 2002

	Change, in CO2 equivalents [Gg]	Change [%]	Reported 2004	Reported 2005
Total national emissions, not including LUCF	**726**	**0,1**	**1014625**	**1015351**
1. Energy	-398	0,0	867038	866640
2. Industrial processes	1207	2,8	43013	44220
3. Solvent and other product use	0	0,0	1922	1922
4. Agriculture	-84	-0,1	88298	88214
5. Land-use changes and forestry	-49123	-353,2	13906	-35217
6. Waste	0	0,0	14355	14355

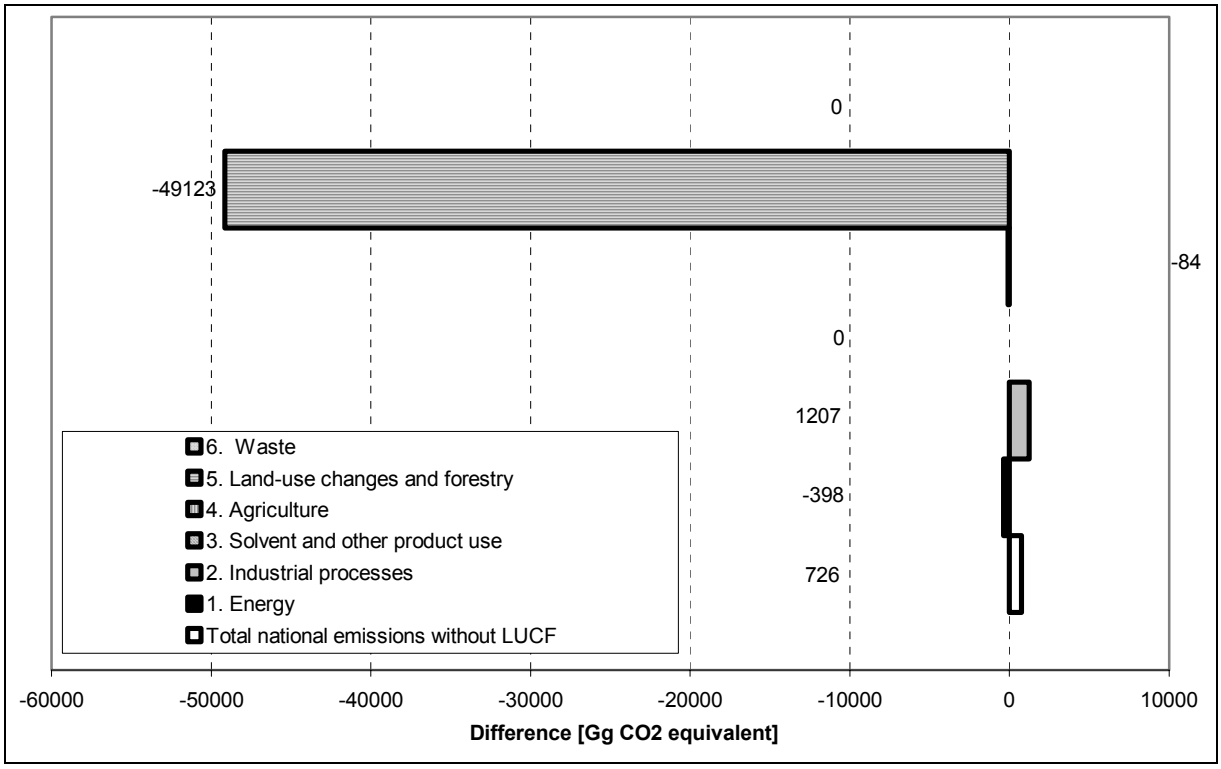

Figure 58: Changes in GG CO_2 equivalents for 2002 (not including LUCF), with respect to reporting for 2004 [Gg]

10.3 Impacts on emissions trends and on time-series consistency

The time-series consistency has improved as a result of the recalculations.

10.4 Recalculations as a response to the review process, and planned inventory improvement

In response to reviews, recalculations were carried out in the following source categories: Other source categories / stationary sources (1.A.4), Other: Military (1.A.5), Fugitive emissions from solid fuels (1.B.1) and Mineral products (2.A.5, 2.A.6).

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Annexes to the National Inventory Report

12 ANNEX 1: GERMAN GREENHOUSE GAS INVENTORY KEY SOURCES

In accordance with the "*IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*"[177] (*Good Practice Guidance*), the Parties to the Framework Convention on Climate Change, and the Kyoto Protocol, are obliged to calculate and publish annual emissions data.

These emissions inventories must be comprehensible to everyone (transparency), calculated in a comparable manner in the time series since 1990 (consistency), be evaluated uniformly at international level via application of the prescribed calculation methods (comparability), contain all the relevant emission sources and sinks in the reporting country (completeness), and be evaluated with error specification and be subject to permanent internal and external quality management (accuracy).

In order to be able to concentrate the many and detailed activities and capacities required for this purpose on the principal source categories of the inventory, the IPCC has introduced the definition of a "key source". This refers to those source categories which are highlighted in the national inventory system because their emissions have a significant influence on the total emission of direct greenhouse gases, either in terms of absolute emissions, as a contribution to the emissions trend over time, or both.

To this end, the Good Practice Guidance specifies, in chapter 7, the methods to be applied for determining key sources. These methods make it possible, via inventory analysis for one year (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 Trend Assessment with consideration of inaccuracies), to identify the respective key sources.

For the identified key sources, the Parties are then required to use very detailed calculation methods (TIER 2 or higher), which are likewise prescribed in the Good Practice Guidance. Should this prove impossible for a variety of reasons (e.g. data availability for the required input variables, etc.), Parties are required to prove that the methods applied nationally at least achieve a comparable degree of accuracy in the calculation result. These records, as well as the key source analysis performed overall, must be outlined in the national inventory report to be prepared annually.

12.1 Description of the method for determining key sources

The results of the key source analysis based on the two Tier 1 techniques (Level and Trend) are outlined below. We also refer the reader to the description of the underlying methods in the *Good Practice Guidance*. In a departure from that source's proposal for the structure of the relevant source categories, a greater degree of detail was chosen for the present analysis. Annual emissions inventories were divided, in keeping with their CO_2-equivalent emissions, into a total of 177 individual activities.

177 This Report was produced as a response to a suggestion by the UN Framework Convention on Climate Change to the Intergovernmental Panel on Climate Change (IPCC). The work to determine uncertainties in inventories was to be completed, and a report submitted on "good practice" in inventory management.
Work was carried out with the aim of supporting governments in the preparation of their emissions inventories. The aim was to avoid over-valuation or under-valuation of the results and to reduce the inaccuracies of the inventories as far as possible.
This report is published on the Internet at : http://www.ipcc-nggip.iges.or.jp/public/gp/gpgaum.htm

12.1.1 Tier 1 Level Approach

As a result of this approach, those source categories responsible for 95 % of total national emissions (als CO_2-equivalent emissions), in 1990 and 2003, are identified as key sources (●). Calculations were performed using formula 7.1 from the Good Practice Guidance.

For the source category summary used in this analysis, a total of 31 key sources are identified in 2003 using this approach (cf. Table 88).

Table 88: Key source categories for Germany (1990-2003) based on the Tier 1 Level Approach

IPCC Source Categories	Activity	Emissions of	2003 [CO_2 Equ.]	Level Assessment	Key Source
1A1a Public electricity and Heat production	Biomass	CH_4	0,018	0,00	
1A1a Public electricity and Heat production	Biomass	CO_2	0,000	0,00	
1A1a Public electricity and Heat production	Biomass	N_2O	1,078	0,00	
1A1a Public electricity and Heat production	Gaseous fuels	CH_4	7,808	0,00	
1A1a Public electricity and Heat production	Gaseous fuels	CO_2	26.118,278	2,56	●
1A1a Public electricity and Heat production	Gaseous fuels	N_2O	97,498	0,01	
1A1a Public electricity and Heat production	Liquid fuels	CH_4	4,227	0,00	
1A1a Public electricity and Heat production	Liquid fuels	CO_2	4.697,170	0,46	●
1A1a Public electricity and Heat production	Liquid fuels	N_2O	21,121	0,00	
1A1a Public electricity and Heat production	Other Fuels	CH_4	1,275	0,00	
1A1a Public electricity and Heat production	Other Fuels	CO_2	506,114	0,05	
1A1a Public electricity and Heat production	Other Fuels	N_2O	31,379	0,00	
1A1a Public electricity and Heat production	Solid fuels	CH_4	87,764	0,01	
1A1a Public electricity and Heat production	Solid fuels	CO_2	291.320,913	28,60	●
1A1a Public electricity and Heat production	Solid fuels	N_2O	3.311,142	0,33	
1A1b. Petroleum Refining	Gaseous fuels	CH_4	0,346	0,00	
1A1b. Petroleum Refining	Gaseous fuels	CO_2	724,999	0,07	
1A1b. Petroleum Refining	Gaseous fuels	N_2O	3,660	0,00	
1A1b. Petroleum Refining	Liquid fuels	N_2O	57,696	0,01	
1A1b. Petroleum Refining	Liquid fuels	CH_4	7,580	0,00	
1A1b. Petroleum Refining	Liquid fuels	CO_2	18.160,413	1,78	●
1A1b. Petroleum Refining	Solid fuels	CH_4	0,131	0,00	
1A1b. Petroleum Refining	Solid fuels	CO_2	487,936	0,05	
1A1b. Petroleum Refining	Solid fuels	N_2O	4,938	0,00	
1A1c. Manufacture of Solid fuels and Other Energy Industries	Biomass	CH_4	1,016	0,00	
1A1c. Manufacture of Solid fuels and Other Energy Industries	Biomass	N_2O	5,397	0,00	
1A1c. Manufacture of Solid fuels and Other Energy Industries	Gaseous fuels	CH_4	1,239	0,00	
1A1c. Manufacture of Solid fuels and Other Energy Industries	Gaseous fuels	CO_2	1.486,584	0,15	
1A1c. Manufacture of Solid fuels and Other Energy Industries	Gaseous fuels	N_2O	6,999	0,00	
1A1c. Manufacture of Solid fuels and Other Energy Industries	Liquid fuels	CH_4	0,191	0,00	
1A1c. Manufacture of Solid fuels and Other Energy Industries	Liquid fuels	CO_2	216,387	0,02	
1A1c. Manufacture of Solid fuels and Other Energy Industries	Liquid fuels	N_2O	1,247	0,00	
1A1c. Manufacture of Solid fuels and Other Energy Industries	Other Fuels	CH_4	0,009	0,00	
1A1c. Manufacture of Solid fuels and Other Energy Industries	Other Fuels	CO_2	4,557	0,00	
1A1c. Manufacture of Solid fuels and Other Energy Industries	Other Fuels	N_2O	0,212	0,00	
1A1c. Manufacture of Solid fuels and Other Energy Industries	Solid fuels	CH_4	6,544	0,00	

IPCC Source Categories	Activity	Emissions of	2003 [CO_2 Equ.]	Level Assessment	Key Source
1A1c. Manufacture of Solid fuels and Other Energy Industries	Solid fuels	CO_2	18.858,204	1,85	•
1A1c. Manufacture of Solid fuels and Other Energy Industries	Solid fuels	N_2O	248,226	0,02	
1A2a-f. Manufacturing Industries and Construction total	Biomass	CH_4	0,000	0,00	
1A2a-f. Manufacturing Industries and Construction total	Biomass	N_2O	0,000	0,00	
1A2a-f. Manufacturing Industries and Construction total	Gaseous fuels	CH_4	37,710	0,00	
1A2a-f. Manufacturing Industries and Construction total	Gaseous fuels	CO_2	50.214,121	4,93	•
1A2a-f. Manufacturing Industries and Construction total	Gaseous fuels	N_2O	239,634	0,02	
1A2a-f. Manufacturing Industries and Construction total	Liquid fuels	CH_4	13,175	0,00	
1A2a-f. Manufacturing Industries and Construction total	Liquid fuels	CO_2	19.040,598	1,87	•
1A2a-f. Manufacturing Industries and Construction total	Liquid fuels	N_2O	103,825	0,01	
1A2a-f. Manufacturing Industries and Construction total	Other Fuels	CH_4	0,686	0,00	
1A2a-f. Manufacturing Industries and Construction total	Other Fuels	CO_2	384,574	0,04	
1A2a-f. Manufacturing Industries and Construction total	Other Fuels	N_2O	17,883	0,00	
1A2a-f. Manufacturing Industries and Construction total	Solid fuels	CH_4	66,132	0,01	
1A2a-f. Manufacturing Industries and Construction total	Solid fuels	CO_2	59.416,906	5,83	•
1A2a-f. Manufacturing Industries and Construction total	Solid fuels	N_2O	465,638	0,05	
1A3a. Transport Civil Aviation	Aviation Gasoline	CH_4	1,143	0,00	
1A3a. Transport Civil Aviation	Aviation Gasoline	CO_2	4.287,688	0,42	•
1A3a. Transport Civil Aviation	Aviation Gasoline	N_2O	63,316	0,01	
1A3b. Transport Road Transportation	Biomass	CH_4	0,645	0,00	
1A3b. Transport Road Transportation	Biomass	N_2O	23,313	0,00	
1A3b. Transport Road Transportation	Diesel Oil	CH_4	28,786	0,00	
1A3b. Transport Road Transportation	Diesel Oil	CO_2	79.943,319	7,85	•
1A3b. Transport Road Transportation	Diesel Oil	N_2O	1.040,756	0,10	
1A3b. Transport Road Transportation	Gasoline	CO_2	79.848,000	7,84	•
1A3b. Transport Road Transportation	Gasoline	CH_4	199,778	0,02	
1A3b. Transport Road Transportation	Gasoline	N_2O	3.028,470	0,30	
1A3b. Transport Road Transportation	Liquid Gas	CH_4	0,006	0,00	
1A3b. Transport Road Transportation	Liquid Gas	CO_2	6,500	0,00	
1A3b. Transport Road Transportation	Liquid Gas	N_2O	0,053	0,00	
1A3b. Transport Road Transportation	Petroleum	CH_4	0,022	0,00	
1A3b. Transport Road Transportation	Petroleum	CO_2	44,400	0,00	
1A3b. Transport Road Transportation	Petroleum	N_2O	0,622	0,00	
1A3c. Transport Railways	Liquid fuels	CH_4	2,210	0,00	
1A3c. Transport Railways	Liquid fuels	CO_2	1.557,700	0,15	
1A3c. Transport Railways	Liquid fuels	N_2O	22,187	0,00	
1A3c. Transport Railways	Solid fuels	CH_4	0,170	0,00	
1A3c. Transport Railways	Solid fuels	CO_2	53,838	0,01	
1A3c. Transport Railways	Solid fuels	N_2O	0,586	0,00	
1A3d. Transport Navigation	Diesel Oil	CH_4	0,655	0,00	
1A3d. Transport Navigation	Diesel Oil	CO_2	769,304	0,08	
1A3d. Transport Navigation	Diesel Oil	N_2O	10,957	0,00	
1A3e. Transport Other Transportation	Gaseous fuels	CH_4	0,608	0,00	
1A3e. Transport Other Transportation	Gaseous fuels	CO_2	811,183	0,08	
1A3e. Transport Other Transportation	Gaseous fuels	N_2O	5,478	0,00	

IPCC Source Categories	Activity	Emissions of	2003 [CO_2 Equ.]	Level Assessment	Key Source
1A3e. Transport Other Transportation	Liquid fuels	CH_4	6,404	0,00	
1A3e. Transport Other Transportation	Liquid fuels	CO_2	2.887,540	0,28	
1A3e. Transport Other Transportation	Liquid fuels	N_2O	41,404	0,00	
1A4a. Other Sectors Commercial/Institutional	Biomass	CH_4	39,553	0,00	
1A4a. Other Sectors Commercial/Institutional	Biomass	N_2O	6,487	0,00	
1A4a. Other Sectors Commercial/Institutional	Gaseous fuels	CH_4	1,201	0,00	
1A4a. Other Sectors Commercial/Institutional	Gaseous fuels	CO_2	27.227,025	2,67	•
1A4a. Other Sectors Commercial/Institutional	Gaseous fuels	N_2O	52,095	0,01	
1A4a. Other Sectors Commercial/Institutional	Liquid fuels	CH_4	0,135	0,00	
1A4a. Other Sectors Commercial/Institutional	Liquid fuels	CO_2	20.262,714	1,99	•
1A4a. Other Sectors Commercial/Institutional	Liquid fuels	N_2O	47,138	0,00	
1A4a. Other Sectors Commercial/Institutional	Solid fuels	CH_4	23,177	0,00	
1A4a. Other Sectors Commercial/Institutional	Solid fuels	CO_2	1.204,645	0,12	
1A4a. Other Sectors Commercial/Institutional	Solid fuels	N_2O	8,295	0,00	
1A4b. Other Sectors Residential	Biomass	CH_4	472,772	0,05	
1A4b. Other Sectors Residential	Biomass	N_2O	90,929	0,01	
1A4b. Other Sectors Residential	Gaseous fuels	CH_4	24,971	0,00	
1A4b. Other Sectors Residential	Gaseous fuels	CO_2	60.536,000	5,94	•
1A4b. Other Sectors Residential	Gaseous fuels	N_2O	103,884	0,01	
1A4b. Other Sectors Residential	Liquid fuels	CH_4	3,748	0,00	
1A4b. Other Sectors Residential	Liquid fuels	CO_2	58.965,015	5,79	•
1A4b. Other Sectors Residential	Liquid fuels	N_2O	150,846	0,01	
1A4b. Other Sectors Residential	Solid fuels	CH_4	76,861	0,01	
1A4b. Other Sectors Residential	Solid fuels	CO_2	2.941,480	0,29	
1A4b. Other Sectors Residential	Solid fuels	N_2O	48,564	0,00	
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Biomass	CH_4	17,311	0,00	
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Biomass	N_2O	2,926	0,00	
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Gaseous fuels	CH_4	0,037	0,00	
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Gaseous fuels	CO_2	847,862	0,08	
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Gaseous fuels	N_2O	1,622	0,00	
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Liquid fuels	CH_4	8,856	0,00	
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Liquid fuels	CO_2	5.730,838	0,56	•
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Liquid fuels	N_2O	61,237	0,01	
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Solid fuels	CH_4	0,264	0,00	
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Solid fuels	CO_2	76,276	0,01	
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Solid fuels	N_2O	1,161	0,00	
1A5 Other Include Military fuel use under this category	Gaseous fuels	CH_4	0,005	0,00	
1A5 Other Include Military fuel use under this category	Gaseous fuels	CO_2	653,113	0,06	
1A5 Other Include Military fuel use under this category	Gaseous fuels	N_2O	1,048	0,00	
1A5 Other Include Military fuel use under this category	Liquid fuels	CH_4	5,713	0,00	

IPCC Source Categories	Activity	Emissions of	2003 [CO_2 Equ.]	Level Assessment	Key Source
1A5 Other Include Military fuel use under this category	Liquid fuels	CO_2	1.355,780	0,13	
1A5 Other Include Military fuel use under this category	Liquid fuels	N_2O	12,820	0,00	
1A5 Other Include Military fuel use under this category	Solid fuels	CH_4	0,293	0,00	
1A5 Other Include Military fuel use under this category	Solid fuels	CO_2	43,676	0,00	
1A5 Other Include Military fuel use under this category	Solid fuels	N_2O	0,587	0,00	
1B1a. Fugitive Emissions from Fuels Coal Mining and Handling	Solid fuels	CH_4	6.871,263	0,67	●
1B1b. Fugitive Emissions from Fuels Solid Fuel Transformation	Solid fuels	CH_4	19,442	0,00	
1B1c. Fugitive Emissions from Fuels Other (Abandoned Mines)	Solid fuels	CH_4		0,00	
1B2a. Fugitive Emissions from Fuels Oil	Oil	CH_4	137,444	0,01	
1B2b. Fugitive Emissions from Fuels Natural Gas	Natural Gas	CH_4	7.213,975	0,71	●
1B2d. Fugitive Emissions from Fuels Other	Oil and Gas	CH_4	0,000	0,00	
2A1. Mineral Products Cement Production		CO_2	13.373,414	1,31	●
2A2. Mineral Products Lime Production		CO_2	5.382,601	0,53	●
2A4. Soda Ash		CO_2	546,768	0,05	
2A7. Glass Production		CO_2	1.455,700	0,14	
2B1. Chemical Industry	Ammonia production	CO_2	1.997,689	0,20	
2B2 Chemical Industry	Nitric Acid Production	N_2O	6.588,683	0,65	●
2B3 Chemical Industry	Adipic Acid Production	N_2O	3.778,285	0,37	●
2B4 Chemical Industry	Carbide Production	CO_2	15,870	0,00	
2B5 Chemical Industry	other	CH_4	404,971	0,04	
2B5 Chemical Industry	other	N_2O	5,766	0,00	
2C1. Metal Production Iron and Steel Production	other	CH_4	2,025	0,00	
2C3. Aluminium Production		CO_2	903,587	0,09	
2C3. Aluminium Production		PFCs	431,010	0,04	
2C4. SF_6 Used in Aluminium and Magnesium Foundries		SF_6	1.217,466	0,12	
2E. Production of Halocarbons and SF_6	Fugitive emissions	SF_6	239,000	0,02	
2E. Production of Halocarbons and SF_6	production of HCFC-22	HFCs	1.211,750	0,12	
2E. Production of Halocarbons and SF_6		PFCs	0,000	0,00	
2F. Industrial Processes	Consumption of Halocarbons and SF_6	HFCs	7.035,400	0,69	●
2F. Industrial Processes	Consumption of Halocarbons and SF_6	PFCs	355,000	0,03	
2F. Industrial Processes	Consumption of Halocarbons and SF_6	SF_6	2.740,618	0,27	
3D.Total Solvent and Other Product Use		N_2O	1.922,000	0,19	
4A.1. Enteric Fermentation	Dairy Cattle	CH_4	9.433,944	0,93	●
4A.1. Enteric Fermentation	Non-Dairy Cattle	CH_4	14.268,156	1,40	●
4A.3. Enteric Fermentation	Sheep	CH_4	443,201	0,04	
4A.6. Enteric Fermentation	Horses	CH_4	191,362	0,02	
4A.8. Enteric Fermentation	Swine	CH_4	836,542	0,08	
4B1. Manure Management	Dairy Cattle	CH_4	7.840,268	0,77	●
4B1. Manure Management	Non-Dairy Cattle	CH_4	3.890,229	0,38	●
4B13. Manure Management Other	Dairy Cows	N_2O	767,910	0,08	
4B13. Manure Management Other	Horses	N_2O	257,901	0,03	
4B13. Manure Management Other	Other Cattle	N_2O	984,515	0,10	
4B13. Manure Management Other	Poultry	N_2O	491,527	0,05	
4B13. Manure Management Other	Sheep	N_2O	10,411	0,00	
4B13. Manure Management Other	Swine	N_2O	414,167	0,04	
4B3. Manure Management	Sheep	CH_4	10,268	0,00	

IPCC Source Categories	Activity	Emissions of	2003 [CO_2 Equ.]	Level Assessment	Key Source
4B6. Manure Management	Horses	CH_4	28,923	0,00	
4B8. Manure Management	Swine	CH_4	11.139,169	1,09	•
4B9. Manure Management	Poultry	CH_4	199,928	0,02	
4D1. Agricultural Soils	Direct Soil Emissions	N_2O	23.686,341	2,32	•
4D2. Agricultural Soils	Animal Production	N_2O	1.910,167	0,19	
4D3. Agricultural Soils	Indirect Emissions	N_2O	11.156,346	1,10	•
4D4. Agricultural Soils	Other	CH_4	633,487	0,06	
6A1 Managed Waste Disposal on Land	Solid Waste Disposal on Land	CH_4	11.655,000	1,14	•
6B2. Wastewater Handling	Domestic and Commercial Wastewater	CH_4	111,993	0,01	
6B2. Wastewater Handling	Domestic and Commercial Wastewater	N_2O	2.275,400	0,22	

12.1.2 Tier 1 Trend Approach

As a result of this analysis, those source categories which have made a particular contribution to changes in total greenhouse gas emissions in 2002, in terms of the development of their contribution since 2003, are identified as key source categories (•). 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 7.2 from the Good Practice Guidance.

For the source category summary used in this analysis, a total of 38 key sources are identified using this approach (cf. Table 89).

Table 89: Key source categories for Germany (1990-2003) based on the Tier 1 Trend Approach

IPCC Source Categories	Activity	Emissions of	1990 [CO_2 Equ.]	2003 [CO_2 Equ.]	Trend Assessment	Key Source
1A1a Public electricity and Heat production	Biomass	CH_4	0,002	0,018	0,000000	
1A1a Public electricity and Heat production	Biomass	CO_2	0,000	0,000	0,000000	
1A1a Public electricity and Heat production	Biomass	N_2O	0,134	1,078	0,000001	
1A1a Public electricity and Heat production	Gaseous fuels	CH_4	3,519	7,808	0,000006	
1A1a Public electricity and Heat production	Gaseous fuels	CO_2	18.463,251	26.118,278	0,000000	•
1A1a Public electricity and Heat production	Gaseous fuels	N_2O	153,683	97,498	0,000034	
1A1a Public electricity and Heat production	Liquid fuels	CH_4	8,085	4,227	0,000003	
1A1a Public electricity and Heat production	Liquid fuels	CO_2	8.474,772	4.697,170	0,002684	•
1A1a Public electricity and Heat production	Liquid fuels	N_2O	98,499	21,121	0,000071	
1A1a Public electricity and Heat production	Other Fuels	CH_4	12,779	1,275	0,000011	
1A1a Public electricity and Heat production	Other Fuels	CO_2	1.250,950	506,114	0,000621	
1A1a Public electricity and Heat production	Other Fuels	N_2O	61,273	31,379	0,000023	
1A1a Public electricity and Heat production	Solid fuels	CH_4	109,140	87,764	0,000002	
1A1a Public electricity and Heat production	Solid fuels	CO_2	306.429,717	291.320,913	0,048646	•
1A1a Public electricity and Heat production	Solid fuels	N_2O	3.337,585	3.311,142	0,000696	
1A1b. Petroleum Refining	Gaseous fuels	CH_4	0,366	0,346	0,000000	
1A1b. Petroleum Refining	Gaseous fuels	CO_2	1.028,732	724,999	0,000140	
1A1b. Petroleum Refining	Gaseous fuels	N_2O	8,590	3,660	0,000004	
1A1b. Petroleum Refining	Liquid fuels	CH_4	9,902	7,580	0,000001	
1A1b. Petroleum Refining	Liquid fuels	CO_2	16.008,949	18.160,413	0,006069	•
1A1b. Petroleum Refining	Liquid fuels	N_2O	167,444	57,696	0,000095	
1A1b. Petroleum Refining	Solid fuels	CH_4	0,786	0,131	0,000001	

IPCC Source Categories	Activity	Emissions of	1990 [CO_2 Equ.]	2003 [CO_2 Equ.]	Trend Assessment	Key Source
1A1b. Petroleum Refining	Solid fuels	CO_2	2.381,264	487,936	0,001752	●
1A1b. Petroleum Refining	Solid fuels	N_2O	24,121	4,938	0,000018	
1A1c. Manufacture of Solid fuels and Other Energy Industries	Biomass	CH_4	0,525	1,016	0,000001	
1A1c. Manufacture of Solid fuels and Other Energy Industries	Biomass	N_2O	4,648	5,397	0,000002	
1A1c. Manufacture of Solid fuels and Other Energy Industries	Gaseous fuels	CH_4	2,154	1,239	0,000001	
1A1c. Manufacture of Solid fuels and Other Energy Industries	Gaseous fuels	CO_2	2.701,718	1.486,584	0,000869	
1A1c. Manufacture of Solid fuels and Other Energy Industries	Gaseous fuels	N_2O	22,480	6,999	0,000014	
1A1c. Manufacture of Solid fuels and Other Energy Industries	Liquid fuels	CH_4	0,444	0,191	0,000000	
1A1c. Manufacture of Solid fuels and Other Energy Industries	Liquid fuels	CO_2	488,354	216,387	0,000220	
1A1c. Manufacture of Solid fuels and Other Energy Industries	Liquid fuels	N_2O	4,886	1,247	0,000003	
1A1c. Manufacture of Solid fuels and Other Energy Industries	Other Fuels	CH_4	2,419	0,009	0,000002	
1A1c. Manufacture of Solid fuels and Other Energy Industries	Other Fuels	CO_2	333,136	4,557	0,000322	
1A1c. Manufacture of Solid fuels and Other Energy Industries	Other Fuels	N_2O	3,296	0,212	0,000003	
1A1c. Manufacture of Solid fuels and Other Energy Industries	Solid fuels	CH_4	19,006	6,544	0,000011	
1A1c. Manufacture of Solid fuels and Other Energy Industries	Solid fuels	CO_2	56.384,031	18.858,204	0,032724	●
1A1c. Manufacture of Solid fuels and Other Energy Industries	Solid fuels	N_2O	607,393	248,226	0,000298	
1A2a-f. Manufacturing Industries and Construction total	Biomass	CH_4	7,827	7,827	0,000002	
1A2a-f. Manufacturing Industries and Construction total	Biomass	N_2O	20,343	20,343	0,000004	
1A2a-f. Manufacturing Industries and Construction total	Gaseous fuels	CH_4	28,561	37,710	0,000017	
1A2a-f. Manufacturing Industries and Construction total	Gaseous fuels	CO_2	45.750,962	50.214,121	0,015322	●
1A2a-f. Manufacturing Industries and Construction total	Gaseous fuels	N_2O	380,837	239,634	0,000086	
1A2a-f. Manufacturing Industries and Construction total	Liquid fuels	CH_4	24,935	13,175	0,000009	
1A2a-f. Manufacturing Industries and Construction total	Liquid fuels	CO_2	28.391,517	19.040,598	0,005030	●
1A2a-f. Manufacturing Industries and Construction total	Liquid fuels	N_2O	266,551	103,825	0,000137	
1A2a-f. Manufacturing Industries and Construction total	Other Fuels	CH_4	25,405	0,686	0,000024	
1A2a-f. Manufacturing Industries and Construction total	Other Fuels	CO_2	1.922,710	384,574	0,001426	●
1A2a-f. Manufacturing Industries and Construction total	Other Fuels	N_2O	48,751	17,883	0,000026	
1A2a-f. Manufacturing Industries and Construction total	Solid fuels	CH_4	173,818	66,132	0,000091	
1A2a-f. Manufacturing Industries and Construction total	Solid fuels	CO_2	120.249,786	59.416,906	0,046764	●
1A2a-f. Manufacturing Industries and Construction total	Solid fuels	N_2O	1.017,356	465,638	0,000440	
1A3a. Transport Civil Aviation	Aviation Gasoline	CH_4	0,822	1,143	0,000001	
1A3a. Transport Civil Aviation	Aviation Gasoline	CO_2	2.897,396	4.287,688	0,002299	●
1A3a. Transport Civil Aviation	Aviation Gasoline	N_2O	18,207	63,316	0,000058	
1A3b. Transport Road Transportation	Biomass	CH_4	0,000	0,645	0,000001	
1A3b. Transport Road Transportation	Biomass	N_2O	0,000	23,313	0,000028	
1A3b. Transport Road Transportation	Diesel Oil	CH_4	40,546	28,786	0,000005	
1A3b. Transport Road Transportation	Diesel Oil	CO_2	54.458,080	79.943,319	0,042434	●
1A3b. Transport Road Transportation	Diesel Oil	N_2O	705,288	1.040,756	0,000556	
1A3b. Transport Road Transportation	Gasoline	CO_2	95.794,488	79.848,000	0,001746	●
1A3b. Transport Road Transportation	Gasoline	CH_4	1.276,714	199,778	0,001014	

IPCC Source Categories	Activity	Emissions of	1990 [CO_2 Equ.]	2003 [CO_2 Equ.]	Trend Assessment	Key Source
1A3b. Transport Road Transportation	Gasoline	N_2O	2.227,031	3.028,470	0,001447	●
1A3b. Transport Road Transportation	Liquid Gas	CH_4	0,009	0,006	0,000000	
1A3b. Transport Road Transportation	Liquid Gas	CO_2	8,970	6,500	0,000001	
1A3b. Transport Road Transportation	Liquid Gas	N_2O	0,073	0,053	0,000000	
1A3b. Transport Road Transportation	Petroleum	CH_4	0,000	0,022	0,000000	
1A3b. Transport Road Transportation	Petroleum	CO_2	0,000	44,400	0,000053	
1A3b. Transport Road Transportation	Petroleum	N_2O	0,000	0,622	0,000001	
1A3c. Transport Railways	Liquid fuels	CH_4	4,038	2,210	0,000001	
1A3c. Transport Railways	Liquid fuels	CO_2	2.825,541	1.557,700	0,000905	
1A3c. Transport Railways	Liquid fuels	N_2O	40,535	22,187	0,000013	
1A3c. Transport Railways	Solid fuels	CH_4	0,181	0,170	0,000000	
1A3c. Transport Railways	Solid fuels	CO_2	53,741	53,838	0,000012	
1A3c. Transport Railways	Solid fuels	N_2O	0,714	0,586	0,000000	
1A3d. Transport Navigation	Diesel Oil	CH_4	1,746	0,655	0,000001	
1A3d. Transport Navigation	Diesel Oil	CO_2	2.049,777	769,304	0,001089	
1A3d. Transport Navigation	Diesel Oil	N_2O	29,206	10,957	0,000016	
1A3e. Transport Other Transportation	Gaseous fuels	CH_4	0,072	0,608	0,000001	
1A3e. Transport Other Transportation	Gaseous fuels	CO_2	637,275	811,183	0,000347	
1A3e. Transport Other Transportation	Gaseous fuels	N_2O	5,303	5,478	0,000001	
1A3e. Transport Other Transportation	Liquid fuels	CH_4	9,756	6,404	0,000002	
1A3e. Transport Other Transportation	Liquid fuels	CO_2	3.634,291	2.887,540	0,000104	
1A3e. Transport Other Transportation	Liquid fuels	N_2O	52,290	41,404	0,000002	
1A4a. Other Sectors Commercial/Institutional	Biomass	CH_4	26,039	39,553	0,000022	
1A4a. Other Sectors Commercial/Institutional	Biomass	N_2O	3,943	6,487	0,000004	
1A4a. Other Sectors Commercial/Institutional	Gaseous fuels	CH_4	0,667	1,201	0,000001	
1A4a. Other Sectors Commercial/Institutional	Gaseous fuels	CO_2	13.633,411	27.227,025	0,019275	●
1A4a. Other Sectors Commercial/Institutional	Gaseous fuels	N_2O	25,679	52,095	0,000037	
1A4a. Other Sectors Commercial/Institutional	Liquid fuels	CH_4	0,190	0,135	0,000000	
1A4a. Other Sectors Commercial/Institutional	Liquid fuels	CO_2	27.280,448	20.262,714	0,002473	●
1A4a. Other Sectors Commercial/Institutional	Liquid fuels	N_2O	63,292	47,138	0,000006	
1A4a. Other Sectors Commercial/Institutional	Solid fuels	CH_4	1.057,531	23,177	0,001010	
1A4a. Other Sectors Commercial/Institutional	Solid fuels	CO_2	20.901,797	1.204,645	0,019071	●
1A4a. Other Sectors Commercial/Institutional	Solid fuels	N_2O	48,867	8,295	0,000038	
1A4b. Other Sectors Residential	Biomass	CH_4	234,948	472,772	0,000336	
1A4b. Other Sectors Residential	Biomass	N_2O	43,059	90,929	0,000067	
1A4b. Other Sectors Residential	Gaseous fuels	CH_4	13,075	24,971	0,000017	
1A4b. Other Sectors Residential	Gaseous fuels	CO_2	31.691,782	60.536,000	0,041502	●
1A4b. Other Sectors Residential	Gaseous fuels	N_2O	54,335	103,884	0,000071	
1A4b. Other Sectors Residential	Liquid fuels	CH_4	1,438	3,748	0,000003	
1A4b. Other Sectors Residential	Liquid fuels	CO_2	56.162,511	58.965,015	0,015599	●
1A4b. Other Sectors Residential	Liquid fuels	N_2O	144,176	150,846	0,000039	
1A4b. Other Sectors Residential	Solid fuels	CH_4	950,232	76,861	0,000841	
1A4b. Other Sectors Residential	Solid fuels	CO_2	41.425,080	2.941,480	0,037132	●
1A4b. Other Sectors Residential	Solid fuels	N_2O	557,664	48,564	0,000489	
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Biomass	CH_4	0,000	17,311	0,000021	
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Biomass	N_2O	0,000	2,926	0,000004	

IPCC Source Categories	Activity	Emissions of	1990 [CO_2 Equ.]	2003 [CO_2 Equ.]	Trend Assessment	Key Source
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Gaseous fuels	CH_4	0,024	0,037	0,000000	
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Gaseous fuels	CO_2	479,218	847,862	0,000547	
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Gaseous fuels	N_2O	0,905	1,622	0,000001	
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Liquid fuels	CH_4	14,087	8,856	0,000003	
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Liquid fuels	CO_2	8.088,680	5.730,838	0,001066	
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Liquid fuels	N_2O	82,063	61,237	0,000007	
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Solid fuels	CH_4	260,558	0,264	0,000255	
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Solid fuels	CO_2	4.750,908	76,276	0,004572	●
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Solid fuels	N_2O	12,562	1,161	0,000011	
1A5 Other Include Military fuel use under this category	Gaseous fuels	CH_4	0,004	0,005	0,000000	
1A5 Other Include Military fuel use under this category	Gaseous fuels	CO_2	509,516	653,113	0,000283	
1A5 Other Include Military fuel use under this category	Gaseous fuels	N_2O	0,821	1,048	0,000000	
1A5 Other Include Military fuel use under this category	Liquid fuels	CH_4	26,559	5,713	0,000019	
1A5 Other Include Military fuel use under this category	Liquid fuels	CO_2	6.659,145	1.355,780	0,004910	●
1A5 Other Include Military fuel use under this category	Liquid fuels	N_2O	59,676	12,820	0,000043	
1A5 Other Include Military fuel use under this category	Solid fuels	CH_4	210,251	0,293	0,000206	
1A5 Other Include Military fuel use under this category	Solid fuels	CO_2	4.657,327	43,676	0,004519	●
1A5 Other Include Military fuel use under this category	Solid fuels	N_2O	15,108	0,587	0,000014	
1B1a. Fugitive Emissions from Fuels Coal Mining and Handling	Solid fuels	CH_4	25.644,421	6.871,263	0,016930	●
1B1b. Fugitive Emissions from Fuels Solid Fuel Transformation	Solid fuels	CH_4	127,215	19,442	0,000102	
1B1c. Fugitive Emissions from Fuels Other (Abandoned Mines)	Solid fuels	CH_4	0,000	0,000	0,000000	
1B2a. Fugitive Emissions from Fuels Oil	Oil	CH_4	226,576	137,444	0,000058	
1B2b. Fugitive Emissions from Fuels Natural Gas	Natural Gas	CH_4	6.383,138	7.213,975	0,002387	●
1B2d. Fugitive Emissions from Fuels Other	Oil and Gas	CH_4	398,372	0,000	0,000391	
2A1. Mineral Products Cement Production		CO_2	15.145,810	13.373,414	0,001174	●
2A2. Mineral Products Lime Production		CO_2	5.890,805	5.382,601	0,000674	
2A4. Soda Ash		CO_2	720,323	546,768	0,000051	
2A7. Glass Production		CO_2	1.213,200	1.455,700	0,000555	
2B1. Chemical Industry	Ammonia production	CO_2	1.747,386	1.997,689	0,000681	
2B2 Chemical Industry	Nitric Acid Production	N_2O	4.673,383	6.588,683	0,003316	●
2B3 Chemical Industry	Adipic Acid Production	N_2O	18.804,600	3.778,285	0,013926	●
2B4 Chemical Industry	Carbide Production	CO_2	443,160	15,870	0,000416	
2B5 Chemical Industry	other	CH_4	331,386	404,971	0,000160	
2B5 Chemical Industry	other	N_2O	5,766	5,766	0,000001	
2C1. Metal Production Iron and Steel Production	other	CH_4	3,919	2,025	0,000001	
2C3. Aluminium Production		CO_2	1.011,580	903,587	0,000091	
2C3. Aluminium Production		PFCs	2.486,000	431,010	0,001923	●
2C4. SF_6 Used in Aluminium and Magnesium Foundries		SF_6	167,300	1.217,466	0,001296	●
2E. Production of Halocarbons and SF_6	Fugitive emissions	SF_6	0,000	239,000	0,000287	

IPCC Source Categories	Activity	Emissions of	1990 [CO_2 Equ.]	2003 [CO_2 Equ.]	Trend Assessment	Key Source
2E. Production of Halocarbons and SF_6	production of HCFC-22	HFCs	3.510,000	1.211,750	0,001992	•
2E. Production of Halocarbons and SF_6		PFCs	70,000	0,000	0,000069	
2F. Industrial Processes	Consumption of Halocarbons and SF_6	HFCs	0,000	7.035,400	0,008439	•
2F. Industrial Processes	Consumption of Halocarbons and SF_6	PFCs	140,000	355,000	0,000288	
2F. Industrial Processes	Consumption of Halocarbons and SF_6	SF_6	3.728,400	2.740,618	0,000372	
3D.Total Solvent and Other Product Use		N_2O	1.922,000	1.922,000	0,000419	
4A.1. Enteric Fermentation	Dairy Cattle	CH_4	12.581,482	9.433,944	0,001034	
4A.1. Enteric Fermentation	Non-Dairy Cattle	CH_4	20.011,612	14.268,156	0,002529	•
4A.3. Enteric Fermentation	Sheep	CH_4	544,233	443,201	0,000003	
4A.6. Enteric Fermentation	Horses	CH_4	185,581	191,362	0,000047	
4A.8. Enteric Fermentation	Swine	CH_4	970,793	836,542	0,000051	
4B13. Manure Management Other	Dairy Cows	N_2O	1.626,268	767,910	0,000675	
4B13. Manure Management Other	Horses	N_2O	250,109	257,901	0,000064	
4B13. Manure Management Other	Other Cattle	N_2O	1.335,395	984,515	0,000130	
4B13. Manure Management Other	Poultry	N_2O	462,912	491,527	0,000135	
4B13. Manure Management Other	Sheep	N_2O	15,021	10,411	0,000002	
4B13. Manure Management Other	Swine	N_2O	784,829	414,167	0,000274	
4B1. Manure Management	Dairy Cattle	CH_4	8.693,637	7.840,268	0,000871	
4B1. Manure Management	Non-Dairy Cattle	CH_4	5.915,240	3.890,229	0,001140	•
4B3. Manure Management	Sheep	CH_4	12,609	10,268	0,000000	
4B6. Manure Management	Horses	CH_4	28,050	28,923	0,000007	
4B8. Manure Management	Swine	CH_4	12.262,169	11.139,169	0,001325	•
4B9. Manure Management	Poultry	CH_4	186,533	199,928	0,000057	
4D1. Agricultural Soils	Direct Soil Emissions	N_2O	27.645,205	23.686,341	0,001275	•
4D2. Agricultural Soils	Animal Production	N_2O	2.518,842	1.910,167	0,000181	
4D3. Agricultural Soils	Indirect Emissions	N_2O	13.711,595	11.156,346	0,000077	
4D4. Agricultural Soils	Other	CH_4	672,035	633,487	0,000100	
6A1 Managed Waste Disposal on Land	Solid Waste Disposal on Land	CH_4	31.478,863	11.655,000	0,016918	•
6B2. Wastewater Handling	Domestic and Commercial Wastewater	CH_4	2.226,210	111,993	0,002051	•
6B2. Wastewater Handling	Domestic and Commercial Wastewater	N_2O	2.213,400	2.275,400	0,000557	

12.1.3 Tier 2 Approach

The key-source analysis pursuant to the Tier 2 approach is based on the results of uncertainties determination pursuant to Tier 2. Previously, no uncertainties for the German greenhouse-gas inventory were determined pursuant to the Tier 2 approach, using Monte Carlo simulation. In the previous procedure, experts' estimations of activity rates and emission factors were carried out, for the various source categories and to various extents. These were complemented with data from the literature, to obtain complete data sets for technical programme implementation of the calculations required for the Tier 2 method. In connection with uncertainties determination pursuant to Tier 2, as planned, plans also call for taking uncertainties into account in determination of key sources. The relevant NIR chapters

(1.7 and, in the Annex, Chapter 18) provide information about the current status of uncertainties determination.

12.1.4 Evaluation

The results presented are based on a highly detailed analysis carried out in conformance with regulations. A total of 45 key sources (36 Level 1990; 31 Level 2003; 38 Trend) were identifed for the year 2003 (total for both TIER 1 procedures). These sources cause total CO_2-equivalent emissions of 986063 Gg, which corresponds to a share of 96.9 % of the total emissions for 2003. These source categories are treated as key sources for all greenhouse gases, regardless of which of their components are the determining factors for their classification as key sources.

The result is summarised in Table 90 below.

In subsequent work in the research project on quality assurance of the inventories, it will then be necessary to identify key sources based on the Tier 2 methodology.

Table 90: Key source categories for Germany (1990-2003) based on the Tier 1 Level and Trend Approach

IPCC SOURCE CATEGORIES	ACTIVITY	EMISSIONS OF	LEVEL 1990	LEVEL 2003	TREND 2003
1A1a Public electricity and Heat production	Gaseous fuels	CO_2	●	●	
1A1a Public electricity and Heat production	Liquid fuels	CO_2	●	●	●
1A1a Public electricity and Heat production	Solid fuels	CO_2	●	●	●
1A1b. Petroleum Refining	Liquid fuels	CO_2	●	●	●
1A1b. Petroleum Refining	Solid fuels	CO_2			●
1A1c. Manufacture of Solid fuels and Other Energy Industries	Solid fuels	CO_2	●	●	●
1A2a-f. Manufacturing Industries and Construction total	Gaseous fuels	CO_2	●	●	●
1A2a-f. Manufacturing Industries and Construction total	Liquid fuels	CO_2	●	●	●
1A2a-f. Manufacturing Industries and Construction total	Other Fuels	CO_2			●
1A2a-f. Manufacturing Industries and Construction total	Solid fuels	CO_2	●	●	●
1A3a. Transport Civil Aviation	Aviation Gasoline	CO_2		●	●
1A3b. Transport Road Transportation	Diesel Oil	CO_2	●	●	●
1A3b. Transport Road Transportation	Gasoline	CO_2	●	●	●
1A3b. Transport Road Transportation	Gasoline	N_2O			●
1A3e. Transport Other Transportation	Liquid fuels	CO_2	●		
1A4a. Other Sectors Commercial/Institutional	Gaseous fuels	CO_2	●	●	●
1A4a. Other Sectors Commercial/Institutional	Liquid fuels	CO_2	●	●	●
1A4a. Other Sectors Commercial/Institutional	Solid fuels	CO_2	●		●
1A4b. Other Sectors Residential	Gaseous fuels	CO_2	●	●	●
1A4b. Other Sectors Residential	Liquid fuels	CO_2	●	●	●
1A4b. Other Sectors Residential	Solid fuels	CO_2	●		●
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Liquid fuels	CO_2	●	●	
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Solid fuels	CO_2	●		●
1A5 Other Include Military fuel use under this category	Liquid fuels	CO_2	●		●
1A5 Other Include Military fuel use under this category	Solid fuels	CO_2	●		●
1B1a. Fugitive Emissions from Fuels Coal Mining and Handling	Solid fuels	CH_4	●	●	●
1B2b. Fugitive Emissions from Fuels Natural Gas	Natural Gas	CH_4	●	●	●
2A1. Mineral Products Cement Production		CO_2	●	●	●
2A2. Mineral Products Lime Production		CO_2	●	●	
2B2 Chemical Industry	Nitric Acid Production	N_2O	●	●	●
2B3 Chemical Industry	Adipic Acid Production	N_2O	●	●	●
2C3. Aluminium Production		PFCs			●
2C4. SF_6 Used in Aluminium and Magnesium Foundries		SF_6			●
2E. Production of Halocarbons and SF_6	production of HCFC-22	HFCs	●		●
2F. Industrial Processes	Consumption of Halocarbons and SF_6	HFCs		●	●
2F. Industrial Processes	Consumption of Halocarbons and SF_6	SF_6	●		
4A.1. Enteric Fermentation	Dairy Cattle	CH_4	●	●	
4A.1. Enteric Fermentation	Non-Dairy Cattle	CH_4	●	●	●
4B1. Manure Management	Dairy Cattle	CH_4	●	●	
4B1. Manure Management	Non-Dairy Cattle	CH_4	●	●	●
4B8. Manure Management	Swine	CH_4	●	●	●
4D1. Agricultural Soils	Direct Soil Emissions	N_2O	●	●	●
4D3. Agricultural Soils	Indirect Emissions	N_2O		●	
6A1 Managed Waste Disposal on Land	Solid Waste Disposal on Land	CH_4	●	●	●
6B2. Wastewater Handling	Domestic and Commercial Wastewater	CH_4			●

13 ANNEX 2: DETAILED DISCUSSION OF METHODOLOGY AND DATA FOR ESTIMATING CO_2 EMISSIONS FROM FOSSIL FUEL COMBUSTION

13.1 Working Group on Energy Balances, and its most important databases

In the Federal Republic of Germany, energy statistics are published by numerous agencies, and these statistics differ in part in terms of their representation, delimitation and aggregation. Against this background, in the early 1970s, associations of the Germany energy industry, along with economic research institutions, formed the Working Group on Energy Balances (AGEB), aimed at evaluating statistics from all areas of the energy industry on the basis of uniform criteria, combining the data into a well-rounded picture, and making these figures available to the general public in the form of energy balances. The energy balances of the Federal Republic of Germany command a pivotal position in the energy data system by virtue of their structure and conclusiveness. They therefore form the basis for determination of energy-related emissions and for development of scenarios and forecasts of the effects of energy policy and environmental policy measures.

The energy balance is prepared by the Working Group on Energy Balances (AGEB), whose members include energy industry associations and energy industry research institutes. The members of the Working Group on Energy Balances (AGEB) include (as of: May 2002):

- Six energy industry associations
  Bundesverband der deutschen Gas- and Wasserwirtschaft e.V. (BGW) (Association of the German Gas and Water Industry), Bonn
  Deutscher Braunkohlen-Industrie-Verein e.V. (DEBRIV) (German Lignite Industry Association), Cologne,
  Gesamtverband des deutschen Steinkohlenbergbaus (GVSt) (General Association of the German Hard Coal Industry), Essen,
  Mineralölwirtschaftsverband (MWV) (Association of the German Petroleum Industry), Hamburg,
  Verband der Elektrizitätswirtschaft - VDEW - e.V. (Association of German Power Utilities), Frankfurt am Main,
  Verband der Industriellen Energie- and Kraftwirtschaft e.V. (VIK) (Association of Industrial Energy and Power Producers), Essen
- as well as three economic research institutes:
  Deutsches Institut für Wirtschaftsforschung (DIW) (German Institute for Economic Research), Berlin,
  Energiewirtschaftliches Institut an der Universität Köln (EWI) (Institute of Energy Economics at the University of Cologne), Cologne,
  Rheinisch-Westfälisches Institut für Wirtschaftsforschung (RWI) (Rhine-Westphalian Institute for Economic Research), Essen.

Until 1994, energy balances were prepared by the General Association of the German Hard Coal Industry (GVSt) in Essen.

Since the 1995 balance year, overall responsibility for the preparation of energy balances has lain with the German Institute for Economic Research (DIW) in Berlin, although the Association of the German Petroleum Industry (MMW) supplies petroleum data and the other

associations represented in the AGEB check the data, particularly when it refers to their own particular energy resources. Overall, with due regard for the available data, the energy balances provide a reliable picture of energy production and use in the German economy.

The most important sources are listed in Table 91. As they indicate, official (e.g. Federal Statistical Office) and semi-official (e.g. coal industry statistics) reporting plays a key role in this context. However, these sources do not provide all necessary data. For this reason, association statistics are also used.

In a number of categories, furthermore, experts personally provide relevant data – in categories, for example, such as non-energetic consumption by the chemicals industry.

Table 91: Data sources for energy balances (ZIESING et al, 2003)

All energy resources	**Federal Ministry of Economics and Labour** Electricity Industry Department – Annual statistical reports Gas Industry Department – Annual statistical reports **Federal Statistical Office** Annual figures for the manufacturing industry Fachserie (Specialised series) F4 Manufacturing Industry - Series 3.1 Production in the manufacturing industry - Series 4.1.1 Employment, revenue and energy supplies of mining and manufacturing companies - Series 6.4 Power generation facilities of mining and manufacturing companies Fachserie (Specialised series) 7 Foreign Trade - Series 2 Foreign trade by types of goods and countries Selected figures on the energy industry **Association of German Power Utilities (VDEW)** VDEW annual statistics VDEW surveys on the use of renewable energy resources Market research results, company data, calculations by the Working Group on Energy Balances (AGEB)
Hard coal and lignite	**Coal Industry Association statistics** Coal mining in the energy industry of the Federal Republic of Germany – annual reports Coal industry statistics Sales statistics and other unpublished energy statistics
Petroleum	**Federal Office of Economics and Export Control** Official Petroleum Statistics for the Federal Republic of Germany **Mineralölwirtschaftsverband e.V. (MWV) (Association of the German Petroleum Industry)** Petroleum Statistics – Annual Reports **Wirtschaftsverband Erdöl- and Erdgasgewinnung e.V. (Association of the Petroleum and Natural Gas Extraction Industry)** Annual reports **Federal Ministry for Food, Agriculture and Forestry** Diesel consumption by agriculture
Gases	**Federal Statistical Office, Düsseldorf branch** Iron and Steel Statistics: Fuel, Gas and Electricity Statistics **Wirtschaftsverband Erdöl- and Erdgasgewinnung e.V. (Association of the Petroleum and Natural Gas Extraction Industry)** Annual reports **Bundesverband der deutschen Gas- and Wasserwirtschaft e.V. (BGW) (Association of the German Gas and Water Industry) Gas Statistics – Annual Reports** Gas statistics – annual reports **Statistics from the Kohlenwirtschaft e.V. (Coal Industry Association)** Gas Statistics **Deutscher Verband Flüssiggas e.V. (German Liquid Petroleum Gas Association)** The LPG Market – Annual Reports
Other energy resources	**Arbeitsgemeinschaft Fernwärme e.V. (Working Group on District Heating)** District heating reports
"Non-energy resources"	**Mineralölwirtschaftsverband e.V. (MWV) (Association of the German Petroleum Industry)** **Verband der Chemischen Industrie e.V. (VCI) (Chemicals Industry Association)**

13.2 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 (cf. Figure 59). 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 (PROGNOS, 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***, as 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 transformation of one substance into another – 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 generation 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 differentiated in accordance with 12 different types of plants.

Energy Balance until 1994	Line
Primary energy balance	
Domestic production	1
Imports	2
Removals from stocks	3
Domestic energy production	4
Exports	5
Maritime bunkering	6
Additions to stocks	7
Domestic primary energy consumption	**8**
Transformation balance	
Transformation Input	
Coking plants	9
Municipal gas works	10
Hard-coal briquetting plants	11
Lignite briquetting plants	12
Public district heat plants	13
Mine power stations	14
Other industrial thermal power stations	15
Nuclear power stations	16
Hydroelectric power stations	17
Thermal power stations, district heat stations	18
Blast furnaces	19
Refineries	20
Other energy producers	21
Total transformation input	**22**
Transformation Emissions	
Coking plants	23
Municipal gas works	24
Hard-coal briquetting plants	25
Lignite briquetting plants	26
Public district heat plants	27
Mine power stations	28
Other industrial thermal power stations	29
Nuclear power stations	30
Hydroelectric power stations	31
Thermal power stations, district heat stations	32
Blast furnaces	33
Refineries	34
Other energy producers	35
Total transformation emissions	**36**
Consumption in energy production and in transformation sectors	
Hard-coal mines, hard-coal briquetting plants	37
Coking plants	38
Municipal gas works	39
Lignite mines, briquetting plants	40
Power stations	41
Oil and gas production	42
Refineries	43
Other energy producers	44
Total energy consumption in the transformation sector	**45**
Flaring and line losses, evaluation difference	**46**
Domestic energy supply and transformation balance	**47**
Non-energy-related consumption	**48**
Statistical differences	**49**
Energy consumption	
Final energy consumption	**50**
Other mining	51
Non-metallic minerals	52
Iron and steel	53
Iron and steel foundries (including malleable casting)	54
Drawing shops and cold rolling mills	55
Non-ferrous metal products and casting	56
Chemical industry	57
Pulp and paper	58
Rubber processing	59
Other basic materials and producer's goods	60
Basic materials and producer's goods	**51-60**
Machine tools	61
Automotive, aircraft and spacecraft	62
Electrical engineering, precision mechanics, optics	63
Ironware, tinware and metalware	64
Other manufacturing of industrial goods	65
Manufacturing of industrial goods	**61-65**
Glass and fine ceramics	66
Production of plastic products	67
Textiles	68
Other manufacturing of consumables	69
Manufacturing of consumables	**66-69**
Sugar industry	70
Other food industry	71
Drink industry	72
Food and drink industry	**70-72**
Other mining and manufacturing, total	**73**
Railway transport	74
Road transport	75
Air transport	76
Coastal and inland shipping	77
Total transport	**78**
Total households and small consumers	**79**
Military agencies	**80**

Energy Balance of the Federal Republic of Germany as of 1995	Line
Primary energy balance	
Domestic production	1
Imports	2
Removals from stocks	3
Domestic energy production	4
Exports	5
Maritime bunkering	6
Additions to stocks	7
Domestic primary energy consumption	**8**
Transformation balance	
Transformation Input	
Coking plants	9
Hard-coal and lignite briquetting plants	10
Public thermal power stations (not including CHP stations)	11
Industrial thermal power stations	12
Nuclear power stations	13
Hydroelectric power stations, windpower and photovoltaic systems	14
Public CHP stations	15
District heat stations	16
Blast furnaces	17
Refineries	18
Other energy producers	19
Total transformation input	**20**
Transformation Emissions	
Coking plants	21
Hard-coal and lignite briquetting plants	22
Public thermal power stations (not including CHP stations)	23
Industrial thermal power stations	24
Nuclear power stations	25
Hydroelectric power stations, windpower and photovoltaic systems	26
Public CHP stations	27
District heat stations	28
Blast furnaces	29
Refineries	30
Other energy producers	31
Total transformation emissions	**32**
Consumption in energy production and in transformation sectors	
Coking plants	33
Hard-coal mines, hard-coal briquetting plants	34
Lignite mines, briquetting plants	35
Power stations	36
Oil and gas production	37
Refineries	38
Other energy producers	39
Total energy consumption in the transformation sector	**40**
Flaring and line losses	**41**
Domestic energy supply and transformation sector	**42**
Non-energy-related consumption	**43**
Statistical differences	**44**
Energy consumption	
Final energy consumption	**45**
Non-metallic minerals, other mining	46
Food and tobacco	47
Paper	48
Primary chemicals	49
Other chemical industry	50
Rubber and plastic products	51
Glass and ceramics	52
Processing of non-metallic minerals	53
Metal products	54
Non-ferrous metal products and casting	55
Metal processing	56
Machine tools	57
Automotive industry	58
Other industrial sectors	59
Total mining, extraction of non-metallic minerals, manufacturing	**60**
Railway transport	61
Road transport	62
Air transport	63
Coastal and inland shipping	64
Total transport	**65**
Households	66
Commerce, trade, services and other consumers	67
Military agencies	68

Figure 59: Line structure of energy balances until 1994 and as of 1995 (AGEB, 2003)

Non-energy consumption, as a component of the consumption balance, is shown as a total, without allocation to plant 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).

Figure 59 shows the structure of the production and consumption balances in the energy balances until 1994 and as of 1995.

Energy resource structure in energy balances ...

Through 1994	
Hard coal	HC coal
	HC coke
	HC briquettes
	HC raw tar
	HC pitch
	HC other
	Crude benzene
Lignite	L coal
	L briquettes
	L coke
	L dust coal
	Hard lignite
Other solid fuels	Firewood
	Peat
	Sewage sludge
Petroleum	Oil
	Gasoline
	Raw gasoline
	Jet kerosine
	Schw. Flkr. [??]
	Diesel
	Heating oil, light.
	Heating oil, heavy.
	Petrol coke
	Other petroleum products
Gases	LP gas
	Refinery gas
	Coke-oven gas
	Blast-furnace
	Natural gas
	Petroleum gas
	Pit gas
	Landfill gas
Electricity and other energy resources	Electricity
	Hydropower
	Nuclear power
	District heat
	Other energy resources
Total energy resources	Primary energy resources
	Secondary energy resources
	Total

As of 1995	
Hard coal	HC coal
	HC briquettes
	HC coke
	Other HC products
Lignite	L coal
	L briquettes
	Other L products
	Hard lignite
Petroleum	Oil
	Gasoline
	Raw gasoline
	Jet kerosine
	Diesel fuel
	Heating oil, light
	Heating oil, heavy
	Petrol coke
	LP gas
	Refinery gas
	Other petroleum products
Gases	Coke-oven and city gas
	Blast-furn. & converter gas
	Natural gas, petroleum gas
	Pit gas
Renewable energies	Hydropower
	Wind and photovol. systems
	Waste and other biomass
	Other renewable energies
Electricity and other energy resources	Electricity
	Nuclear power
	District heat
Total energy resources	Primary energy resources
	Secondary energy resources
	Total

Figure 60: Fuels in the Energy Balance of the Federal Republic of Germany (ZIESING et al, 2003)

The energy flow in the energy balances is depicted for 30 energy resources. These energy resources may 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, firedamp, excluding landfill gas and the aforementioned gases)
- Renewable energy resources (including waste fuels)
- Electrical power and other energy resources

The main group structure (until 1994 and as of 1995) is shown in Figure 60. Via the "Renewable energies" satellite balance, renewable energies can be further broken down as of 1996 (AGEB 2003).

In the energy balance, energy resources are first listed with their specific units. The so-called *natural units* used are tonnes (t) for solid and liquid fuels, cubic metres (m^3) for gases, kilowatt hours (kWh) for electrical power, 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 or international energy balances, the energy balance lists even gases in terms of calorific value.

13.3 Shifting of statistical differences into the sector "residential, institutional and commercial" (households and small consumers)

The AGEB energy balances, for the old German Länder, and the IfE energy balances, for the new German Länder, are being aggregated for the new energy balances prepared in the framework of the EUROSTAT project (ZIESING et al, 2003) for the year 1990, and for Germany as a whole. In keeping with the system used since 1995, the following change, *inter alia*, has been made in the original balances for 1990 and for the years 1991 to 1994:

The statistical differences listed separately for electrical energy in the energy balances for the old German Länder, until 1994, are now assigned, more properly, to the area "residential, institutional and commercial" ("households and small consumers"; new name: commerce, trade, services).

The statistical differences transferred to the residential, institutional and commercial sector (households and small consumers), in the area of electrical energy, consist of the following values, which are added to the sector's consumption:

Figures in GWh	1990	1991	1992	1993	1994
Allocation of statistical differences in electrical energy to the households sector	8658	13848	14748	16522	18682

13.4 Preparation of provisional energy balances onwards from 1999 by the Federal Environmental Agency

At present, the final energy balances show a backlog of four years compared with the "due" balance year (previous year). In order to meet the requirements of up-to-date emissions reporting, the Federal Environmental Agency has prepared provisional energy balances for the years 2000 to 2003 on the basis of detailed evaluation tables by the Working Group on Energy Balances (AGEB). The ***evaluation tables for the energy balance*** are posted every summer on the homepage of the Working Group on Energy Balances (AGEB), and are thus available to the general public; in each case, they include data for the previous year. However, it should be noted that the data in the evaluation tables, where not directly derived from the final energy balances for previous years, is of a provisional nature.

The *evaluation tables on the energy balance* contain the following information:

- Structure of energy consumption, by source categories
- Primary energy consumption, by energy resources
- Domestic primary energy production, by energy resources
- Total final energy consumption, by energy resources
- Final energy consumption by the rest of the mining and manufacturing sectors, by energy resources
- Final energy consumption by traffic, by energy resources
- Final energy consumption by households, by energy resources
- Final energy consumption by the trade, commerce and services sector, by energy resources
- Final energy consumption by military agencies, by energy resources
- Use of energy resources for power generation.

The Federal Environmental Agency has supplemented the transformation balance for 1999, thereby producing provisional energy balances for the years 2000 to 2003. It has accomplished this by adding key data, arranged by source categories, on primary energy consumption, fuel input for power generation, the domestic energy supply pursuant to the transformation balance (this consists of primary consumption, minus transformation losses and energy consumption in the transformation sector), non-energy-related consumption and final energy consumption.

13.5 Methodological issues: Energy-related activity rates

Essentially, the inventories for air pollutants prepared by the UBA are strictly based on the energy balances for Germany prepared by the Working Group on Energy Balances (AGEB). In some areas, however, the activity rates determined from the energy balance have been supplemented with activity rates from other sources; this is the case, for example, for firewood consumption in the source categories residential, institutional and commercial (trade, commerce, services).

13.5.1 Supplements to the energy balance data

In the area of waste incineration, the Federal Environmental Agency has undertaken an initial supplement to the energy balance data up until 1994.

Lines 11, 15 and 16 of the energy balance (in the version from 1995; in the version valid until 1994, this affects lines 13 and 18) contain data on the use of sewage sludge, waste etc. in public thermal power plants (line 11 in the version from 1995; line 13 in the version valid until 1994), public heat/power plants and district heat plants (lines 15 and 16 in the version from 1995; line 18 in the version valid until 1994).

The Federal Environmental Agency has supplemented this data with its own estimates, based on an evaluation of operator data, on total input of household waste in waste incineration plants. The difference between the overall total calculated in this way, for the use of household waste for the public electricity and district heating supply, and the energy balance data is distributed in proportion to the energy balance data. Up until the year 1994, such supplementation was only carried out for the old *Länder*; for the new *Länder*, the approach was based on the energy balance data excluding any supplements (cf. Table 92).

Table 92: Supplementation of the activity rates for household-waste input in thermal power plants, public heating plants and district heating plants, old *Länder*, 1990-1994, and Germany, 1995-1998

	Public thermal power stations				CHP plants, district heat plants			
	Energy B	CSE			Energy B	CSE		
	l. 13/11	Energy B	Additional	Total	l. 18/15+16	Energy B	Additional	Total
	TJ							
1990	22216	22216	9967	32183	20970	20970	9407	30377
1991	23491	23491	11423	34914	20294	20294	9868	30162
1992	25952	25952	12339	38291	19892	19892	9457	29349
1993	25637	25637	11964	37601	22149	22149	10335	32484
1994	29384	29384	12463	41847	21372	21372	9064	30436
1995	27143	27143	-	27143	9203	9203	-	9203
1996	29233	29233	-	29233	7516	7516	-	7516
1997	32575	32575	-	32575	7730	7730	-	7730
1998	29847	29847	-	29847	12189	12189	-	12189
Remark: from 1990 to 1994, old German Länder; as of 1995, Germany								

Source: Working Group on Energy Balances (AGEB), UBA, calculations by the Öko-Institut

For the period until 1994, inclusion of the additional activity data yields additional CO_2 emissions of about 300,000 t. As of 1995, the currently available data contains no further such supplements (the relevant time series have been established, however).

A similar procedure is adopted for waste incineration in industrial thermal power plants. However, in such cases, supplementation of fuel quantities is linked to a differentiation of fuels for spent sulphite liquor, which is not emissions-relevant in relation to energy-related CO_2 emissions. The basis in such cases consists of figures on total industrial-waste incineration, where such figures are available (DESTATIS, 1991-2004). The input of sewage sludge, waste etc. in industrial thermal power plants recorded in the energy balance (line 15 of energy balances up to 1994, and line 12 in energy balances from 1995 onwards) and in other industrial combustion plants (line 73 in the energy balances up to 1994, and line 60 in energy balances from 1995 onwards) is deducted from this total.

This difference is allocated to the input of spent sulphite liquor in industrial thermal power plants, which must be attributed to heat generation, whilst the quantity of fuel allocated to the use of spent sulphite liquor for electricity generation in industrial thermal power plants is deducted from the total use of sewage sludge, waste etc. reported in the energy balance for industrial heating and power stations (line 15 up to 1994, and line 12 from 1995 onwards).

For the new German Länder, the total input of sewage sludge, waste etc. reported in the energy balance is allocated to the use of industrial waste.

In the current version of the Central System of Emissions, however, this method has not been maintained for the period from 1995 onwards. In such cases, the activity data currently in the system differs substantially from the energy balance data.

Table 93: Supplementation and differentiation of the activity rates for the use of industrial waste and spent sulphite liquor in industrial thermal power plants and other industrial heat producers, old *Länder*, 1990-1994, and Germany, 1995-1998

	Industrial thermal power stations				Industrial heat producers				
	Energy B	CSE			Energy B	CSE			
	L. 15/12	Energy B	Of this, industrial w.	Of this, w.sulphite liq	L. 73/60	Energy B	Of this, industrial w.	Added Industrial w.	Added w. sulph. liq.
	TJ								
1990	31921	31921	28690	3231	0	0	0	0	9655
1991	31344	31344	28257	3087	0	0	0	14677	9259
1992	28157	28157	25164	2993	537	537	537	14763	8977
1993	28041	28041	24683	3358	8852	11149	11149	5918	10073
1994	32290	32290	28890	3400	5661	5661	5661	15612	10000
1995	32918	-	-	-	10472	4155	4155	5559	-
1996	35510	-	-	-	10038	3389	3389	5446	-
1997	37457	-	-	-	10038	2450	2450	4212	-
1998	56442	-	-	-	14254	3820	3820	1212	-
Remarks: from 1990 to 1994, old German Länder, as of 1995, Germany. UBA data for 1993 and as of 1995 requires clarification.									

(AGEB, 2003, UBA, Öko-Institut)

Finally, with regard to the use of waste, combustion in other plants of the transformation sector also deserves mention. From 1993 to 1994, the energy balances for the old *Länder* include data on the use of sewage sludge and waste under "energy consumption in the transformation sector for coke ovens" (line 38 of the energy balance); from 1995 onwards, the corresponding data for Germany is listed under "consumption in energy production and in the transformation sectors for other energy producers" (line 39 of the energy balance).

In the Central System for Emissions (CSE), this is interpreted as the use of plastic wastes. The data previously included in the CSE is consistent with the corresponding energy balance data until 1994, but from 1995 onwards there is a deviation. Here too, there is a need for clarification.

Table 94: Supplementation and differentiation of the activity rates for the use of sewage sludge and waste in the transformation sector for coking plants and in the transformation sectors for other energy producers, old *Länder*, 1990-1994, and Germany, 1995-1998

	1993	1994	1995	1996	1997	1998
	TJ					
Energy Balance (lines 38 and 39)	5540	6212	11511	12969	13707	14080
Data implemented in CSE	5540	6212	11485	10818	8387	14879
Remark: until 1994, old German Länder; as of 1995, Germany						

Source: Working Group on Energy Balances (AGEB), UBA, calculations by the Öko-Institut

The energy balance has also been supplemented (in a second instance) with regard to use of natural gas by compressors in the natural gas network. This is calculated by means of a fixed-rate factor (0.005) that is linked to consumption of natural gas in Germany. The corresponding activity rates until 1994 – for the inventory data analysed in detail to date – are not deducted from the energy consumption data in the transformation sector listed in line 42 or 44 (until 1994). In other words, these are included as additional emissions. For Germany

as a whole, in the first half of the 1990s, this produced annual emissions of approximately 700,000 tonnes of CO_2. From 1995 onwards, the use of natural gas for gas compressors is deducted from the energy balance data; however, there is still a need for clarification vis-à-vis the precise procedure (Ziesing et al., 2003).

13.5.2 Reclassification of energy balance data

A series of reclassifications have been carried out as part of the Federal Environmental Agency's preparation of the inventories. The involve reclassification, between various fuels, and transfers of some fuel inputs to other consumption sectors.

The following reclassifications were carried out:

- Until 1994, use of jet kerosene in the commerce, trade and services sector (energy balance line 79) was allocated to petroleum use in small combustion installations. From 1995 onwards, use of jet kerosene in the trade, commerce and services sector (line 74), which now also includes the military, has been allocated, as a whole, to military air traffic. However, this transfer represents an emissions volume of no more than 30,000 tonnes of CO_2. This reclassification will only be implemented in the Central System for Emissions (CSE).
- Jet kerosene in the transport sector is allocated to international air traffic at a fixed rate of 80 %. This allocation is only implemented in the CSE.

In source-category-specific allocation, only a few additional deviations – that cancel each other out – are to be expected.

13.6 Uncertainties and time-series consistency in the Energy Balance

In an endeavour to ensure that energy balances are always meaningful, it is necessary to make allowance for changes in the underlying statistics, for changes in the energy sector and for changes in requirements of data users. Such changes were made as early as the 1970s. Partly as a result of increasing energy-market liberalisation, and in conjunction with the formation of a single European market, the condition of the statistical energy database (along with that of other data) worsened in that period (Ziesing et al., 2003). By contrast, the Energy Statistics Act, which entered into force in 2003, will have a positive effect.

Energy balances from the year 1950 are available for the Federal Republic of Germany in the territorial delimitation prior to 3 October 1990. Moreover, energy balances have been drawn up for the years 1991 to 1994 separately for the old and new *Länder*, and for Germany as a whole. With the conversion of the official statistics to the classification of industrial sectors (edition 1993, WZ 93), since 1995 only energy balances for Germany as a whole (in the territorial delimitation of 3 October 1990) have been submitted. The most recent energy balance available is for the year 1999.

13.6.1 The balance year 1990 and the energy balances for 1991 to 1994

The base year 1990 plays a key role in national emissions inventories, and it is especially important as a reference year for agreed emissions-reduction targets under climate protection policy. For Germany, admittedly, this is linked to the problem that the country did

not have the same national territorial status throughout the entire year of 1990. Radical changes in the territory of the GDR and the new *Länder*, including profound economic woes and fundamental organisational/structural problems, greatly complicated the process of collecting energy statistics in eastern Germany for 1990. This also had certain repercussions for the old *Länder*, for which the AGEB was still able to prepare and publish balances in the conventional manner (ZIESING et al, 2003).

For the GDR / new German Länder, the Institut für Energetik (IfE) in Leipzig assumed the tasks of preparing an energy balance for 1990 that would be compatible with western German balances and of presenting the pertinent underlying data in detail (IFE, 1991). In this effort, the Institute had access to a study, carried out under the direction of DIW Berlin (German Institute for Economic Research), whose aims included preparing suitable energy balances for the GDR and the years 1970 to 1989 (DIW, 1991).

The AGEB energy balances, for the old German Länder, and the IfE energy balances, for the new German Länder, are being aggregated for the new energy balances prepared in the framework of the EUROSTAT project (ZIESING et al, 2003) for the year 1990, and for Germany as a whole. In keeping with the system in force as of 1995, the changes described below have been made in the original balances for 1990 and for the years 1991 to 1994 (cf. ZIESING et al, 2003).

In keeping with the procedure used by international organisations (IEA, EUROSTAT, ECE), the so-called "efficiency approach" is used, instead of the formerly used "substitution approach", for energy balances for Germany since 1995.

This approach is used for assessment of energy resources for which there is no standardised measure for conversion (such as calorific value). The categories involved include foreign trade in electricity, hydroelectric and wind power, photovoltaic systems and nuclear power.

The statistical differences listed separately for electrical energy in the energy balances for the old German Länder, until 1994, are now assigned, more properly, to the residential, institutional and commercial area (new name: trade, commerce, services) (data in Chapter 13.3).

Due to a lack of relevant data, it was not possible to adapt the differentiation of final energy consumption by source categories in the manufacturing sector, for which the system changed considerably as of 1995 via transition from the production sector system (SYPRO) to the economic-sector classification system (Klassifikation der Wirtschaftszweige), 1993 edition (DESTATIS, 2002c).

The aforementioned changes have been used to revise the energy balances for Germany, and for the old and new German Länder, for all years from 1990 to 1994.

In the view of DIW Berlin, these energy balances may be considered the standard energy-statistical basis for determining energy-relevant CO_2 emissions in Germany.

Starting with the energy balance for 1995, a further series of adjustments became necessary. These essentially concern methodological changes for the evaluation of energy resources in accordance with standard international procedures, for which there is no uniform conversion yardstick such as calorific value, as well as amendments to individual columns (energy resources) and – due to a new system for the branches of industry in the manufacturing

sector (WZ 93) – lines (source categories) in the energy balance matrix. Moreover, from 1995 onwards, energy balances were only submitted for the Federal Republic of Germany as a whole, since the database no longer permits consistently separate representation for the old and new *Länder*. The structures of energy balances until 1994, and as of 1995, are shown in **Fehler! Verweisquelle konnte nicht gefunden werden.** and Figure 60.

13.7 Documentation of data for the BEU Module

Data documentation is carried out downstream from the BEU-module process (for structure, cf. Table 10 to Table 16). Such documentation is divided into four steps:

- Description of the sector, and provision of a list of literature references
- Compilation of data from the energy balance and from additional sources, with citing of relevant sources
- Data supplementation and evaluation
- Definition of model data

All four work steps are divided in accordance with the source categories within the BEU structure.

In the first step, the relevant sector is described – for example, via provision of production data and the sector's importance within the energy balance. Any special statistical aspects are noted, and origins of the pertinent data are precisely cited.

Data evaluation takes place in the second step (data library). In addition to fuel inputs, data for other source-category-specific, energy-related characteristics (survey aspects) is included in the evaluation. Such data includes, for example, thermal combustion output, emissions, electrical output, power generation and steam generating capacity of power-station boilers. In individual cases, other data is included as well, if it supports conclusions regarding energy input and generation – for example, production data. The data is then prepared in time-series form. On this level, bases for source-specific recalculations are also documented.

In the third step (supplementation and evaluation),

- Uncertainties and time-series consistency are studied, and
- Source-specific quality assurance / control and verification are carried out.

These studies apply to all survey characteristics contained in the data library. The processes of selection of a form for time-series presentation, inclusion of data from various different sources and consideration of other survey characteristics all provide opportunities to check data consistency and quality:

- Time-series presentation makes it possible to identify data items that don't fit within the overall pattern,
- Via comparison of data with similar survey characteristics, but from different sources, sources can be confirmed, rejected or corrected,
- Via addition of data with other survey characteristics, plausibility of unusual data items can be checked (for example, comparison of power generation and fuel input),
- Linking with data with other survey characteristics (such as derivation of efficiencies, determination of fuel inputs from thermal combustion output and their use over time) makes it possible to replace data and close gaps as necessary,
- Enquiries of plant operators can be carried out in order to supplement or correct data,

- Comparison of data with different survey characteristics makes it possible to determine whether data for a certain year, or survey characteristics within a time series (such as older characteristics), always covers the same group of plants (for example, the emissions for a given plant may be listed, but the relevant fuel input is lacking).

These review options cannot be generally formalised. The question of which options can be used depends on the individual case in question and the available data. Any reviews and evaluations are referred to in the documentation.

This evaluation provides the basis for the fourth step, selection of model data. Data for all surveyed characteristics, assessed as sufficiently reliable, is compiled and then combined in the model with data of other source categories / sub-sectors. In the model, the data is linked with the energy balance, and the fuel inputs are entered in the BEU module. The BEU module, and the data for other survey characteristics, provide the basis for forecasts and scenarios regarding the impacts of emissions-reduction measures.

To date, documentation has been carried out for the lignite mining sector. This documentation covers the period 1992 – 1999.

13.7.1 Lignite mining

13.7.1.1 Description of the sector

In 2002, a total of 175.4 Mt of crude lignite were mined in the German lignite mining sector. Lignite mining is carried out in 6 districts (Reviere), with the following production quantities:

Rhineland	94,349	kt
Helmstedt	4,073	kt
Hesse	165	kt
Bavaria	59	kt
Lausatia (Lausitz)	57,503	kt
Central Germany (Mitteldeutschland)	19,215	kt

Of this quantity of mined crude lignite, a total of 153.2 Mt (91%) was converted into electrical power in public thermal power stations.

The lignite mining sector's activities, in addition to mining crude lignite, include producing products from lignite. In 2002, more than 5 Mt of lignite products were produced:

- Lignite briquettes 1.740 Mt
- Dust coal, dry coal and fluidised bed coal 3.222 Mt
- Lignite coke 0.177 Mt

Crude lignite is processed in lignite briquetting plants. Lignite briquetting plants are operated in the Rhineland, Lausatia and central German districts.

In order to meet their own energy demands, briquetting plants operate their own mine power stations. At present, such mine power stations have an electrical output of about 400 MW, and they generate some 2000 GWh of electrical energy. In addition, as combined heat/power generating systems, they generate process steam that is used to dry crude lignite in coal processing.

The briquetting plants in the Lausatia and Mitteldeutschland (central Germany) districts no longer operate their own mine power stations. The remaining briquetting plants obtain electrical power and process steam either from power stations that were integrated within the public grid in 1994 or from new power stations that have come on line (public grid) since 1998. In energy statistics, these power stations are listed as part of the public grid.

In lignite mining, combustion-related emissions occur through operation of:

- Mine power stations, with fuel inputs for generation of electricity and heat
- Other heat generators needed for operation of lignite mines and briquetting plants

The Energy Balance for the Federal Republic of Germany does not have a separate balance line for mine power stations. Until 1994, fuel inputs for electricity generation, by power stations in the hard-coal mining sector, were summarised in line 14, under the heading "Mine and mine-pit power stations" ("Zechen- und Grubenkraftwerke").

Until that year, it was not difficult to separate fuel inputs in line 14 by hard-coal and lignite mining. Since no mine power stations are operated in the new German Länder, line 14 includes only the fuel inputs for mine-pit (Grube) power stations. In the old German Länder, only crude lignite was used in mine-pit power stations, and thus it was possible to assign the remaining fuel inputs to mine (Zeche) power stations.

In early 1995, when the new economic-sector system (WZ 93) was introduced, mine (Zeche and Grube) power stations were combined with other industrial power stations (includes power stations in the sector "Production of non-metallic minerals, other mining and production", power stations of oil refineries and power stations of Deutsche Bahn AG), in line 12 "Industrial thermal power stations". In addition, the new system did not make a distinction between the old and new German Länder.

Mine-pit (Grube) power stations, in contrast to other industrial power stations, have a special position with regard to allocation of fuel inputs for heat generation. As of balance year 1980, in the energy balance this fuel input is no longer allocated to the own consumption of lignite pits and briguetting plants (until 1994, line 40, as of 1995, line 35). Since then, it has been combined with raw-material input, for transformation, of lignite briquetting plants (until 1994, line 12; as of 1995, line 10, "Hard-coal and lignite briquetting plants". Unlike inputs for transformation (crude lignite that is dried and then processed into products), these quantities are burned and produce emissions. For this reason, they must be calculated out of the transformation input.

For it to be possible to continue to identify lignite mining as a source category, and to update its energy data, additional statistics and information have to be evaluated.

The following compilation shows these additional sources, along with the energy balance. The evaluated data has been combined, in the data library, in time-series form. The short-form names of the sources are used.

13.7.1.1.1 Remarks on data sources

GDR Statistics 1989:

The former GDR kept detailed statistics on power stations from 1970 to 1989. These documents were not available to the general public.

These statistics contain information about all of the GDR's power stations, broken down by economic sectors. They include detailed information about equipment (for example, numbers of steam boilers, along with their dates of production and steam generating capacity; numbers and routed outputs of turbines and generators), fuels used and generation of electricity, process heat and district heat.

The 1989 statistics were evaluated for the lignite mining sector, with regard to generator performance and steam generating capacity. Taking into account the dates on which these plants were decommissioned (cf. the source Directive 88/609/EEC), it was possible to extrapolate the above figures, approximately, until 1999 and to use them for sector differentiation and plausibility checks.

DEBRIV, 2003a
In 1993, the Federal Environmental Agency, working from considerations of thermodynamics, derived a procedure for determining use of crude lignite products, in drying of crude lignite, from produced quantities of lignite products. Operators of briquetting plants then used this procedure, on the basis of their specific circumstances (for example, moisture content of crude lignite and products, plants' efficiency coefficients), to determine energy consumption factors. DEBRIV also prepared findings and transmitted the findings with the aforementioned letter.

DEBRIV, 2003b
This source was compiled by the Association of the German lignite industry (Dachverband der deutschen Braunkohlenindustrie - DEBRIV), on the basis of data provided by member companies for the period 1992 to 2001. Along with data on public lignite power stations, this source also provides information about mine-pit (Grube) power stations.

For the new German Länder, and for the aforementioned period, the source provides information on rated electrical output, electricity generation and fuel input in electricity generation. The figures on fuel inputs for heat generation in these plants are incomplete and were not adopted.

The data has been aggregated into two operator groups. In the course of the period in question, the operator groups were repeatedly restructured and renamed. For this reason, the chronological development of survey characteristics for this sector can be derived only by summing over the operator groups.

For the old German Länder, data on mine-pit (Grube) power stations is included only for the years 1998 and 1999.

DEBRIV o. J.
This report series presents the activities of the lignite industry. It contains overviews and tables with figures on lignite production, product production, lignite input in power stations, the stations' electrical output and the stations' expected development. This source can be used to close gaps in data and to confirm some data from other sources.

Jahrbuch Bergbau 1994-2004
Chapter 1.2 "Braunkohle" (Lignite) of this yearbook presents reports of lignite-industry companies, with relevant data. From this data, time series – for example, on power generation of pit power stations in the Rhineland – and quantity data on lignite products, by companies and regions, have been compiled for the data library.

LAUBAG 2002
The LAUBAG letters are the results of a study on mine-pit power stations in the Lausitz district. From these letters, additional information was gleaned, especially information on the old power station "Schwarze Pumpe", that supplemented information from other sources.

RHEINBRAUN
The information consists of an excerpt, prepared by the company, from emissions declarations submitted in the framework of compliance with the German Ordinance on large combustion plants (Großfeuerungsanlagen-Verordnung – 13th. BImSchV). This information complements the information in the source Directive 88/609/EEC.

Directive 88/609/EEC
This is the EU Directive on large combustion plants. This directive requires Member States to provide information, at two-year intervals, on progress in reducing emissions from large combustion plants. Information is requested on thermal output of combustion, as well as on SO_2 and NO_X emissions. The old German Länder have been subject to reporting obligations since 1990, while the new German Länder have been so subject since 1992.

In Germany, Länder immission-control authorities compile data for their areas of responsibility and provide it to the Federal Environmental Agency. The Federal Environmental Agency aggregates the data at the federal level and reports the result to the EU.

Information provided by the Länder in addition to requested information varies greatly in structure. Such information includes details about the operator, the type of plant in question (power station, combustion plant), the relevant economic sector, the location and the fuels used. Because such information varies in structure and comprehensiveness, it is not possible to compile an overview for all of Germany based on such characteristics. For some source categories, such an overview can be prepared through addition of other statistics or through enquiries directed to supervisory authorities and operators. This is the case for the lignite mining sector. The relevant emissions data varies in quality. A distinction must be made between annual data updating on the basis of emissions declarations and annual data updating on the basis of information regarding the relevant previous years. Information of the latter sort can normally be recognised in that its data remains unchanged over certain periods of time.

The Federal Environmental Agency's data compilation for mine-pit (Grube) power stations is oriented, initially, to the former GDR's division of its lignite mining sector into collective combines (Kombinaten); for later periods, the compilation is oriented to the companies that emerged from such combines. The compilation also includes dates of plant decommissioning. Decommissioning dates are used in order to update data, for the entire group of plants in question, with regard to trends for other survey characteristics (such as electrical output).

Federal Statistical Office (DESTATIS, Fachserie 4 Reihe 6.4, 1991-2004)
The Federal Statistical Office also collects energy data within the framework of its official statistics on the manufacturing sector. This data is published, inter alia, in Fachserie (specialised series) 4, Reihe (series) 6.4, power-generation plants of mining and manufacturing companies.

VIK

The Association of the Energy and Power Generation Industry (VIK) has compiled time series from the Federal Statistical Office's annual reports. These time series are incorporated within the data library for the lignite mining sector (electrical output, steam generating capacity, electrical work and fuel input for power generation in the lignite mining sector).

13.7.1.2 Electrical output of mine-pit power stations

For statistical purposes, electrical output is the characteristic value for describing an economic sector's power stations. Formerly, statistics listed gross bottleneck output (Bruttoengpassleistung). Increasingly, plant operators have been recording and reporting their plants' net bottleneck output, and thus statistics include a mixture of both types of figures. This fact hampers statistical comparisons and time-series analysis.

For mine-pit power stations, data of the Federal Statistical Office (old and new German Länder, separate until 1994 and combined for all Germany as of 1995) and data in DEBRIV 2001 has been evaluated. Furthermore, the former GDR's power-station statistics (DDR-Statistik, 1989) for 1989 were included, and extrapolated.

Comparisons with the two other sets of statistics make it possible to delimit the sector and to categorise plants by districts (Reviere).

Such extrapolation was carried out on the basis of the decommissioning dates pursuant to Directive 88/609 EEC and of other information on reassignment of power stations (for example, to the public sector). The resulting extrapolation is presented in the outline of GDR statistics, by collective combines, in Tables II 1.5.4.1 to II 1.5.4.3, and it is summarised in II 1.5.4.4.

In Table II 1.5.1, locations of power stations have been allocated to the Mitteldeutschland (central Germany) and Lausatia districts. Power stations of the former Senftenberg lignite collective combine are allocated to the Lausatia district, while power stations of the former Bitterfeld lignite collective combine are allocated to the Mitteldeutschland district. The Lausatia district, except for the power stations in Espenhain, includes all plants of the former Schwarze Pumpe gas combine.

Table II 1.5.1 shows this reorganisation, and in Table II 1.5.2, these districts are completed through addition of the Rhineland district.

These figures are compared to the aggregated data of the Federal Statistical Office (Table II 1.5.3). In preparation of the Table, an effort was made to determine what locations the Federal Statistical Office did not include and which it included additionally (greyed out until 1994). Direct comparison of the data for the new German Länder is possible only until 1994. The figures yield a good approximation to the data of the Federal Statistical Office.

Table 95: Data availability for various power stations

Power station	Federal Statistical Office (II 1.5.3)	DEBRIV (II 1.5.7)	Federal Environmental Agency (II 1.5.8)
Brieske	Missing value for 1997	Continuous time series, no value for 1997	Continuous time series until 1998
Sonne	Additional value for 1998	Time series until 1996	Time series until 1996
Schwarze Pumpe 1	No values for 1992 and 1997	Continuous time series from 1992 to 1997 (i.e. listed as a mine-mine-pit power station)	Continuous time series from 1992 to 1997
Schwarze Pumpe 3	No data for 1992, 1993, 1995, 1997	Value available only for 1994	Not a mine-pit power station
Schwarze Pumpe 4	No values for 1993-1995, but there is a value for 1996	Value available only for 1994	Not a mine-pit power station
Amsdorf	Data for 1995 and 1997 is lacking	Data for 1995, 1996 and 1997 is lacking	Continuous time series from 1992 to 1999

Direct comparison with the extrapolated data as of 1995 is not possible, since the Federal Statistical Office only provides figures for Germany. Nonetheless, it is possible to determine what locations in the new German Länder were surveyed, or additional included, in the time series for Germany (grey background as of 1995), as well as approximately what data for the Rhineland district the data of the Federal Statistical Office is based on. It must be remembered that the basic statistical data for the Rhineland is known:

- Listed for 1990 to 1994 (old German Länder)
- Data for 2000 and 2001 is identical with the data for Germany (plants in the new German Länder were decommissioned or were no longer classified with the mine-pit power stations)

This basic data indicates that plants in the old German Länder, as a whole, had relatively constant electrical output. This is confirmed in that the gross bottleneck output in the Rhineland district is 386 MW for the entire period (the net output does not remain constant, even in cases in which the plant itself does not change). If, as of 1995, one subtracts the sum for the various locations from the figures for Germany, then a plausible time series results for the Rheinland district (cf. Table II 1.5.3, 2nd line).

The same approach was carried out with the figures in DEBRIV 2001 (Tab. II 1.5.6).

For Table II 1.5.7, an attempt was made to determine what locations DEBRIV does not include, in comparison to our extrapolation (this was not possible for 1994, since DEBRIV lists electrical output incompletely).

From the two comparisons, the conclusions can be drawn, with respect to the original extrapolation pursuant to Table II 1.5.1, that the Schwarze Pumpe 3 and 4 power stations have not been counted among the mine-pit power stations, and that the Amsdorf power station also has not been counted as part of this sector as of 1999.

The extrapolation was modified in keeping with these conclusions (II 1.5.8).

Tab. II 1.5.9 shows trends in electrical output of mine-pit power stations, by districts, in Germany.

13.7.1.3 Power generation (electrical work) in mine-pit power stations

Longer time series for electrical work in mine-pit power stations can be derived from data of

- Federal Statistical Office (DESTATIS)
- DEBRIV, 2003b
- "Bergbau, Energie" ("mining, energy") Yearbook

Time series for the old and new German Länder until 1994, and for Germany as of 1995, can be derived from publications of the Federal Statistical Office.

DEBRIV 2003b reports on the new German Länder from 1992 to 2001, and the "Bergbau und Energie" yearbook fills in all the data gaps for the period 1992 to 2001, for the old German Länder.

Table II 1.6.1 presents the data of the Federal Statistical Office and the time series, based on the yearbook, for the old German Länder. For the comparison period 1992 to 1994, the figures from both sources are identical for the old German Länder (cf. Table 1.6.1.1 and 1.6.6.4). In II 1.6.1, the Federal Statistical Office's time series for the new German Länder was added in the form of a difference to the data for Germany; this was made possible via completion of the time series for the old German Länder, for the period 1995 to 2001.

A comparison of this addition with the data for the new German Länder pursuant to DEBRIV is shown in Table II 1.6.2. Following initial good agreement, the data sets begin to diverge in later periods. The discrepancies are a result of the gaps found in both sources. The two sources can be harmonised well using the individual-plant data in the data library.

For example, the data of the Federal Statistical Office does not include the Amsdorf power stations as of 1996; furthermore, it categorises the Deuben power station inconsistently and in 1998 it does not include the Brieske power station (cf. Table II 1.6.3), while the DEBRIV data does not include the Schwarze Pumpe power station in 1998 (cf. Table II 1.6.4). When such gaps are filled in in both sets of statistics, the statistics agree nearly completely. The resulting agreement has been incorporated within Table II 1.6.5. It shows power generation in the old and new German Länder, and in Germany as a whole, until 2001.

13.7.1.4 Fuel consumption in mine-pit power stations

The following remarks refer to

- Fuel input for power generation
- Fuel input for heat generation (drying of crude lignite)
- Total fuel input

In Germany, mine-pit power stations are operated in the Rhineland (old German Länder), Lausatia (new German Länder) and Central Germany (new German Länder) districts.

An important aspect is to break down fuel inputs in accordance with these districts, since the districts must be differentiated by emission factors, due to variations in their fuel characteristics (e.g. carbon content, sulphur content, water content and net calorific value).

13.7.1.4.1 Fuel consumption for power generation

Data on fuel inputs for power generation are compiled in the data library. The most important sources include:

- AGEB (old and new German Länder), until 1994
- Federal Statistical Office (old and new German Länder until 1994, and Germany as of 1995)
- DEBRIV (new German Länder), until 2001

The first result of these evaluations is shown in Table II 1.7.5, which summarises the relevant comparison and evaluation of the various statistics and literature information.

Specifically:

1) Tab. II 1.7.1 (for the old German Länder) and II 1.7.2 (for the new German Länder) show the comparison between Federal Statistical Office and AGEB data until 1994.
   For the old German Länder, the two sources are identical; for the new German Länder, comparison is possible only for 1994. This comparison shows good agreement.
   For the new German Länder, DEBRIV (pursuant to Table II 1.7.2.5) was included in this comparison (II 1.7.2).
   For 1992 and 1993, the DEBRIV data show minor discrepancies with the Energy Balance; for 1994, they deviate more strongly from the Energy Balance. On the basis of their good agreement with Federal Statistical Office data, and of their completeness, the AGEB data for the period 1992 to 1994 are included in Table II 1.7.5.

2) As of 1995, the Federal Statistical Office data for Germany, pursuant to Table 1.7.1.1, and the results pursuant to DEBRIV (Table II 1.7.2.5), for the new German Länder, are combined.
   The difference between the two data sets is an estimate of the fuel input for the old German Länder (Table 1.7.3). Apart from the years 1998 and 1999, this estimate fits well in the known data for the period 1992 to 1994, and for the period as of 2000, for Germany (since that year: Germany = old German Länder). Since power generation for 1998 and 1999 in these plants (cf. Table II 1.6.5) shows no unusual features, the estimate for these years is rejected and replaced with DEBRIV data (Table II 1.7.1.2). In addition, the last plants still in operation in the new German Länder, in 1998 and 1999, can be identified from data of Federal Statistical Office and DEBRIV (Table II 1.7.4).
   When the DEBRIV data for the old German Länder is added, calculations produce the fuel inputs shown in Table II 1.7.4. Together with figures in Table II 1.7.3 (except for those for 1998 and 1999), the data was included in Table II 1.7.5.

3) Table II 1.7.5 includes a first breakdown of fuel inputs by districts (Reviere). With decommissioning of mine-pit power stations in the Central Germany district in 1996, the data for the new German Länder, as of 1997, is identical with that for the Lausatia district. The time series for the Lausatia district ends with the decommissioning of the last mine-pit power station in 1999.

Tables II 1.7.7 and II 1.7.8 provide a differentiated presentation of the fuel inputs shown in Table II 1.7.5. Until 1994, AGEB figures for lignite were used; as of 1995, the DEBRIV figures for lignite were used.

For other fuels, as of 1995 data of the Federal Statistical Office is used to complete the time series after 1994. It should be noted that the figures for Germany apply to the new German Länder, since only crude lignite was used in the old German Länder.

13.7.1.4.2 Fuel consumption for heat generation (drying of crude lignite)

Table II-1.8.2 shows fuel input for production, in the Rhineland district, of products from crude lignite; it is broken down by products. This table is the result of calculation with the production data in Table I 1.15.6.1 and the specific energy consumption for production (per tonne of these products; Table 1.15.2.1).

Tables II-1.8.3 and II-1.8.4 list the data for the Lausatia and Central Germany districts. As of 1995, an additional breakdown by manufacturers of lignite products is carried out for the Central Germany district. This breakdown is necessary, since the MIBRAG power stations have been part of the public grid since 1995 and their fuel inputs for heat generation must be assigned to the public district heating network. For the firm of ROMONTA, which opreates the Amsdorf power station, production of small quantities of other lignite is only a by-product of mineral-wax production, which requires most of the process steam used by the company.

The specific fuel inputs for mineral-wax production are not known; as a result, they have to be disregarded here.

Statistically, fuel inputs of other operators must be classified as part of briquetting plants' own consumption.

Table II-1.8.1 summarises fuel inputs for lignite drying, by products.

13.7.1.4.3 Fuel consumption for heat and power generation, by districts

Table II 1.7.10 summarises the results to date on lignite input in power stations in the new German Länder. Lignite inputs for heat generation have already been broken down by districts. Such a breakdown remains to be carried out for power generation.

To this end, the following approximation was used:
From the quotient of a) the entire fuel input in the new German Länder and b) the thermal output from combustion in power stations (Table II 1.1.3), the duration of utilisation of the thermal output from combustion is determined. The thermal outputs from combustion, in the Lausatia and Central Germany districts, are multiplied by this duration of utilisation. This approach is based on the assumption that the utilisation duration is the same in both districts. The result, in each case, is the district's total fuel input. The fuel input for heat generation is then deducted from this total fuel input. The difference is the fuel input for power generation, by district.

The fuel input for power generation, as shown in Table II 1.7.8, consists of crude lignite and lignite products. Lignite products have also been broken down by districts.
This is done on the basis of the districts' production data (Table 1.15.6.2 and 1.15.6.3). In Table II 1.6.20, the product shares for the various districts are shown. These quotients are used to break products down by districts (results shown in Tables II 1.7.21 and II 1.7.22). Table II 1.7.23 also includes these results for the Rhineland district.

The other energy resources are not broken down by districts (Table II 1.7.24).

For fuel inputs for heat generation in the Lausatia and Central Germany districts, it is assumed that only crude lignite is used (Tables II 1.7.25 and II 1.7.26). This assumption holds for the Rhineland district (Table II 1.7.27).

Tables II 1.7.29 and II 1.7.30 present the relevant results, broken down by fuel input for electricity and power generation and by districts.

Tables II 1.7.31 through II 1.7.33 present fuel inputs for electricity and heat generation, for purposes of further calculation (emission factors.

13.7.1.4.4 Planned improvements

In drying of lignite, part of each quantity of lignite is burned (emissions-relevant use for energy recovery) in order to dry the other part (substance recycling, no combustion, no CO_2 emissions). Previously, statistics listed the entire mass flow for crude lignite, with the result that the emissions-causing portion of the flow had to be calculated before activity rates – for emissions calculation – could be calculated.

The procedure that the Federal Environmental Agency has used to date – and that is still used in the present inventory report – is currently being modified. Correction of the base year, on the basis of a new calculation method, from 17 million tonnes (the figure currently used) to 15 million tonnes, is being discussed. Relevant consultations of the national group of experts will be completed in May 2004. Correction of the activity rates would affect the entire time series from 1990 to 2002 – including, especially, the base year, 1990.

13.7.1.5 Thermal output from combustion, SO_2 and NO_X emissions from mine-pit power stations

In immission-control law, the thermal outputs of combustion plants fired with standard types of fuels are the key criteria used for classifying plants (subject to licensing requirements, not subject to licensing requirements); such thermal outputs are also the key criteria used for defining graduated scales of standards, in legal ordinances and administrative provisions pursuant to the Federal Immission Control Act (BImSchV).

Where data on fuel inputs is lacking or is unreliable, thermal output from combustion, linked with its use over time, is an important figure for determining or estimating fuel inputs and for checking plausibility of fuel-input data.

In energy balance structures, thermal output from combustion is an important structural element for allocating sub-quantities of listed fuel inputs, for delimiting inputs from those of other plants of a given industrial sector and for representing emissions time series. In this light, the thermal output from combustion was used in preparation of the Balance of Emissions Causes (Bilanz der Emissionsursachen - BEU).

In Germany, plants' thermal output from combustion is not recorded in statistics. The data for large combustion plants used here comes from compilations relative to EU Member States' reporting obligations under Directive 88/609/EEC on large combustion plants. This directive requires Member States to provide information, at two-year intervals, on progress in reducing emissions from large combustion plants, and to report such information to the EU. The information obligations include data on thermal output from combustion and on SO_2 and NO_X emissions. For Germany, these obligations have been in force since 1990 (old German Länder) and since 1992 (new German Länder).

In Germany, Länder immission-control authorities compile data for their areas of responsibility and provide it to the Federal Environmental Agency. The Federal Environmental Agency processes the relevant documents and reports the results to the EU.

Information provided by the Länder in addition to requested information varies greatly in structure. Such additional information, which varies in composition and completeness, includes information on the plant operator, the type of plant in question (for example, power stations, district heating plants, industrial combustion plants), the plant's location, the relevant industrial sector and the fuels used. Due to the structural and content differences in such information, it is not possible to use it to prepare a standardised, complete compilation for all of Germany. With additional effort, it is usually possible to classify the plants by sectors.

The relevant emissions data varies in quality. A distinction must be made between annual use of data from plant operators' emissions declarations and updating/extrapolation on the basis of data provided in earlier years. The latter type of data can be recognised in that it exhibits data constancy over certain time periods. The quality of data can be evaluated during further processing (for example, plausibility of emission factors, in terms of their levels and development over time).

The Federal Environmental Agency's data compilation for mine-pit (Grube) power stations in the new German Länder is oriented, initially, to the former GDR's division of its lignite mining sector into collective energy combines (Kombinaten); for later periods, the compilation is oriented to the companies that emerged from such combines. The compilation also contains dates for decommissioning of plants, with the result that other characteristics of the total group of plants in question (such as electrical output) can also be determined.

Table II 1.1.1 provides a compilation, from the data library, relative to thermal output from combustion. Table II 1.1.2 takes account of reallocation of plants into the public grid and of transfers into (regional) districts. For purposes of further calculations relative to fuel inputs, the relevant output percentages are determined for the decommissioning years in question (Table II 1.1.3), and Table II 1.1.4 summarises the decommissioning data.
The relevant SO_2 and NO_X emissions are shown in Tables II 1.2.1 and II 1.2.2 and in Tables II 1.3.1 and II 1.3.2.

13.7.1.6 Compilation of model data (last revision: 31 January 2004)

II-1.5.9 Electrical output of mine-pit power stations in Germany: New definition of districts and corrected extrapolation of the former GDR's statistics (own calculations)

II-1.6.5 Power generation in mine-pit power stations in Germany (own calculation)

II-1.7.29 Fuel input for power generation in mine-pit power stations in Germany (own calculation)

II-1.7.30 Fuel input for heat generation in mine-pit power stations in Germany (own calculation)

II-1.1.5 Thermal output from combustion in mine-pit power stations in Germany (own calculation, last revised 31 December of the relevant year)

II-1.2.1 SO_2 emissions generation in mine-pit power stations in Germany (own calculation)

II-1.2.2 SO_2 emission in mine-pit power stations in Germany, taking reallocations into other source categories into account (own calculation)

II-1.3.1 NO_x emissions generation in mine-pit power stations in Germany (own calculation)

II-1.3.2 NO_x emission in mine-pit power stations in Germany, taking reallocations into other source categories into account (own calculation)

II-1.5.9 Electrical output of mine-pit power stations in Germany: New definition of districts and corrected extrapolation of GDR statistics (own calculations)

		1992	1993	1994	1995	1996	1997	1998	1999	2000
Total	MW	2.434	2.411	2.041	1.767	1.104	1.081	525	410	360
Rheinland (Tab. II-1.5.3)	MW	371	377	358	352	362	386	380	365	360
Lausitz (new definition)	MW	1.278	1.278	1.195	1.166	716	650	100	0	0
Mitteldeutschland (new definition)	MW	785	756	489	249	26	45	45	45	0

Sources:
Table II-1.5.3 (Rheinland) and II-1.5.8 (Lausitz, Mitteldeutschland)
Remark:

II-1.6.5 Power generation in mine-pit power stations in Germany (own calculation)

		1992	1993	1994	1995	1996	1997	1998	1999	2000
Germany	GWh	10.292	9.533	8.888	7.224	5.559	4.361	3.536	2.297	2.063
Old German Länder	GWh	1.958	2.057	2.029	1.947	2.191	2.206	2.126	2.064	2.063
New German Länder	GWh	8.334	7.476	6.859	5.277	3.368	2.155	1.410	233	0

Sources
NGL (1992-2001) pursuant to F. Stat. Office as in Tab. II-1.6.3
OGL (1992-2001) pursuant to F. Stat. Office as in Tab. II-1.6.1

II-1.7.29 Fuel input for power generation in mine-pit power stations in Germany (own calculation)

		1992	1993	1994	1995	1996	1997	1998	1999	2000
Total	TJ	116.163	109.514	96.668	84.253	62.905	47.057	37.414	21.425	17.324
Crude lignite, Rheinland district	TJ	14.590	15.819	15.537	16.645	16.706	17.654	18.570	18.092	17.324
Raw lignite, Lausitz district	TJ	57.489	52.022	37.914	40.497	28.720	23.483	15.890	875	0
Raw lignite, Mitteldeutschland district	TJ	23.529	27.727	27.262	13.030	9.082	4.166	2.955	2.459	0
Lignite briquettes, Lausitz district	TJ	0	0	0	73	36	0	0	0	0
Dry coal and coal dust, Lausitz district	TJ	3.798	3.977	8.955	4.459	1.544	0	0	0	0
Dry coal and coal dust, Mitteldeutschland district	TJ	15.300	8.269	4.914	5.829	952	0	0	0	0
Heavy heating oil, NGL, total	TJ	82	41	41	34	3	3	0	0	0
Coke-oven and city gas, NGL, total	TJ	0	0	0	2.090	2.933	993	0	0	0
Natural gas, NGL, total	TJ	32	32	32	20	1.759	3	0	0	0
Sewage sludge and waste, NGL, total	TJ	1.343	1.627	2.013	1.576	1.170	755	0	0	0

Source:
Tables II-1.7.21, II-1.7.22, II-1.7.23, II-1.7.24
Remark: Lausitz and Mitteldeutschland have been redefined in Table II-1.1.1
Remark: the term "sewage sludge, waste" has been taken from the Energy Balance. In lignite power stations in the new German Länder, this refers to residues from lignite processing: carbonising, gasification, and abrasion in product manufacturing.

II-1.7.30 Fuel input for heat generation in mine-pit power stations in Germany (own calculation)

		1992	1993	1994	1995	1996	1997	1998	1999	2000
insgesamt	TJ	52.425	43.903	31.767	26.009	24.694	20.480	16.452	15.490	12.139
Crude lignite, Rheinland district	TJ	18.175	17.107	15.720	14.817	14.893	14.161	12.526	11.660	12.139
Raw lignite, Lausitz district	TJ	20.231	16.807	12.771	9.485	9.083	6.319	3.926	3.830	0
Raw lignite, Mitteldeutschland district	TJ	14.018	9.989	3.276	1.707	718	0	0	0	0
Lignite briquettes, Lausitz district	TJ									
Dry coal and coal dust, Lausitz district	TJ									
Dry coal and coal dust, Mitteldeutschland district	TJ									
Heavy heating oil, NGL, total	TJ									
Coke-oven and city gas, NGL, total	TJ									
Natural gas, NGL, total	TJ									
Sewage sludge and waste, NGL, total	TJ									

Source:
Tables II-1.7.25, II-1.7.26, II-1.7.27
Remark: Lausitz and Mitteldeutschland have been redefined in Table II-1.1.1
Remark: the term "sewage sludge, waste" has been taken from the Energy Balance. In lignite power stations in the new German Länder, this refers to residues from lignite processing: carbonising, gasification, and abrasion in product manufacturing.

II-1.1.5 Thermal output from combustion of mine-pit power stations in Germany (own calculation, last revision 31 December)

		1992	1993	1994	1995	1996	1997	1998	1999	2000
Total	MW	12.935	12.701	10.777	6.480	4.071	3.642	1.890	1.496	1.496
Lausitz (new definition)	MW									
Mitteldeutschland (new definition)	MW									
Rheinland	MW									

Sources:
Table II-1.1.2 and 1.1.8.2
Remark:
Division of "Schwarz Pumpe" gas combine: Espenhain power station went to Mitteldeutschland district, all other power stations went to Lausitz district
Rheinland assumed to be constant as of 1996

II-1.2.1 SO_2 emissions in mine-pit power stations in Germany (own calculation)

		1992	1993	1994	1995	1996	1997	1998	1999	2000
Total	t/a	359.138	338.421	258.291	177.290	131.606	k.A	k.A	k.A	k.A
Lausitz district (new definition)	t/a									
Mitteldeutschland district (new definition)	t/a									
Rheinland district	t/a									

II-1.2.2 SO_2 Emissions in mine-pit power stations in Germany, taking account of reallocation into other sectors (own calculation)

		1992	1993	1994	1995	1996	1997	1998	1999	2000
Total	t/a	359.138	338.421	231.264	110.628	81.878	33.147	17.840	2.623	0
Lausitz district (new definition)	t/a									
Mitteldeutschland district (new definition)	t/a									
Rheinland district	t/a									

II-1.3.1	NO_x emissions in mine-pit power stations in Germany (own calculation)										
			1992	1993	1994	1995	1996	1997	1998	1999	2000
	Total	t/a	37.708	33.946	26.729	22.118	16.108	k.A	k.A	k.A	k.A
	Lausitz district (new definition)	t/a									
	Mitteldeutschland district (new definition)	t/a									
	Rheinland district	t/a									

II-1.3.2	NO_x emissions in mine-pit power stations in Germany, taking account of reallocations into other sectors (own calculations)										
			1992	1993	1994	1995	1996	1997	1998	1999	2000
	Total	t/a	37.708	33.946	25.370	18.452	12.896	k.A	k.A	k.A	k.A
	Lausitz district (new definition)	t/a									
	Mitteldeutschland district (new definition)	t/a									
	Rheinland district	t/a									

[k.A. = no data available]

13.8 CO_2 emission factors

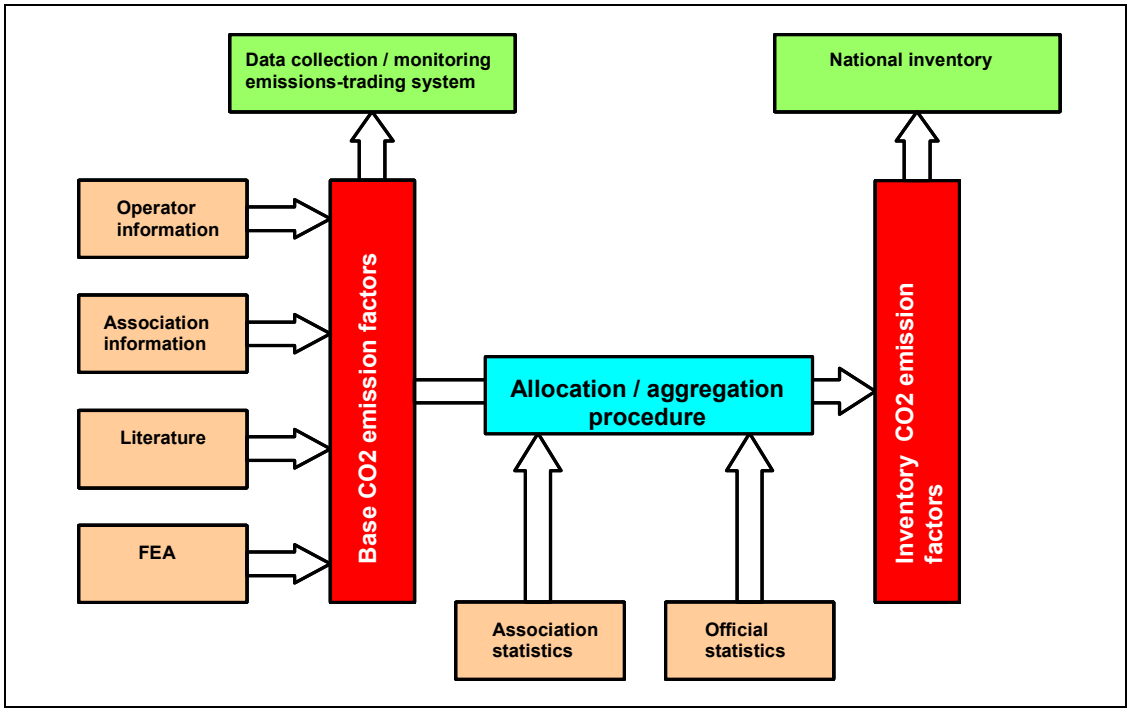
The emission factors on which the inventory is based were derived from the list of *"CO_2 Emissionsfaktoren für die Erstellung der nationalen CO_2-Inventare*" ("*CO_2 Emission factors for preparation of national CO_2 inventories;* Öko-Institut, 2004c).

13.8.1 Preliminary remarks on methods

In the framework of data gathering for the National Allocation Plan, the need arose to provide highly differentiated CO_2 emission factors for plant operators, to ensure that determination of plant-specific emissions would be as precise as possible.

At the same time, the CO_2 emission factors for preparation of national inventories are considerably less differentiated, and there is also a need to provide the greatest possible degree of consistency. A high level of consistency between a) the CO_2 emission factors for data collection and monitoring in the framework of the emissions-trading system and b) those used for preparation of national inventories can significantly enhance the quality of inventories and provide a more substantial basis for dealing with inventory-based issues of the National Allocation Plan.

Figure 61 Base and inventory emission factors for CO_2



Source: Öko-Institut

With this in mind, a consistent concept for CO_2 emission factors was developed (Figure 61).

The system is based on a set of differentiated CO_2 emission factors that – for the most part – are geared to the requirements of the emissions-trading system (so-called "base" emission factors for CO_2). These emission factors were developed on the basis of a range of very different data sources. The data includes operator data, data provided by associations and data gained from literature research. Finally, in some cases Federal Environmental Agency data was used, although the origins of such data are not normally specifically documented.

The basic emission factors for CO_2, with the help of structural data from association statistics and (quasi-) official statistics, are allocated and aggregated in such a manner that they can fit with the activity rates that can be used to prepare the national inventories. Emission factors on such an aggregation and allocation level are then referred to as "inventory emission factors" for CO_2.

13.8.2 Base emission factors for CO_2

Many of the base emission factors were determined in the context of data collection for the national allocation plan. For the others, the factors customarily used by the Federal Environmental Agency were chosen.

The following data was obtained for the updated CO_2 emission factors:

- The carbon content from elementary analysis (with respect to the raw state), for solid and liquid fuels, and the gas composition, for gaseous fuels;
- The lower calorific value.

It must be noted that both the carbon content and the calorific values refer to the relevant samples being considered; they do not necessarily have to be representative (this applies especially for solid fuels, whose ash and water content can vary widely). The calorific-valued-oriented CO_2 emission factors determined from both factors are relatively representative, however, since the uncertainties relative to ash content can be completely eliminated and those relative to water content can be largely eliminated.

With regard to *hard coal* (including ballast coal and anthracite for use in power stations), for boiler coal extensive data and analyses of the large power utilities E.ON AG and RWE AG was available; this data was discussed and co-ordinated within the VGB. The data for the various districts and mines was aggregated for the various German Länder, and for German mines, by simple averaging at the Länder level.

The carbon content and calorific value of *anthracite for the heat market* were taken from the relevant customer-information data of DSK Anthrazit Ibbenbüren GmbH. The emission factors were obtained as the average value of five different qualities of anthracite intended for the heat market.

For *hard-coal briquettes* and *hard-coal coke,* use was made of the emission factors traditionally applied by the Federal Environmental Agency (and not further documented to date).

The CO_2 emission factors for *raw lignite* were determined for the Rhine, Lausatian (Lausitz) and Central German mining districts on the basis of data on carbon content and lower calorific value provided by the producers RWE Power, Vattenfall Europe and MIBRAG. For use of lignite from the Helmstedt area, and from Hesse, the emission factors traditionally applied by the Federal Environmental Agency (and not further documented to date) were used.

All emission factors for *lignite products* were determined on the basis of company or literature data:

- For fluidised-bed lignite, lignite dust, lignite briquettes and lignite coke from the Rhineland mining district, on the basis of data from RWE Power AG;
- For fluidised-bed lignite, lignite dust and lignite briquettes from the Lausatian mining district, on the basis of data from Vattenfall Europe AG;
- For lignite dust and lignite briquettes from the Central German district, on the basis of data from MIBRAG GmbH (and supplementary literature data on lignite additive briquettes).

For *hard lignite,* the emission factor traditionally applied by the Federal Environmental Agency (and not further documented to date) was used.

For *fuel peat,* the emission factor traditionally applied by the Federal Environmental Agency (and not further documented to date) was used.

For the *petroleum products* crude petrol, engine petrol, diesel fuel, petroleum and aircraft-engine kerosine, light heating oil, heavy heating oil, refinery gas, petroleum coke and other petroleum products, the emission factors traditionally applied by the Federal Environmental Agency (and not further documented to date) were used.

The CO_2 emission factors for the LP gases *propane* and *butane*, and for *methanol*, were derived from stoichiometric analysis.

The CO_2 emission factors for natural gas, in the qualities mixed gas H, Russia H and Netherlands, and natural gas from the Altmark region, were determined on the basis of gas-composition data provided by Ruhrgas AG, VNG AG and EEG Erdgas-Erdöl GmbH.

For *petroleum gas,* the emission factor traditionally applied by the Federal Environmental Agency (and not further documented to date) was used.

The figures relative to emission factors for *city gas* were obtained, for the old German Länder, on the basis of data of Ruhrgas AG. For city gas used in the new German Länder, data was drawn from the literature. The firm of GASAG provided data relative to the specific quality of city gas from high-pressure separation plants.

The emission factor for coking-plant gas was determined on the basis of data on coking-plant-gas composition at five German coking plants; this data was provided by Deutsches Stahlinstitut.

The typical compositions and calorific values of *blast-furnace gas* and c*onverter gas* were provided, for determination of CO_2 emission factors, by Hüttenwerke Krupp Mannesmann GmbH.

For *pit gas,* the emission factor traditionally applied by the Federal Environmental Agency (and not further documented to date) was used.

The CO_2 emission factors for *biogas* and *gas from sewage treatment* are zero by definition – where such gases fulfill the definition of biomass.

For *household waste / municipal waste*, a value was used for which the non-organic carbon fraction and the calorific value were estimated in a current Federal Environmental Agency research project.

For *industrial waste,* the emission factors traditionally applied by the Federal Environmental Agency (and not further documented to date) were used. (Up until 1994, these emission factors differed between the old and new German Länder.).

For *plastic waste,* the emission factor traditionally applied by the Federal Environmental Agency (and not further documented to date) was used; this emission factor corresponds to the emission factor for Other Oil Products.

Waste sulphite and sulphate liquor and *firewood and other biomass* are also, by definition, assessed as having an emission factor of zero where complying with the definition of the term "biomass".

Table 96: CO_2 emission factors for the German national allocation plan (last revision: 27 October 2003)

		CO_2 emission factor	Remarks
Hard coal			
Ballast hard coal		**t CO_2/TJ 90**	
Anthracite			
	Ruhr (use in power stations)	t CO_2/TJ 95	
	Heat generation	t CO_2/TJ 98	
Whole coal, Germany		**t CO_2/TJ 93**	
	Ruhr	t CO_2/TJ 93	
	Saar	t CO_2/TJ 92	
Whole coal, import		**t CO_2/TJ 95**	**General value for orientation**
	South Africa	t CO_2/TJ 96	General value for orientation, exporting mine pits
	Goedehoop	t CO_2/TJ 95	
	Kleinkopje	t CO_2/TJ 98	
	Forzando	t CO_2/TJ 95	
	Arthur Taylor	t CO_2/TJ 97	
	Koornfontein	t CO_2/TJ 97	
	Douglas P2	t CO_2/TJ 97	
	Middelburg	t CO_2/TJ 95	
	Twistdraai	t CO_2/TJ 92	
	Kromdraai	t CO_2/TJ 95	
	ATC 1	t CO_2/TJ 97	
	Kangra	t CO_2/TJ 98	
	Columbia	t CO_2/TJ 94	General value for orientation, exporting mine pits
	Cerrejon	t CO_2/TJ 93	
	Cerrejon Central	t CO_2/TJ 93	
	Cerrejon Prodeco	t CO_2/TJ 95	
	Cerrejon Carbocol	t CO_2/TJ 95	
	Cerrejon Norte	t CO_2/TJ 94	
	Drummond	t CO_2/TJ 95	
	Primero	t CO_2/TJ 93	
	Venezuela	t CO_2/TJ 93	General value for orientation, exporting mine pits
	Guasare	t CO_2/TJ 95	
	Paso Diablo	t CO_2/TJ 91	
	USA	t CO_2/TJ 94	General value for orientation, exporting mine pits
	Kerr McGee	t CO_2/TJ 94	
	AMCI	t CO_2/TJ 94	
	Scotts Branch	t CO_2/TJ 94	

	CO_2 emission factor	Remarks
ANR	t CO_2/TJ 94	
Drayton	t CO_2/TJ 95	
Permeke	t CO_2/TJ 94	
Baltimore	t CO_2/TJ 95	
Consol	t CO_2/TJ 94	
Canada		
Mountian	t CO_2/TJ 95	
Poland	t CO_2/TJ 94	General value for orientation, exporting mine pits
Mischkohle	t CO_2/TJ 96	
Poduff	t CO_2/TJ 95	
Anna	t CO_2/TJ 95	
Makoszowy	t CO_2/TJ 93	
Halemba	t CO_2/TJ 93	
Qualität 6000	t CO_2/TJ 93	
Australia	t CO_2/TJ 95	General value for orientation, exporting mine pits
Stewarton	t CO_2/TJ 93	
Ulan	t CO_2/TJ 94	
Newlands	t CO_2/TJ 94	
Hunter Mischkohle	t CO_2/TJ 95	
MIM	t CO_2/TJ 95	
Blair Athol	t CO_2/TJ 96	
Drayton	t CO_2/TJ 95	
Burton	t CO_2/TJ 94	
South Black Water	t CO_2/TJ 96	
South Walker Creek	t CO_2/TJ 96	
Indonesia	t CO_2/TJ 95	General value for orientation, exporting mine pits
Satui	t CO_2/TJ 95	
Pinang	t CO_2/TJ 96	
Kaltim Prima	t CO_2/TJ 94	
Spitzbergen		
SVEA	t CO_2/TJ 94	
Russia	t CO_2/TJ 95	General value for orientation, exporting mine pits
Kuzbass	t CO_2/TJ 94	
Kedrowsky	t CO_2/TJ 100	
Murmask-Mischkohle	t CO_2/TJ 96	
Vorgashore	t CO_2/TJ 95	
Kusheyakovsky	t CO_2/TJ 93	

		CO_2 emission factor	Remarks
	Prokopievskugol	t CO_2/TJ 93	
	China (Chenhua)	t CO_2/TJ 95	General value for orientation, exporting mine pits
	Nantun	t CO_2/TJ 96	
	Yanzhou	t CO_2/TJ 95	
Hard-coal briquettes		**t CO_2/TJ 93**	
Hard-coal coke		**t CO_2/TJ 105**	
Lignite			
Crude lignite			
	Rheinland	t CO_2/TJ 114	
	Lausitz	t CO_2/TJ 113	
	Mitteldeutschland	t CO_2/TJ 104	
	Helmstedt	t CO_2/TJ 111	
	Hessen (Hirschberg)	t CO_2/TJ 111	
Fluidised-bed lignite			
	Rheinland	t CO_2/TJ 98	
	Lausitz	t CO_2/TJ 101	
Lignite dust			
	Rheinland	t CO_2/TJ 98	
	Lausitz	t CO_2/TJ 99	
	Mitteldeutschland	t CO_2/TJ 94	
Lignite briquettes			
	Rheinland	t CO_2/TJ 99	
	Lausitz	t CO_2/TJ 101	
	Mitteldeutschland	t CO_2/TJ 98	
Lignite coke			
	Rheinland	t CO_2/TJ 108	
Hard lignite		**t CO_2/TJ 97**	
Fuel peat		**t CO_2/TJ 98**	
Oil products			
Crude oil		**t CO_2/TJ 80**	
Crude petrol		**t CO_2/TJ 80**	
Engine petrol		**t CO_2/TJ 72**	
Diesel fuel		**t CO_2/TJ 74**	
Petroleum and aircraft-engine kerosine		**t CO_2/TJ 74**	
Heating oil, light		**t CO_2/TJ 74**	
Heating oil, heavy		**t CO_2/TJ 78**	
LP gas (butane)		**t CO_2/TJ 64**	
LP gas (propane)		**t CO_2/TJ 65**	
Refinery gas		**t CO_2/TJ 60**	**Considerable range; must be specifically determined in each case**
Petroleum coke		**t CO_2/TJ 101**	
Methanol		**t CO_2/TJ 71**	

	CO_2 emission factor	Remarks
Other oil products	**t CO_2/TJ 80**	
Gases		
Natural gas L, Netherlands	**t CO_2/TJ 56**	
Natural gas H, mixed	**t CO_2/TJ 56**	
Natural gas H, Russia	**t CO_2/TJ 55**	
Natural gas, Altmark	**t CO_2/TJ 56**	
Petroleum gas	**t CO_2/TJ 58**	
Coking plant gas	**t CO_2/TJ 40**	**Considerable range; must be specifically determined in each case**
City gas (old German Länder)	**t CO_2/TJ 40**	
City gas (new German Länder)	**t CO_2/TJ 50**	
City gas (gas separated under high pressure from natural gas)	**t CO_2/TJ 53**	**West Berlin until 1995**
Blast furnace gas	**t CO_2/TJ 268**	**Considerable range; for plant-specific study, must be specifically determined in each case; for national inventories, for reasons of consistency, 105 t CO_2/TJ**
Converter gas	**t CO_2/TJ 183**	**Considerable range; for plant-specific study, must be specifically determined in each case; for national inventories, for reasons of consistency, 105 t CO_2/TJ**
Pit gas	**t CO_2/TJ 55**	
Biogas	**t CO_2/TJ 0**	**Where recognised as biomass**
Gas from sewage treatment	**t CO_2/TJ 0**	**Where recognised as biomass**
Other fuels		
Household waste	**t CO_2/TJ 15**	
Industrial waste	**t CO_2/TJ 20**	**Lignite waste, only new German Länder: 94 t/TJ**
Sewage sludge		**No EF available**
Firewood and other biomass	**t CO_2/TJ 0**	**Where recognised as biomass**

Sources: Federal Environmental Agency, figures from companies and associations, AG Energiebilanzen, ifeu-Institut für Energie und Umweltforschung, calculations of Öko-Institut

13.8.3 Determination of inventory emission factors for CO_2

With the basic emission factors for CO_2, along with data on energy-consumption structures, the CO_2 emission factors were determined at the differentiation level required for national CO_2 inventories (cf. Table 97 and Table 98).

With regard to *hard coal*, it was initially assumed that anthracite is used in small combustion systems, in residential heat-generation systems licensed in accordance with provisions of the Technical Instructions on Air Quality Control (TA Luft), in the small consumption sector (as of 1995: commerce, trade, services) and by military agencies. No further differentiation was carried out for anthracite. Neither was any further differentiation carried out for use of ballast coal.

For mine-pit power stations of the German hard-coal industry, an energy-related mix of German hard-coal production, differented by districts (Ruhr, Saar, Aachen, Lower Saxony) was assumed; data for such a mix is available via the Statistik der Kohlenwirtschaft (coal-industry statistics). The relevant district-specific emission factors were then used, on this basis, to calculate a weighted average.

For other hard-coal uses, a mix of domestic coal and foreign imports, broken down by countries of origin, was determined. The relevant database consisted of the aforementioned domestic-production figures and, initially, detailed data from the Association of Coal Importers (Verein der Kohlenimporteure). For calculation of the import mix, all hard-coal imports, by supplier countries, were adjusted to take account of relevant amounts of coke and coking coal, and of the relevant (small) amounts of imports of other hard-coal products, and then converted to energy content.

The mix for domestic hard-coal production, and that for imports, are linked via the import fraction of hard coal used. This fraction is based on data, provided by the Association of Coal Importers (Verein der Kohlenimporteure), on fractions of imported coal found in the various areas of application. This did not include uses in the iron and steel industry and in coking plants.

The basis for country-specific CO_2 emission factors that enter into the CO_2 emission factor for the import mix consists of (unweighted) averages for the relevant countries of origin. For German hard coal, corresponding production data were used for weighting.

No further differentiation was carried out for hard-coal briquettes and hard-coal coke.

Region-specific data for *raw lignite* was used to obtain aggregated CO_2 emission factors. With data from the Association of the German Lignite Industry (Deutscher Braunkohlen-Industrie-Verein (DEBRIV)), on lignite use in public power stations in the various mining districts (Rhineland, Lausatia, Central Germany, Helmstedt, Hesse, Bavaria), mix values were calculated for the old German Länder, for the new German Länder and for Germany as a whole. In addition, the same database was used to produce a mix for lignite use in public power stations of the Free State of Saxony (Saxony records data on raw lignite production in both the Lausatian and Central German regions).

Through subtraction of amounts of crude lignite used in public power stations, and of amounts used in product production, from total production and import amounts (imports are significant only in connection with use of hard lignite in Bavaria), a difference is obtained that represents crude lignite use. This figure, in turn, can then be broken down by areas of origin.

DEBRIV production data was also used as a basis for calculating weighted averages, for the old and new German Länder and for Germany as a whole, from separate data sets for the various lignite products (lignite briquettes, fluidised-bed coal, pulverised lignite, dry lignite and lignite coke).

No further aggregation was carried out for the CO_2 emission factors for all other fuels; the values shown in Table 96 were used. The following should be noted with respect to allocations:

- For the period 1990 to 1994, during which separate balances were drawn up for the old and the new German Länder, weighted CO_2 emission factors differentiated according to old and new German Länder were used where appropriate.
- For the period until 1994, the CO_2 emission factor for Russian natural gas was assumed for the new German Länder.
- Gas separated under high pressure from natural gas is only relevant for West Berlin (until 1995).

Finally, it should be noted that, for reasons of consistency, the emission factor for hard-coal coke was used for blast-furnace and converter gas, in preparation of national CO_2 inventories.

Table 97: Aggregation and allocation of basic emission factors for CO_2, 1990-1994

	1990	1991	1992	1993	1994
	t CO_2/TJ				
Steinkohlen					
Steinkohle-Mix	**93,3**	**93,4**	**93,4**	**93,4**	**93,4**
Inländische Produktion	92,9	92,9	92,9	92,9	92,9
Ruhr	93,0	93,0	93,0	93,0	93,0
Saar	92,0	92,0	92,0	92,0	92,0
Aachen	93,0	93,0	93,0	93,0	93,0
Niedersachsen	95,0	95,0	95,0	95,0	95,0
Summe Drittlandsimporte (ohne Koks und Kokskohlen)	95,1	95,0	95,0	94,9	94,9
Polen	94,0	94,0	94,0	94,0	94,0
CSFR	95,0	95,0	95,0	95,0	95,0
UdSSR/GUS	95,0	95,0	95,0	95,0	95,0
Norwegen	94,0	94,0	94,0	94,0	94,0
USA	94,0	94,0	94,0	94,0	94,0
Kanada	95,0	95,0	95,0	95,0	95,0
Kolumbien	94,0	94,0	94,0	94,0	94,0
Südafrika	96,0	96,0	96,0	96,0	96,0
Australien	95,0	95,0	95,0	95,0	95,0
VR China	95,0	95,0	95,0	95,0	95,0
Indonesien	95,0	95,0	95,0	95,0	95,0
Venezuela	93,0	93,0	93,0	93,0	93,0
Sonstige Drittländer	95,0	95,0	95,0	95,0	95,0
Steinkohlenbriketts	93,0	93,0	93,0	93,0	93,0
Steinkohlenkoks	105,0	105,0	105,0	105,0	105,0
Anthrazit					
Stromerzeugung	95,0	95,0	95,0	95,0	95,0
Wärmemarkt	98,0	98,0	98,0	98,0	98,0
Braunkohlen					
Rohbraunkohlen					
(Öffentliche) Kraftwerke	112,1	112,3	112,4	112,5	112,6
(Öffentliche) Kraftwerke (Rheinland, Lausitz, Mitteldeutschlan	112,4	112,7	112,9	112,9	113,0
(Öffentliche) Kraftwerke ABL	113,2	113,2	113,2	113,2	113,3
(Öffentliche) Kraftwerke NBL	111,0	111,2	111,5	111,7	111,7
(Öffentliche) Kraftwerke Sachsen					
Rheinland	114,0	114,0	114,0	114,0	114,0
Helmstedt	111,0	111,0	111,0	111,0	111,0
Hessen	111,0	111,0	111,0	111,0	111,0
Bayern (Hartbraunkohle)	97,0	97,0	97,0	97,0	97,0
Lausitz	113,0	113,0	113,0	113,0	113,0
Mitteldeutschland	104,0	104,0	104,0	104,0	104,0
Restgröße	109,2	109,3	108,2	108,7	109,2
Restgröße ABL	113,9	113,9	113,9	113,9	113,9
Restgröße NBL	108,8	108,7	107,7	108,1	108,6
Rheinland	114,0	114,0	114,0	114,0	114,0
Helmstedt	111,0	111,0	111,0	111,0	111,0
Hessen	111,0	111,0	111,0	111,0	111,0
Bayern	97,0	97,0	97,0	97,0	97,0
Lausitz	113,0	113,0	113,0	113,0	113,0
Mitteldeutschland	104,0	104,0	104,0	104,0	104,0
Braunkohlenbriketts					
Braunkohlenbrikett-Mix Deutschland	99,7	99,9	99,8	99,8	99,9
Braunkohlenbrikett-Mix ABL	99,0	99,0	99,0	99,0	99,0
Braunkohlenbrikett-Mix NBL	99,7	100,0	100,0	100,0	100,3
Rheinland	99,0	99,0	99,0	99,0	99,0
Lausitz	101,0	101,0	101,0	101,0	101,0
Mitteldeutschland	98,0	98,0	98,0	98,0	98,0
Wirbelschicht-, Staub- und Trockenkohle					
Wirbelschicht-, Staub- und Trockenkohle Mix Deutschland	97,6	97,8	97,8	97,9	97,8
Wirbelschicht-, Staub- und Trockenkohle Mix ABL	98,0	98,0	98,0	98,0	98,0
Wirbelschicht-, Staub- und Trockenkohle Mix NBL	96,7	96,6	96,8	97,5	97,1
Rheinland	98,0	98,0	98,0	98,0	98,0
Lausitz	99,0	99,0	99,0	99,0	99,0
Mitteldeutschland	94,0	94,0	94,0	94,0	94,0

Table 97 (con'd).

	1990	1991	1992	1993	1994
	t CO_2/TJ				
Braunkohlen					
Braunkohlenkoks					
Braunkohlenkoks Mix Deutschland	108,0	108,0	108,0	108,0	108,0
Braunkohlenkoks Mix ABL	108,0	108,0	108,0	108,0	108,0
Braunkohlenkoks Mix NBL	108,0	108,0	108,0	108,0	108,0
Rheinland	108,0	108,0	108,0	108,0	108,0
Lausitz	108,0	108,0	108,0	108,0	108,0
Mitteldeutschland	108,0	108,0	108,0	108,0	108,0
Gase					
Kokerei-/Stadtgas	40,0	40,0	40,0	40,0	40,0
Stadtgas NBL	50,0	50,0	50,0	50,0	50,0
Stadtgas West-Berlin (Spaltgas)	53,0	53,0	53,0	53,0	53,0

Table 98 Aggregation and allocation of basic emission factors for CO_2, 1995-2002

	1995	1996	1997	1998	1999	2000	2001	2002
	t CO_2/TJ							
Steinkohlen								
Steinkohle-Mix	**93,4**	**93,5**	**93,6**	**93,7**	**93,7**	**93,7**	**93,8**	**93,9**
Inländische Produktion	92,9	92,9	92,9	92,9	92,9	92,9	92,9	92,9
Ruhr	93,0	93,0	93,0	93,0	93,0	93,0	93,0	93,0
Saar	92,0	92,0	92,0	92,0	92,0	92,0	92,0	92,0
Aachen	93,0	93,0	93,0	93,0	93,0	93,0	93,0	93,0
Niedersachsen	95,0	95,0	95,0	95,0	95,0	95,0	95,0	95,0
Summe Drittlandsimporte (ohne Koks und Kokskohlen)	94,8	95,0	94,9	94,9	94,8	94,6	94,7	94,8
Polen	94,0	94,0	94,0	94,0	94,0	94,0	94,0	94,0
CSFR	95,0	95,0	95,0	95,0	95,0	95,0	95,0	95,0
UdSSR/GUS	95,0	95,0	95,0	95,0	95,0	95,0	95,0	95,0
Norwegen	94,0	94,0	94,0	94,0	94,0	94,0	94,0	94,0
USA	94,0	94,0	94,0	94,0	94,0	94,0	94,0	94,0
Kanada	95,0	95,0	95,0	95,0	95,0	95,0	95,0	95,0
Kolumbien	94,0	94,0	94,0	94,0	94,0	94,0	94,0	94,0
Südafrika	96,0	96,0	96,0	96,0	96,0	96,0	96,0	96,0
Australien	95,0	95,0	95,0	95,0	95,0	95,0	95,0	95,0
VR China	95,0	95,0	95,0	95,0	95,0	95,0	95,0	95,0
Indonesien	95,0	95,0	95,0	95,0	95,0	95,0	95,0	95,0
Venezuela	93,0	93,0	93,0	93,0	93,0	93,0	93,0	93,0
Sonstige Drittländer	95,0	95,0	95,0	95,0	95,0	95,0	95,0	95,0
Steinkohlenbriketts	93,0	93,0	93,0	93,0	93,0	93,0	93,0	93,0
Steinkohlenkoks	105,0	105,0	105,0	105,0	105,0	105,0	105,0	105,0
Anthrazit								
Stromerzeugung	95,0	95,0	95,0	95,0	95,0	95,0	95,0	95,0
Wärmemarkt	98,0	98,0	98,0	98,0	98,0	98,0	98,0	98,0
Braunkohlen								
Rohbraunkohlen								
(Öffentliche) Kraftwerke	112,5	112,3	112,3	112,2	112,2	112,1	111,9	112,1
(Öffentliche) Kraftwerke (Rheinland, Lausitz, Mitteldeutschlan	112,8	112,6	112,7	112,7	112,6	112,4	112,3	112,3
(Öffentliche) Kraftwerke ABL	113,3	113,3	113,3	113,2	113,2	113,2	113,2	113,6
(Öffentliche) Kraftwerke NBL	111,4	110,8	110,9	110,8	110,9	110,6	110,4	110,4
(Öffentliche) Kraftwerke Sachsen	111,2	110,8	111,0	110,6	108,9	108,9	109,0	109,2
Rheinland	114,0	114,0	114,0	114,0	114,0	114,0	114,0	114,0
Helmstedt	111,0	111,0	111,0	111,0	111,0	111,0	111,0	111,0
Hessen	111,0	111,0	111,0	111,0	111,0	111,0	111,0	111,0
Bayern (Hartbraunkohle)	97,0	97,0	97,0	97,0	97,0	97,0	97,0	97,0
Lausitz	113,0	113,0	113,0	113,0	113,0	113,0	113,0	113,0
Mitteldeutschland	104,0	104,0	104,0	104,0	104,0	104,0	104,0	104,0
Restgröße	109,8	112,2	113,1	113,1	111,9	112,5	112,0	112,1
Restgröße ABL	113,9	114,0	113,9	114,0	113,9	114,0	114,0	113,7
Restgröße NBL	108,8	111,2	112,2	110,9	106,1	104,0	104,0	104,0
Rheinland	114,0	114,0	114,0	114,0	114,0	114,0	114,0	114,0
Helmstedt	111,0	111,0	111,0	111,0	111,0	111,0	111,0	111,0
Hessen	111,0	111,0	111,0	111,0	111,0	111,0	111,0	111,0
Bayern	97,0	97,0	97,0	97,0	97,0	97,0	97,0	97,0
Lausitz	113,0	113,0	113,0	113,0	113,0	113,0	113,0	113,0
Mitteldeutschland	104,0	104,0	104,0	104,0	104,0	104,0	104,0	104,0
Braunkohlenbriketts								
Braunkohlenbrikett-Mix Deutschland	100,0	100,0	99,9	99,7	99,7	99,7	99,7	99,7
Braunkohlenbrikett-Mix ABL	99,0	99,0	99,0	99,0	99,0	99,0	99,0	99,0
Braunkohlenbrikett-Mix NBL	100,4	100,5	100,5	100,6	100,6	100,6	100,7	100,7
Rheinland	99,0	99,0	99,0	99,0	99,0	99,0	99,0	99,0
Lausitz	101,0	101,0	101,0	101,0	101,0	101,0	101,0	101,0
Mitteldeutschland	98,0	98,0	98,0	98,0	98,0	98,0	98,0	98,0
Wirbelschicht-, Staub- und Trockenkohle								
Wirbelschicht-, Staub- und Trockenkohle Mix Deutschland	97,8	97,7	97,7	97,8	97,9	98,0	98,0	97,9
Wirbelschicht-, Staub- und Trockenkohle Mix ABL	98,0	98,0	98,0	98,0	98,0	98,0	98,0	98,0
Wirbelschicht-, Staub- und Trockenkohle Mix NBL	97,0	96,7	96,6	97,2	97,7	97,9	98,1	97,8
Rheinland	98,0	98,0	98,0	98,0	98,0	98,0	98,0	98,0
Lausitz	99,0	99,0	99,0	99,0	99,0	99,0	99,0	99,0
Mitteldeutschland	94,0	94,0	94,0	94,0	94,0	94,0	94,0	94,0

Table 98 (con'd).

	1995	1996	1997	1998	1999	2000	2001	2002
	t CO_2/TJ							
Braunkohlen								
Braunkohlenkoks								
Braunkohlenkoks Mix Deutschland	108,0	108,0	108,0	108,0	108,0	108,0	108,0	108,0
Braunkohlenkoks Mix ABL	108,0	108,0	108,0	108,0	108,0	108,0	108,0	108,0
Braunkohlenkoks Mix NBL	108,0	108,0	108,0	108,0	108,0	108,0	108,0	108,0
Rheinland	108,0	108,0	108,0	108,0	108,0	108,0	108,0	108,0
Lausitz	108,0	108,0	108,0	108,0	108,0	108,0	108,0	108,0
Mitteldeutschland	108,0	108,0	108,0	108,0	108,0	108,0	108,0	108,0
Gase								
Kokerei-/Stadtgas	40,0	40,0	40,0	40,0	40,0	40,0	40,0	40,0
Stadtgas NBL	50,0	50,0	50,0	50,0	50,0	50,0	50,0	50,0
Stadtgas West-Berlin (Spaltgas)	53,0	53,0	53,0	53,0	53,0	53,0	53,0	53,0

14 ANNEX 3: OTHER DETAILED METHODOLOGICAL DESCRIPTIONS FOR INDIVIDUAL SOURCE OR SINK CATEGORIES

14.1 Other detailed methodological descriptions for the source category "energy" (1)

14.1.1 Energy Industries (1.A.1)

14.1.1.1 Methodological aspects of determination of emission factors (Chapter 3.1.1.2)

This section of the Annex describes the main steps carried out in the research project RENTZ et al (2002) for determination of emission factors. (This description does not apply to the CO_2 emission factors whose determination is described in Annex 2 (Chapter 13.8).

Determination of emission factors requires detailed analysis of all operating plants with regard to technologies used and design-specific emission behaviour. Three superordinated source 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 plants, in terms of percentage shares for various plant types). This procedure thus consists of the following steps:

1. Characterisation of the equipment-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.

2. Analysis of source-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) is divided by source categories that are derived from the national energy balance – cf. Chapter 3.1 – and are not based on the combustion technologies used. The project has defined and analysed the following source 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-heat 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, institutional and commercial users (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, relevant statistics, communications of industry associations

(VGB, VDEW, VIK), operator information and technical publications. Furthermore, excerpts of emissions declarations from the year 1996, as provided by some Länder authorities, were also evaluated in the present context.

3. 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 were aggregated to form source-category-specific factors. Finally, factors for Germany as a whole were formed. The source-category-specific factors are sub-divided in accordance with the categories large combustion systems, TA Luft combustion systems and gas turbines, as well as in accordance with the fuel used. Aggregated emission factors are formed first for the reference year 1995.

4. Projections for 2000 and 2010
   For description of continuing technological development, technology-specific emission factors are again determined. 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. Applicable immission-control laws are used as a framework for updating for the year 2000. It is assumed that the requirements of the amended TA Luft (Technical Instructions on Air Quality Control) and of the EU directive on large combustion systems will be met by the reference year 2010.

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 source-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 62 below.

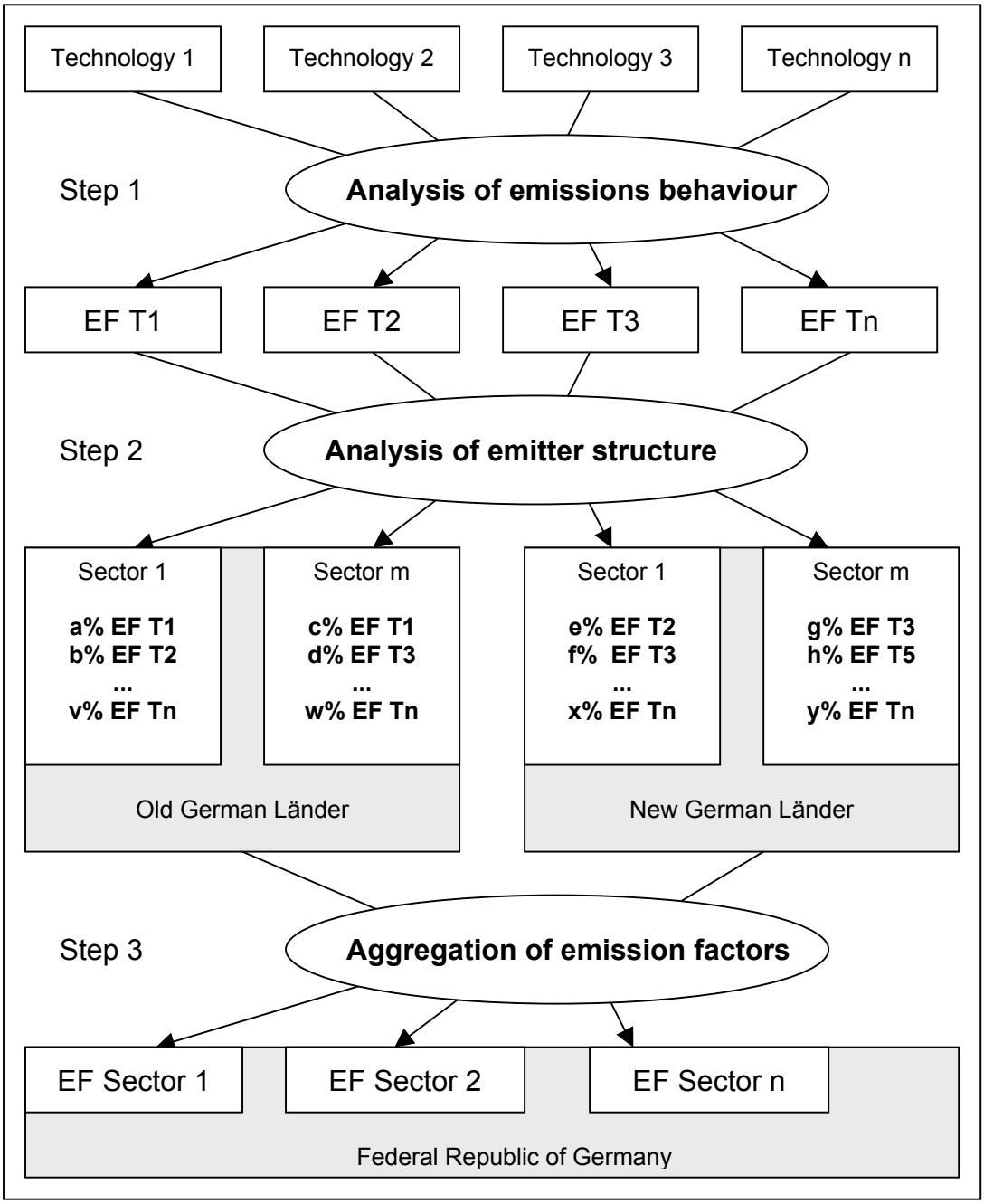


Figure 62: Methods for calculating emission factors

The origins and quality of the data are described in detail in the project report (Rentz et al, 2002). A large part of the data comes from emissions declarations of the Länder Baden-Württemberg, Brandenburg, North Rhine – Westfalia and Thuringia for 1996. The annual pollutant loads listed therein are based, depending on the pollutant concerned, on measurements from continuous monitoring, on individual measurements or on calculation on the basis of 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 pollutants in question. This will then make 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 %[178]. 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 calculation 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 installations subject to abbreviated (K) or complete (V) declarations. For each of the three groups of installations, evaluation and derivation of emission factors is carried out, using the example data from Baden-Württemberg and with separation by measurements and assumptions.

Table 99 provides an overview of the installation types in question and lists the relevant numbers under the 4th BimSchV and the relevant type of declaration required.

Table 99: Installation types pursuant to Annex of 4th BImSchV

Index	**LARGE COMBUSTION PLANTS**	**Type of declaration required**
1 01 1	Power stations ≥ 50 MW for solid, liquid and gaseous fuels	V
1 02A 1	Combustion plants ≥ 50 MW for solid and liquid fuels	V
1 02B 1	Combustion plants ≥ 50 MW for gaseous fuels	V
Index	**TA LUFT INSTALLATIONS**	**Type of declaration required**
1 02A 2	Combustion plants 1 - < 50 MW, solid and liquid fuels (except for heating oil EL)	V
1 02B 2	Combustion plants 5 - < 50 MW heating oil EL	K
1 02C 2	Combustion plants 10 - < 50 MW for natural gas Combustion plants 10 - < 50 MW, except for natural gas installations	K V
1 03 1	Combustion plants > 1 MW, other fuels	V
Index	**GAS-TURBINE INSTALLATIONS**	**Type of declaration required**
1 05 1	Gas turbines ≥ 50 MW for natural gas Gas turbines ≥ 50 MW, except for natural gas installations	K V
1 05 2	Gas turbines < 50 MW for natural gas Gas turbines < 50 MW, except for natural gas installations	K V

Types of declaration: abbreviated (K), complete (V)

In the analyses, emissions data is differentiated by combustion technologies. Table 100 provides an overview of this technology classification based on types. Categories 110 to 118

178 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. This value is termed a *quantile*: or, where percentage shares are used, as a *percentile*:). The best-known percentile that separates the lower half of all values from the upper half is the 50% percentile, the so-called *median*. The 25 and 75% 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).

apply mainly to solid fuels, while 120 to 125 apply to liquid fuels and 130 to 132 apply to gaseous fuels.

Table 100: Classification of sources by type of combustion system

Technology	
Type	**Type meaning**
110	Combustion plants for solid fuels / waste
111	Filled-shaft combustion plants
112	Combustion plants with belt feed
113	Combustion plants with pneumatic feed
114	Combustion plants with bottom feed
115	Combustion plant with mechanically moving grid
116	Dust combustion with dry-ash removal
117	Dust combustion with wet-ash removal
118	Fluidised-bed combustion
120	Combustion systems for liquid fuels / waste
121	With vaporizer burner
122	With pressurised atomiser burner
123	With steam-atomiser burner
124	With rotating atomiser burner
125	With air-atomiser burner
130	Combustion plants for gaseous fuels / waste
131	With atmospheric gas burner
132	With gas-blower burner
141	Multiple-fuel combustion plants
142	Mixed combustion plants
815	Gas turbines

14.1.1.2 Methods for determining uncertainties of emission factors (Chapter 3.1.1.3.1)

This section of the Annex describes the main steps carried out in the research project RENTZ et al (2002) for determining the uncertainties of emission factors (except for those of CO_2 emission factors).

The guide on describing uncertainties in measurements (Leitfaden zur Angabe der Unsicherheit beim Messen; DIN, 1995: DIN 1319) recommends the following systematic approach for cases in which not enough observations have been carried out to yield a meaningful result, via calculation of averages and standard error:

On the basis of the available information, limits (upper and lower limit a_+ and a_-) are determined for the value to be determined, X_i. If no special findings regarding possible values of X_i within this range are available, then it must be assumed that all possible values have the same probability, an assumption that corresponds to a uniform or square distribution of possible values. Then, the expected value x_i lies in the middle of the estimated range. The following relationship holds for the pertinent variation:

$$u^2(x_i) = (a_+ - a_-)^2 / 12 \qquad (A1)$$

For actual physical reasons, values in the vicinity of the middle of the range often have a higher probability than values near the limits. This leads to the assumption of a symmetric trapezoidal distribution, with a base line of length a+ - a- (= 2a) and a top line of length 2aβ with $0 < \beta < 1$. For $\beta = 0$, a triangular distribution results. The following relationship holds for the pertinent variation:

$$u^2(x_i) = a^2 (1 + \beta^2) / 6$$

The estimated standard error u is thus calculated as the positive square root of u^2.

The standard error of approximated, normally distributed values can also be roughly estimated via the interdecile range (Sachs 1992). The following approximation holds:

$$u \approx 0{,}39 (DZ_9 – DZ_1), \qquad (A2)$$

where DZ_9 and DZ_1 stand for the 90th and 10th percentiles, respectively.

The IPCC guidelines recommend that the uncertainty be given via the 95% confidence interval, which can be approximated as double the value of the standard error. To obtain a relative error, one determines the share of 2u in the value X_i. Via multiplicative linking of various independent values that are subject to uncertainties, one can calculate the *combined standard error* as the positive square root of the sum of variations. This approximation holds, pursuant to IPCC-GPG (2000), as long as the relative standard error of any component does not exceed a value of 30 %.

$$u_{total} = \sqrt{u_1^2 + u_2^2 + \ldots + u_n^2} \qquad (A3)$$

Quantification of the uncertainties of emission factors for combustion plants

For derivation of emission factors, various sets of data, of varying extensiveness depending on pollutant and source category, are available for Germany; this data can be used as a basis for determining the pertinent uncertainties. The data is classified in keeping with the main groups defined for the report – large combustion plants, combustion plants under the TA Luft and gas turbines. First, the uncertainty of the relevant technology-specific factors is evaluated. Then, the uncertainty must be taken into account that results from aggregation of these factors for the various source categories used for the emissions calculation. Finally, the uncertainty resulting from extrapolation of the emission factors for 2000 and 2010 must be taken into account.

The relationships A1 and A2 above, for determination of the standard error and 2u, respectively, were reviewed via examples for which a comparatively large number of individual data items is available (30 – 70) and thus the standard error of the relevant random sample can be calculated.

Example: NO_X emissions from large combustion plants (lignite)

a) New German Länder

Random sample: n = 77;

DZ_1: 68.4 g/GJ; quartile 25%: 113.5 g/GJ; median: 134 g/GJ; mean value: 135.6 g/GJ;

quartile 75%: 154.5 g/GJ; DZ_9: 187.7 g/GJ;

Calculated standard error u = 45.3 g/GJ (relative error of 67.6 %)

Estimation of u pursuant to A1: 46.9 g/GJ (69.9 %)

Estimation of u pursuant to A2: 46.4 g/GJ (69.2 %)

b) Old German Länder

Random sample: n = 30;

DZ_1: 67.5 g/GJ; quartile 25%: 70.6 g/GJ; median: 74 g/GJ; mean value: 72.6 g/GJ;

quartile 75%: 75.9 g/GJ; DZ_9: 77.7 g/GJ;

Calculated standard error u = 6.1 g/GJ (relative error of 16.6 %)

Estimation of u pursuant to A1: 5.3 g/GJ (14.3 %)

Estimation of u pursuant to A2: 4 g/GJ (10.8 %)

The examples considered show that, especially for smaller random samples, estimation with A1 yields better agreement with the calculated standard error than does estimation with A2. The quantiles, the upper and lower limits, were set at 5 % and 95 %. With even smaller random samples, conventional calculation methods produce larger standard errors. Determination of emission factors, in contrast to determination of the correctness of measurements, involves assessing the robustness of results. In actual emissions calculation, some compensation can occur through simultaneous overestimation and underestimation within the totality of all sources. For example, in example a), the individual factors are widely scattered, while the higher emission factors account for smaller shares of the relevant activities. If the random sample is considered as a complete survey, then a factor of 119 g/GJ results for the observed emission, which corresponds to a 15 g/GJ deviation from the median.

The robustness of the emissions calculation can be characterised by noting that consideration of the entire range of factors is likely to lead to overestimation of the actual uncertainty. The upper and lower boundaries of the range are thus estimated with the upper and lower quartiles. In the case of a), this produces a relative error of 18 %. This also corresponds to the order of magnitude estimated, in other studies, for the uncertainty of NO_X emission factors from energy conversion.

To evaluate the uncertainty of the proposed emission factors, the upper (a_+) and lower (a_-) quartiles are determined, on the basis of the surveyed individual data, and then the standard error is estimated in accordance with equation (A1). Similarly, the relative uncertainty is calculated as $2u/X_i$. This procedure is used first to determine the uncertainties of the technology-specific factors. Then, these uncertainties are linked with the uncertainty resulting from aggregation to form source-category-specific factors.

In aggregation of technology-specific factors to form source-category-specific factors, the former are weighted and added in accordance with their relative contributions to the source-category structure. As a simplification, such weighting is also carried out in linking of the relative errors.

14.1.1.3 Methane emission factors in the research project RENTZ et al, 2002

The following Table 101 summarises the emission factors shown in Tables 3, 4 and 5 of Annex E of the research project RENTZ et al (2002):

Table 101: Methane emission factors for combustion systems < 50 MW thermal output and for gas turbines, pursuant to RENTZ et al, 2002

Plant type	Fuel	German Länder	CH_4 EF [kg/TJ]
Combustion systems < 50 MW thermal output	Hard coal	ABL	3,4
		NBL	3,3
	Hard-coal coke	ABL/NBL	19
	Lignite	NBL, Lausatian district	269
		NBL, Central German district	184
	Heating oil EL	ABL	0,02
	Natural gas	ABL/NBL	0,02
Gas turbines	Heating oil EL	D	0,5
	Natural gas	D	2

ABL Old German Länder
NBL New German Länder
D Total for Federal Republic of Germany

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

14.1.2.1 Manufacturing industry – iron and steel (1.A.2a)

14.1.2.1.1 Methodological issues (1.A.2a)

In the blast furnace process used in the iron and steel industry, energy is consumed (final energy consumption) and energy is produced, at the same time, in the form of blast-furnace gas (transformation output). In order to avoid duplication in the energy balance, the coke equivalent of the relevant quantity of blast furnace gas, in terms of calorific value, is deducted from the coke consumption of the iron-producing industry and reported as blast-furnace transformation input (Energy Balance, line 17).

The coke input in blast furnaces, reduced by the coke equivalent, is allocated to final energy consumption. In the Balance of Emissions Causes, this coke consumption is listed in Table 15.

In terms of process procedure, the correct approach for the emission balance would be to allocate the CO_2 contained in blast furnace gas to the blast furnace process and to assign oxidation of the CO contained in blast furnace gas to combustion of blast furnace gas. This would require the composition of the blast furnace gas in question to be precisely known. In view of the many different types of blast-furnace-gas analysis carried out, this approach is theoretically useful but impractical. For this reason, the CO_2 emissions from blast furnace gas combustion are evaluated with the CO_2 emission factor for hard coal coke. This helps to ensure that the CO_2 emissions from the blast furnace process and blast-furnace-gas combustion are no greater than the potential CO_2 emissions brought into blast furnaces with hard coal coke.

14.1.2.1.2 Industrial-process combustion, blast furnaces

The procedure described below currently applies for production of activity-rate time series as of 1995. It will also be the methodological starting point for the time-series recalculations that remain to be carried out for the 1990-1994 period for the old and new Länder.

The sources used for the production data include the Energy Balance for the Federal Republic of Germany for the years 1990 to 1999 (AGEB, 2003: lines 17 and 54), along with relevant internal updates carried out by the Federal Environmental Agency (calculations of UBA 2003; last revision, October 2004) and statistics of the manufacturing sector (DESTATIS, Fachserie 4 Reihe 8.1, 1991-2004: Produzierendes Gewerbe. Eisen und Stahl, Tabelle 3.25, 4. Vierteljahr 2003). Figures for input of liquid fuels, coke-oven gas, blast-furnace gas and natural gas were taken directly from the Federal Statistical Office's statistics. These figures have been converted into TJ, using the relevant average caloric values pursuant to the Energy Balance, and then reported in the CSE as activity rates under heating oil, heavy, coke-oven/city gas, blast furnace gas and natural gas.

The "hard-coal coke" activity rate is determined in accordance with the same principle, with the difference that, following conversion to TJ, the Federal Statistical Office's figures have to be reduced by the relevant coke-equivalent value from the Energy Balance, line 17.

The Federal Statistical Office's figures are not suitable for determination of hard-coal input in blast-furnace operations, since those figures do not only refer to blast-furnace and sintering plants – they also include inputs for electric power generation.
The "hard coal" activity rate is thus calculated as the difference between hard-coal consumption pursuant to the Energy Balance, line 54, and that portion of solid fuels in sintering facilities that is assigned to hard coal (cf. sintering facilities).
The "other petroleum products" activity rate has been taken from the Energy Balance, line 54, and it comprises the plastic waste used in blast furnaces.
The further breakdown of the "heating oil, heavy" activity rate, into fractions with an average of 1.9 % or more than 2.8 % sulphur, is not relevant for emissions determination; it is part of a balance in which sales of heavy heating oil with a high sulphur content (source: Association of the German Petroleum Industry (MWV)) are distributed, in accordance with plausibility criteria, among source categories with minimal emissions relevance.

Table 102 provides an overview of the activity rates determined.

14.1.2.1.3 Industrial process combustion, sintering plants

The procedure described below currently applies for production of activity-rate time series as of 1995. It will also be the methodological starting point for the time-series recalculations that remain to be carried out for the 1990-1994 period for the old and new Länder.

The sources used for the production data include the Energy Balance for the Federal Republic of Germany (AGEB, 2003: line 54), and manufacturing industry statistics (DESTATIS Fachserie 4 Reihe 8.1 1991-2004: Produzierendes Gewerbe. Eisen und Stahl, Tabelle 3.25, 4. Vierteljahr 2003). For sintering plants, the Federal Statistical Office solely lists total use of solid fuels, in 1,000 t SKE. This value is first converted into TJ, the key units for energy-related activity rates.

In a next step, the fuel inputs summarised therein are identified on the basis of the Energy Balance, line 54, under the assumption that all figures in this line that are attributable to solid fuels can be assigned to process combustion for blast furnaces and sintering plants. The figures for lignite briquettes pursuant to line 54 are listed as the lignite-briquettes activity rate, in TJ, while those for other lignite products are listed as the lignite-coke activity rate, also in TJ. The activity rate for hard-coal coke, in TJ, is calculated as the difference between the

Energy Balance value and the blast-furnace activity rate (cf. blast-furnace plants). The hard-coal activity rate, in TJ, is then calculated from solid-fuel inputs, in TJ, pursuant to the Federal Statistical Office, minus the previously determined activity rates for lignite briquettes, lignite coke and hard-coal coke. Since for sintering plants the Federal Statistical Office only lists solid-fuel inputs, while about 0.18 GJ of gaseous fuels are consumed per tonne of finished sinter (for priming), the amounts of gas consumed must be determined via the sinter production. From this value, the activity rates for coke-oven/city gas, blast-furnace gas and natural gas can be calculated as equal proportions – an assumption that is supported by the relevant figures from the Energy Balance, line 54. Table 102 provides an overview of the activity rates determined.

Table 102: Determined activity rates (AR) of emissions-relevant energy consumption (EMEV) in industrial process combustion, blast furnaces and sintering plants (DESTATIS, Fachserie 4 Reihe 8.1, 1990-2004: Tab.3.25)

Fuel consumption of blast-furnace operations	**Unit**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Coke (= hard-coal coke)	1,000 t	11392	10482	11372	10778	9886	11562	10871	11000
Liquid fuels (= heating oil, heavy)	1,000 t	1475	1318	1374	1354	1116	869	1074	1030
1.9% S	1,000 t	1088	864	977	868	818	571	670	879
>2.8% S	1,000 t	387	454	397	486	298	298	404	151
Coke-oven gas	millions of m³ (Vn) bf	212	165	156	134	103	143	143	130
Blast-furnace gas	millions of m³ (Vn) bf	1452	1372	1479	1435	1254	1370	1309	1310
Natural gas	millions of m³ (Vn) bf	237	232	268	262	268	263	193	240
Calorific values of fuels, pursuant to Energy Balance									
Hard-coal coke	TJ/1,000 t	28,650	28,650	28,650	28,650	28,650	28,650	28,650	28,650
Heating oil, heavy	TJ/1,000 t	40,557	40,539	40,968	40,968	40,921	40,921	40,404	40,404
Coke-oven gas	TJ/ millions of m³ Hu	31,736	31,736	31,736	31,736	31,736	31,736	31,736	31,736
Blast-furnace gas	TJ/ millions of m³ Hu	31,736	31,736	31,736	31,736	31,736	31,736	31,736	31,736
Natural gas	TJ/ millions of m³ Hu	31,736	31,736	31,736	31,736	31,736	31,736	31,736	31,736
Coke in blast-furnace operations, DESTATIS (1)	TJ	326381	300309	325808	308790	283234	331251	311454	315150
Production of blast-furnace gas, DESTATIS	millions of m³ (Vn) bf						4724	4479	4495
Hard-coal coke, EB line 17 (2)	TJ	167889	152590	167574	161758	148837	166138	157522	158085
AR hard-coal coke, blast furnace (3)	TJ	158492	147719	158234	147032	134397	165113	153932	157065
Hard-coal coke, EB line 54 (4)	TJ	185000	188000	187772	188804	177401	205007	187485	166458
AR hard-coal coke, sintering (5)	TJ	26508	40281	29538	41772	43004	39894	33553	9393
Solid fuels in sintering plants, DESTATIS	1,000 t HCE	1619	1659	1706	1832	1667	1752	1638	1540
Solid fuels in sintering plants, DESTATIS (6)	TJ	47450	48622	49999	53692	48856	51348	48007	45134
Lignite briquettes, EB line 54	TJ	19	6	12		3			
Other lignite products, EB line 54, (= lignite coke)	TJ	308	150	209	230	178	216	198	205
AR hard coal, sintering (7)	TJ	20614	8185	20240	11690	5671	11238	14256	35537
Hard coal, EB line 54	TJ	55930	51430	65381	70128	73501	73078	70625	70625
AR hard coal, blast furnace (8)	TJ	35316	43245	45141	58438	67830	61840	56369	35088

EMEV blast furnace									
AR hard coal (8)	TJ	35316	43245	45141	58438	67830	61840	56369	35088
AR hard-coal coke (3)	TJ	158492	147719	158234	147032	134397	165113	153932	157065
AR heating oil, heavy (9)	TJ	59822	53430	56290	55471	45668	35560	43394	41616
1.9% S	TJ	44126	35033	40011	35565	33468	23359	27071	35515
>2.8% S	TJ	15696	18397	16279	19906	12199	12201	16323	6101
AR Other petroleum products, EB line 54	TJ	398	319	393	398	398	351	98	304
AR coke-oven / city gas (10)	TJ	6728	5236	4951	4253	3269	4538	4538	4126
AR blast-furnace gas (10)	TJ	46081	43542	46938	45541	39797	43478	41542	41574
AR natural gas (10)	TJ	7521	7363	8505	8315	8505	8347	6125	7617
AR Total	**TJ**	**374179**	**354285**	**376741**	**374918**	**345531**	**354788**	**349393**	**329006**
Pig-iron production	1000 t	30012	27722	30940	30162	27934	30845	29184	29427
Specific energy consumption per t of pig iron	GJ	12,47	12,78	12,18	12,43	12,37	11,50	11,97	11,18
Sinter production	1,000 t	28243	27268	28759	28883	26740	27959	27055	26104
Specific gas consumption per t of finished sinter	GJ	0,18	0,18	0,18	0,18	0,18	0,18	0,18	0,18
Gas consumption for sinter production	TJ	5084	4908	5177	5199	4813	5033	4870	4699
EMEV sintering plants									
AR hard coal (7)	TJ	20614	8185	20240	11690	5671	11238	14256	35537
AR hard-coal coke (5)	TJ	26508	40281	29538	41772	43004	39894	33553	9393
AR lignite briquettes, EB line 54	TJ	19	6	12		3			
AR lignite coke, EB line 54	TJ	308	150	209	230	178	216	198	205
AR coke-oven/city gas (11)	TJ	1695	1636	1726	1733	1604	1678	1623	1566
AR blast-furnace gas (11)	TJ	1695	1636	1726	1733	1604	1678	1623	1566
AR natural gas (11)	TJ	1695	1636	1726	1733	1604	1678	1623	1566
AR Total	**TJ**	**52533**	**53530**	**55176**	**58891**	**53670**	**56380**	**52876**	**49833**
Specific energy consumption per t of finished sinter	GJ	1,86	1,96	1,92	2,04	2,01	2,02	1,95	1,91

(1) Hard-coal coke in 1,000 t * calorific value pursuant to Energy Balance

(2) The figures for the period 2000 to 2002 – like the values from Energy Balances of the last few year – are calculated from blast-furnace-gas production pursuant to DESTATIS (1991-2004), in millions of m³ (Vn) Ho*35,169 TJ/millions m³

(3) Coke in blast-furnace operations, DESTATIS (1991-2004. /. Hard-coal coke (Working Group on Energy Balances, 2003: line 17)

(4) The Energy Balance (AGEB, 2003) figures for 1995 (194992 TJ) and 1996 (196568 TJ) have been provisionally reduced, and the difference has been transferred to line 53, since that line lists too little hard-coal coke. The Working Group on Energy Balances (AGEB) has been informed about this matter.

(5) Hard-coal coke (AGEB, 2003: line 54) / AR hard-coal coke, blast furnace

(6) Solid fuels in sintering plants (DESTATIS, 1991-2004) [1,000 t HCU*29.308 TJ/1,000 t HCU (SKE)]

(7) Solid fuels in sintering plants (DESTATIS, 1991-2004) [TJ] / AR hard-coal coke, sintering / Lignite briquettes (AGEB, 2003: line 54) / Other lignite products, EB line 54

(8) Hard coal (AGEB, 2003: line 54) / AR hard coal, sintering

(9) Liquid fuels (= heating oil, heavy) [1,000 t * calorific value] pursuant to Working Group on Energy Balances (2003)

(10) [millions of m³ (Vn) Ho*31,736 TJ/ millions of m³ Hu]

(11) Gas consumption for sinter production distributed equally between coke-oven/city gas, blast-furnace gas and natural gas.

14.1.2.1.4 Industrial process combustion, hot rolling mills

In the Central System of Emissions (CSE), energy-related activity rates, emissions factors and emissions of hot rolling millis are listed under the module name "INPFWA" (Industrieprozessfeuerung Warmwalzwerk = industrial process combustion, hot rolling mills).

The source for the fuel inputs is the Federal Statistical Office (DESTATIS Fachserie 4 Reihe 8.1, 1991-2004: Produzierendes Gewerbe. Eisen und Stahl, Tabelle 3.25, 4. Vierteljahr 2003).

The procedure described below currently applies for production of activity-rate time series oriented to the area of Germany as of 1995. It will also be the methodological starting point for the time-series recalculations that remain to be carried out for the 1990-1994 period for the old and new Länder.

For hot rolling mills, the Federal Statistical Office lists figures for use of liquid fuels, coking-oven gas, blast-furnace gas and natural gas. These figures have been converted into TJ, using the relevant average caloric values pursuant to the Energy Balance, and then reported in the CSE as activity rates under heating oil, heavy, coke-oven/city gas, blast furnace gas and natural gas. In the Energy Balance, these activity rates are shown in line 54. Table 103 provides an overview of the activity rates determined.

Table 103: Determined activity rates (AR) for emissions-relevant energy consumption (EMEV) for industrial process combustion, hot rolling mills (DESTATIS, Fachserie 4 Reihe 8.1, 1991-2004: Tab. 3.25)

Fuel consumption of hot rolling mills	**Units**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Liquid fuels (= heating oil, heavy)	1,000 t	18	23	24	24	19	16	16	28
Coking oven gas (= coke-oven gas)	millions of m³ (Vn) bf	722	686	723	642	522	583	478	462
Blast furnace gas (3)	millions of m³ (Vn) bf	201	188	210	193	185	184	174	170
Natural gas	millions of m³ (Vn) bf	1384	1358	1512	1505	1528	1595	1599	1587
Calorific values of fuels, pursuant to Energy Balance									
Heating oil, heavy	TJ/1,000 t	40,557	40,539	40,968	40,968	40,921	40,921	41,404	41,404
Coking gas	TJ/ millions of m³ Hu	31,736	31,736	31,736	31,736	31,736	31,736	31,736	31,736
Blast furnace gas	TJ/ millions of m³ Hu	31,736	31,736	31,736	31,736	31,736	31,736	31,736	31,736
Natural gas	TJ/ millions of m³ Hu	31,736	31,736	31,736	31,736	31,736	31,736	31,736	31,736
EMEV hot rolling mill									
AR heating oil, heavy (1)	TJ	730	932	983	983	777	655	662	1159
AR coking / city gas (2)	TJ	22913	21771	22945	20375	16566	18502	15170	14662
AR blast-furnace gas (2)	TJ	6379	5966	6665	6125	5871	5839	5522	5395
AR natural gas (2)	TJ	43923	43097	47985	47763	48493	50619	50746	50365
AR total	**TJ**	**73945**	**71767**	**78578**	**75245**	**71707**	**75615**	**72100**	**71581**

((1) Liquid fuels (= heating oil, heavy) in 1,000 t * calorific value pursuant to Energy Balance
(2) millions of m³ (Vn) Ho*31,736 TJ/ millions of m³ Hu
(3) Figure for 2002 estimated, since it was secret (unprecedented secrecy for this statistic)

14.1.3 Transport (1.A.3)

14.1.3.1 Transport – Civil aviation (1.A.3a)

14.1.3.1.1 Sulphur content of aircraft fuel

On the other hand, the sulphur content is subject to regional fluctuations. For reasons of consistency, this content is determined by the Federal Environmental Agency transport section that provides all fuel-relevant indexes (these were last provided in September 2003). Pursuant to measurements carried out in 1998, the sulphur concentration in fuel is about 210 ppm, i.e. 0.021 mass-percent (DÖPELHEUER, 2002). According to Shell AG (Germany) and the Association of the German Petroleum Industry (deutscher Mineralölwirtschaftsverband; MWV), the sulphur content of kerosine is on the order of that of low-sulphur diesel fuel – no precise, generally valid relevant data was provided, however. Taking the available, substantiated figures into account, the content is likely to be significantly greater than the average content in diesel fuel, about 50 ppm. For this reason, the value given in (Döpelheuer, 2002) is used as a basis. Assuming complete combustion, this would result in an emission factor of 0.4 g/kg SO_2. For the reader's information, it should be added that a small part of emitted sulphur dioxide is further oxidised into SO_3 which, in turn, reacts with water to form sulphuric acid. The values listed in the IPCC guidelines, 1.0 g/kg for cruising flight and 2.4 g/kg for the LTO cycle, are not considered up to date.

14.1.3.1.2 Detailed explanation of the EF used and relevant verification (1.A.3a)

Profound changes have occurred in connection with emissions of ***nitrogen oxides***, since efforts to make aircraft engines more fuel-efficient have led to increases in average

emissions factors. On the other hand, in earlier studies the effects of cruising flight were overestimated, and this is reflected in the value in Table 20. Determining the emissions factor for nitrous oxide has proven to be difficult (DÖPELHEUER, 2002; RAND, 2003; UBA, 2001a). At this juncture, it would be more correct to speak first of nitrogen oxides in general – i.e. of the sum of nitrogen monoxide and nitrogen dioxide. In an aircraft engine, primarily nitrogen monoxide is produced; this substance, after leaving the engine, is then converted into nitrogen dioxide. For this reason, the emissions factor listed below refers to the totality of all nitrogen oxides, even where complete oxidation to nitrogen dioxide effectively occurs.

The primary source of the nitrogen is the nitrogen in the air, although organically bound nitrogen in fuel also plays a role. Formation of nitrogen oxides depends on the combustion-chambre intake temperature, the combustion-chambre intake pressure, the amount of time that hot gases remain in the combustion chambre and the local equivalence level of the fuel/air mixture. Aircraft engines can be divided into different type groups, in keeping with the range of different technologies that are currently in service. Three groups of engines are differentiated: engines with high / medium / low emissions levels (RAND, 2003).

At present, reliable values are available only from the ICAO database (ICAO, 2002). These values refer only to the LTO cycle, however. The cycle is used to determine whether engines comply with binding standards under international law (to date, standards have been defined for nitrogen oxides, CO, hydrocarbons and soot). The standards are certification standards, covering flight phases of specified duration and with specified thrust, as listed below (cf. Table 104).

Table 104: Reference-phase duration for engines, pursuant to ICAO

	Taxiing	Rolling for take-off	Climbing	Approach and landing	Total
Thrust [v.max. thrust]	7 %	100 %	85 %	30 %	-
Duration [min]	26:00	0:42	2:12	4:00	**32:54**

Derivation of cruising-flight emissions factors from LTO-cycle emissions factors requires correlation methods, such as the p^3-T^3 method which is used by the German Aerospace Association (Deutsches Zentrum für Luft- und Raumfahrt - DLR), and which is oriented to temperatures and pressures at the combustion-chambre intake. Engines with higher bypass ratios have slightly lower specific nitrogen-oxide emissions (DLR, 1999).

Aircraft with "high NO_X emissions" were found to have average NO_X emissions of about 14.5 g/kg, while those with "medium" NO_X emissions have about 13.5 g/kg and engines using technologies that provide "low" specific nitrogen-oxide emissions have about 11 g/kg (refers to values in the ICAO database, i.e. applies only to the LTO cycle) (RAND, 2003).

Emissions factors for NO_X, HC and CO, based on various different sources, are highly relevant in this context (IPCC, 1999). On the other hand, these refer to the base year 1992 and to predictions for 2015. The following values are given by 3 research institutions for 1992 and 2015. All values successively provided by DLR, NASA (National Aeronautics and Space Administration) and ANCAT (Abatement of Nuisances from Civil Air Transport) refer to entire average flights, i.e. both the LTO range and cruising flight (cf. Table 22).

Table 105: NO_X emission factors for 1992 and 2015, from NASA, ANCAT and DLR[6], without military air transports

	1992	2015
NASA	12,6	13,7
ANCAT	14,0	12,4
DLR	14,2	12,6

It must be remembered that the average emissions factors for NO_X have risen as a result of the increases, over the past few decades, in combustion-chambre pressures and temperatures. The values determined in the DLR and ANCAT scenarios are likely to have been affected by the assumption that a large percentage of engines in 2015 will have lower specific nitrogen oxide emissions, and thus the zenith in the emissions factor will have been passed by then.

On the basis of 1995, an average worldwide EI (NO_X) of 13.0 g/kg can be assumed (UBA, 2001a). This value is based on calculations that the DLR carried out explicitly for this study, for certain flight profiles.

The following factors should be taken into account in specifying EI (NO_X):

- The mean estimate for 1992 is 13.6, while that for 1995 is 13.0.
- The EI(NO_X) has increased with respect to 1992, as a result of the increased combustion-chambre pressures and temperatures of the "average fleet". The "LTO average" of the majority of the world's current aircraft fleet is thus about 14.5 (RAND, 2003). The percentage of engines with very low specific nitrogen oxide emissions is still low.

Consequently, a mean EI (NO_X) of about 14.0 g/kg can currently be assumed. The values given in the IPCC Reference Manual (IPCC, 1996b, p. 1.96) are considered to be too high for Germany. The primary reason for this is that the average value was determined using aircraft types (and, thus, engine types) that do not reflect the current fleet operating on intra-German routes. Furthermore, the underlying data used by the IPCC is comparatively old.

Unburned ***hydrocarbons***, along with carbon monoxide, are among the main products resulting from incomplete combustion of kerosine. Hydrocarbons are emitted primarily at low thrust levels. As engine efficiencies have improved, a process that has involved increases in combustion-chambre temperatures and pressures, the specific emissions factor for unburned hydrocarbons has decreased. For example, the EI (HC) for global airline transports in 1986, for all flight phases, is given as 1.34 g/kg, while that for 1989 is 1.25 g/kg and that for 1992 is 1.12 g/kg (DLR, 1999). Studies of emitted hydrocarbons have shown that the size of hydrocarbon fractions formed in kerosine combustion decreases with increasing engine thrust. At 80 % thrust, primarily C1-C2 fractions form, while at 7 % and 30 % thrust maximum emissions of molecules with C2 and C3 fractions occur. On the other hand, at lower thrust levels, larger numbers of considerably longer hydrocarbon fractions occur. The emissions factor varies considerably from thrust level to thrust level. For example, in a test run with the TF-39-1C engine, it was 18.9 g/kg at 7 % thrust and only 0.04 g/kg at 80 % thrust. The higher the thrust level, the higher the ratio of alkanes to alkenes; aromates range between 3 and 9 %, while oxygen-containing hydrocarbons account for about 25 % (DÖPELHEUER, 2002).

In *Aviation and the Global Atmosphere, Chap. 9, Aircraft Emissions*, the IPCC lists NASA values for emissions factors, for various years (all flight phases) (IPCC, 1999). The values

refer to all air traffic worldwide, except for military air traffic. According to this source, in 1976 the EI (HC) was 5.1 g/kg, in 1984 it was 3.3 g/kg and in 1992 it was 2.3 g/kg. An average value of 1.0 g/kg is forecast for 2015. Since engine efficiency has been improving smoothly and continuously, without major jumps, and since the level of EI (HC) is inversely proportional to such efficiency, the average of the 1992 and 2015 values may justifiably be used as the current report value. As a result, a current EI (HC) of 1.65 g/kg is assumed for hydrocarbons (with methane).

On the other hand, this includes the C1-body fraction, in addition to the larger hydrocarbon fractions. If the species in question is not a radical one, and a pure hydrocarbon is involved, this group also includes methane. To determine the methane percentage, one would have to calculate back to methane on the basis of the average load level, and of other factors – a complicated procedure due to the methodological difficulties involved. In general, therefore, no reliable scientific basis is currently available for determining EI (CH_4) precisely. On the other hand, the European PARTEMIS (Measurement and prediction of emissions of aerosols and gaseous precursors from gas turbine engines) project includes chromatographic studies of emitted hydrocarbon species that support conclusions regarding the emissions factor of methane. The results, which will soon be published, may well make it possible to provide a more precise value.

In the mid-1990s, some measurements made with one Pratt & Whitney engine (PW 305) and one Rolls Royce engine (RB211) were published (WIESEN et al, 1994 and 1996).

Taking the available information into account, an ***emissions factor of 0.04 g/kg may be assumed for methane***. Methane is already included in the aforementioned figure for hydrocarbons, however. ***The mean EI for NMVOC must thus be given as 1.61 g/kg***.

Carbon monoxide results from incomplete carbon oxidation in combustion of kerosine. While the first sub-reaction involved, oxidation of carbon to carbon monoxide, is fast, the second sub-reaction, oxidation to carbon dioxide, determines the rate of the overall reaction. In combustion, part of the carbon monoxide is not completely converted.

Using a procedure similar to that used for HC, the IPCC gives an average emissions factor for CO for four different years, and for all flight phases (LTO and cruising flight) (IPCC, 1999). According to the IPCC, the factor, also taking military air traffic into account, was 19.7 g/kg in 1976, 15.2 g/kg in 1984 and 11.3 g/kg in 1992. For the year 2015, NASA forecasts a value of 7.1 g/kg (IPCC, 1999). Since a continuous, largely linear decrease is also apparent in this area as well, the average of the 1992 and 2015 figures may again be taken as the current EI (CO). ***An EI figure for CO of 9.2 g/kg is thus assumed.***

Since ***carbon dioxide*** is of predominant importance among emissions, in terms of amount, care must be taken to obtain the most precise emissions factor possible (DÖPELHEUER, 2002). The basis for determining the emissions factor for kerosine consists of the average composition of this fuel. Kerosine consists of alkanes (about 35 % by volume), cycloalkanes (about 45 % by volume), aromates (about 17 % by volume) and alkenes (about 1 % by volume). As a rule, the fuel's composition varies widely by region. Among the lengths of the hydrocarbon chains involved, the fraction with 11 to 12 carbon atoms predominates by amount. Taking into account kerosine's average hydrogen content, and its average mol-weight of 176 kg/mol, kerosine can be simply described via the sum formula $C_{12}H_{23}$. In complete combustion, in strict stoichiometric terms, one kg of kerosine produces 1.24 kg of water and 3.15 kg of carbon dioxide. ***The average carbon-dioxide emissions factor for***

kerosine may thus be assumed as 3,150 g/kg. This value has also been confirmed in numerous publications (including IPCC, 1999).

Nitrous oxide is also a product of nitrogen oxidation in the combustion chamber, and it can occur in traces. The literature contains very little data on this substance. The substance has also been measured in the PARTEMIS project, the results of which have not yet been published. As described above in connection with methane, in the mid-1990s measurements were published for nitrous oxide and methane, obtained during a study of a Pratt & Whitney engine (PW 305) and a Rolls Royce engine (RB211), and measured with infrared spectroscopy under various flight conditions (Wiesen et al, 1994 and 1996). These studies yielded an ***average emissions factor of 0.15 g/kg for N_2O***. In general, it must be assumed that more N_2O is produced in the combustion chamber than ammonia, since N_2O is a product with a medium oxidation level. Currently, a factor of 0.1 g/kg is being used in calculations. A value of 0.32 g/kg is used in the TREMOD framework. All in all, a value of 0.15 g/kg, as given in the above publications, seems plausible.

The customary breakdown for determining the contribution made by domestic air traffic to total emissions (DESTATIS, Fachserie 8, Reihe 6, 2002c) was obtained by allocating 80 % of determined total emissions to international air traffic. This breakdown is based on a study carried out by the TÜV technical control association, under commission to the Federal Environmental Agency (UBA, 1989). Since then, air traffic has become more and more international, and thus the domestic share of air traffic has become relatively smaller.

The breakdown must be based on the relevant IPCC guidelines' definition for preparation of national emissions inventories. Pursuant to those guidelines, domestic air traffic includes all passenger and cargo flights that start and end on the territory of a single country. International air traffic comprises all civil air traffic that originates in other countries or that leaves the relevant country's national territory.

Domestic air travel accounted for 11.9 % of all the passengers that moved through German airports in 2002. A total of 114 million passengers were transported; of these, 13.6 million fell within the category *domestic air travel*. Including all transfer passengers, however, a total of 19.8 million passengers, or 17.4 % of all passengers, flew on intra-German routes in 2002. Under the IPCC's definitions, transfer passengers must be included, as a rule. In the area of cargo traffic, international flights accounted for 2.1 million of the total of 2.2 million t of freight transported in 2002. The national / domestic share was thus 4.5 %.

As to overall numbers of flights, in 2002 a total of 1.45 million flights were made in Germany, of which 0.339 million had destinations within Germany. This number represents a share of 23.4 %.

Another category that can be useful for calculating domestic shares of total transports, for purposes of calculating emissions, is that of seat-km (tonne-km). Here as well, no close correlation to fuel consumption may be assumed. The reasons for this include variances in fleet fuel consumption, and the relatively large fuel consumption during the LTO cycle, especially during take-off and climbing. Air freight accounted for 23.8 % of total transport performance (assuming 0.1 tkm to be equivalent to one seat-km). A total of 7.81 billion tonne-kilometers were found to have been completed in 2002. National flights accounted for 21.4 % of all passenger seat-km in 2002. The combined figure for freight and passenger km together is smaller, since most freight transports – as described above – serve international destinations.

At present, no calculation procedure is available for converting existing data into fuel-consumption figures, and no data that would support such conversion is collected; consequently, a 20 % domestic air transport share will continue to be assumed for calculation purposes. The smaller percentage is based on the number of passengers, as a percentage of all passengers, who must be assigned to intra-German air transports (including transfers, base year 1995) (UBA, 2001a). While the data on passengers, flights and seat-km for 2002 also points to this share, no correlation with fuel consumption can be derived, and such a correlation should actually be used as a calculation basis.

14.1.3.2 Derivation of activity rates for road transport (1.A.3b)

14.1.3.2.1 Cross-check with 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 correspond to the Energy Balance data, in TJ. The relevant basic Energy Balance data is shown in Table 106 below.

Table 106: Energy balances, 1990-2002

Year	Country	Line	Petrol	Petroleum	Diesel fuel	Liquid gas	Biodiesel
Energy consumption in road transports, pursuant to energy balances 90-99 (last revision: 12/2002), in TJ							
1990	ABL	75	1159942	0	657443	138	0
	NBL	75	170537	0	78477	0	0
1991	ABL	75	1156589	0	700405	137	0
	NBL	75	175696	0	84769	0	0
1992	ABL	75	1157939	0	740248	229	0
	NBL	75	186190	0	113254	0	0
1993	ABL	75	1158636	473	777146	184	0
	NBL	75	191981	0	130641	0	0
1994	ABL	75	1082653	559	787800	184	0
	NBL	75	193984	0	144260	0	0
1995	D	62	1299982	610	964013	138	1504
1996	D	62	1299879	638	964580	115	2046
1997	D	62	1297487	357	979586	106	3652
1998	D	62	1300463	637	1022794	106	4081
1999	D	62	1300602	637	1097036	100	5370
Provisional figures pursuant to evaluation tables*							
2000	D	62	1238000	600	1107754	100	14000
2001	D	62	1200000	600	1098117	100	19000
2002	D	62	1167000	600	1107123	100	23000

Sources:
Energy balances 90-99 (AGEB, Last revision: 12/2002), in TJ
Evaluation tables (Auswertetabellen), Energy Balance:
for petrol: Energy Balance evaluation tables, last revision 31 July 2003; diesel fuel: Energy Balance evaluation tables, last revision 31 July 2003, (figures for diesel fuel) – (figures for railways and inland shipping); biodiesel: Energy Balance evaluation tables, last revision 31 July 2003, (figures for other fuels) – 1 PJ [approximation]
[ABL = old German Länder; NBL = new German Länder]

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 (DIW, 2002). Some of the results of the calculation, for automobile traffic, 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 IFEU, 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 average 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 of the Working Group on Energy Balances (AGEB) are used (cf. Table 107).

Table 107: Net calorific values for petrol and diesel fuel

Year	Petrol	Diesel fuel
1990-1992	43.543 MJ/kg	42.704 MJ/kg
As of 1993	43.543 MJ/kg	42.960 MJ/kg

Source: Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen)

In TREMOD, the correction factors are derived separately for the categories "automobiles" and "other motor vehicles". The reason for this differentiation is that to date TREMOD contains relatively low basic consumption values for diesel automobiles; these values yield an average fuel consumption that is considerably below the DIW values (DIW, 2002). For this reason, upward correction for the consumption figures for diesel automobiles is considerably greater than that for the consumption figures for diesel-powered commercial vehicles. This differentiation was applies as of the reference year 1994.

For 2002, provisional Energy Balance data is now available, but no data on transport quantities is yet available. The transport quantities in TREMOD 2002 are thus still scenario figures. The correction factors will thus certainly change as soon as the model is updated to 2002 in the mileage category.

Table 108 below summarises the correction factors used.

Table 108: Correction factors for adjustment to the Energy Balance

Year	Country	Petrol		Diesel fuel	
		Automobiles	Other	Automobiles	Other
1990	ABL	1,0182	1,0182	1,0660	1,0660
	NBL	1,0091	1,0091	1,5264	1,5264
1991	ABL	1,0189	1,0189	1,0309	1,0309
	NBL	1,0638	1,0638	1,0597	1,0597
1992	ABL	1,0253	1,0253	1,0745	1,0745
	NBL	1,0246	1,0246	1,1146	1,1146
1993	ABL	1,0582	1,0582	1,1563	1,1563
	NBL	0,9808	0,9808	1,0702	1,0702
1994	ABL	1,0500	1	1,2	1,0434
	NBL	1,0500	1	1,2	1,0434
1995	D	1,0694	1	1,2	1,0422
1996	D	1,0699	1	1,2	1,0389
1997	D	1,0674	1	1,19	1,0226
1998	D	1,0570	1	1,183	1,0515
1999	D	1,0474	1	1,19	1,0709
2000	D	1,0401	1	1,20	1,0627
2001	D	1,0421	1	1,20	1,0134
2002	D	1,0207	1	1,18	0,9887
Remarks: Until 1993, for ABL (old German Länder) and NBL (new German Länder) no differentiation by vehicle categories; in 1994, correction factors for ABL and NBL as in D as a whole					

14.1.3.2.2 Allocation of biodiesel, petroleum and LP gas to the structural elements

In the Energy Balance, biodiesel, petroleum and LP gas are listed in the transport sector; for this reason, they have not been included in TREMOD, to date, as separate categories. For purposes of importing into CSE, the results for these fuels are thus derived additionally. To this end, the energy consumption, pursuant to the Energy Balance, is allocated to the relevant structural elements in keeping with the specifications of the Federal Environmental Agency (for abbreviations, cf. Table 16):

- **Biodiesel** is allocated to all structural elements with diesel engines, in keeping with their percentage shares of consumption of conventional diesel fuel.
- **Petroleum** is allocated to busses on roads outside of municipalities – and, thus, to the structural elements SV BUS KOAO and SV BUS MTAO – in keeping with their percentage shares of consumption of conventional diesel fuel
- **LP gas** is allocated to conventional automobiles, with petrol engines, on municipal roads (structural element SV PKWO KOIO).

14.1.3.2.3 Activity rate for evaporation

The activity rate for evaporation emissions is set as total petrol consumption, on municipal roads, pursuant to TREMOD; the corresponding figure for mopeds is the total consumption. The values corrected for the Energy Balance are used.

14.1.3.3 Derivation of emission factors

14.1.3.3.1 Emission factors from TREMOD

In the CSE, emission factors for the "engines" ("Antrieb") category are listed in kg/TJ, while those for the "Evaporation" category are given in kg/t. For the subtances "petrol" and "diesel fuel", these values can be derived from TREMOD for all structural elements. To this end,

emissions (in tonnes) and energy consumption (in TJ; converted from the results "energy consumption in t", using the net calorific values pursuant to Table 107) are derived from the TREMOD results and allocated to the relevant structural elements. The emission factor for each structural element then results as the quotient resulting from emissions, in tonnes per structural element, divided by the energy consumption, per structural element, in TJ. A similar procedure is used to obtain the emission factors for evaporation (evaporation emissions, in kg / consumption on municipal roads, in t).

For purposes of this derivation, TREMOD results without correction to the Energy Balance are used, since such correction is already contained in the activity rates for the CSE. Use of the corrected values (emissions and energy consumption) leads to the same results, however, since the correction factor cancels out in calculation of mean emission factors (emissions corrected / energy corrected = emissions uncorrected / energy uncorrected).

14.1.3.3.2 Emission factors for biodiesel, petroleum and LP gas

For all structural elements, the emission factors for biodiesel and petroleum, in keeping with the Federal Environmental Agency's specifications, are set to the same values as those for conventional diesel fuel. Exceptions:

- The CO_2 emission factor for biodiesel is set to "0"
- The SO_2 emission factor for Petroleum: in those years in which diesel fuel has a higher value, this factor is set to 24 kg/TJ. In all other years, the lower value for diesel fuel is used.

The emission factors for automobiles that run on LP gas are set as follows, in keeping with the Federal Environmental Agency's specifications:

Table 109: Emission factors for automobiles that run on LP gas

Gas	Type of vehicle	Structural element	EBL	Units	1995-2001
CH_4	Automobile	SV PKWO KOIO	EBL 62	kg/TJ	3
CO	Automobile	SV PKWO KOIO	EBL 62	kg/TJ	350
CO_2	Automobile	SV PKWO KOIO	EBL 62	kg/TJ	65'000,00
N_2O	Automobile	SV PKWO KOIO	EBL 62	kg/TJ	1,7
NH_3	Automobile	SV PKWO KOIO	EBL 62	kg/TJ	0,5
NMVOC	Automobile	SV PKWO KOIO	EBL 62	kg/TJ	157
NO_X	Automobile	SV PKWO KOIO	EBL 62	kg/TJ	975
SO_2	Automobile	SV PKWO KOIO	EBL 62	kg/TJ	1,7

14.1.3.4 Expansion to include natural gas as a fuel

TREMOD updating includes the option of listing natural gas as a fuel, if the Working Group on Energy Balances (AGEB) lists natural gas as a transport fuel in future. In the present interface, this is possible only if the allocation criteria are precisely defined, in a manner similar to that used for biodiesel, natural gas and petroleum:

- Listing of the affected structural elements and their respective percentage shares of consumption
- Listing of emission factors for the relevant structural elements

Furthermore, general data tables could now be defined into which these figures could be explicitly entered. The minimum requirements are listed in the following tables (Table 110 and Table 111):

Table 110: Entry structure for natural gas: Structural element's percentage share of energy consumption

Material	Structural element	Share/year
Natural gas	For example, SV BUS MTIO	60%
Natural gas	...	...
Natural gas	Total	100%

Table 111: Entry structure for natural gas: Emission factors

Gas	Structural element	Units	Values/reference year
CHx	For example, SV BUS MTIO	kg/TJ	
CO	For example, SV BUS MTIO	kg/TJ	
CO_2	For example, SV BUS MTIO	kg/TJ	
N_2O	For example, SV BUS MTIO	kg/TJ	
NH_3	For example, SV BUS MTIO	kg/TJ	
NMVOC	For example, SV BUS MTIO	kg/TJ	
NOx	For example, SV BUS MTIO	kg/TJ	
SO_2	For example, SV BUS MTIO	kg/TJ	

Alternatively, the percentage shares for structural elements can be given in a form similar to that used for existing structures (as is done for petroleum and biodiesel). To this end, a suitable calculation rule would have to be defined and developed (for example, breakdown of natural gas by the vehicle categories BUS, LNF and SNF on municipal roads, in keeping with the various categories' shares of diesel-fuel consumption). This approach is more complex, and it is more difficult to adapt to changed allocation rules, but it offers the advantage that the percentage shares do not have to be defined explicitly, for each year, in a table.

Since it is difficult to specify a relevant calculation rule at present, natural-gas tables should be added to the current interface; these tables could then be filled as necessary. Such tables will also be integrated into the final version if necessary. In future, an attempt should be made to integrate the fuels biodiesel, petroleum, LP gas and natural gas directly within TREMOD, however.

14.1.3.5 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 parameters include:

- The sum total of activity rates for engines (Antrieb) must correspond to the relevant Energy Balance values (in each case, old and new German Länder).
- In the overall result, emissions resulting from linking activity rates with emission factors must correspond to the TREMOD results for Germany.
- With these parameters, the present study can carry out a relevant breakdown only under the following assumptions:
- The emission factors for old and new German Länder are set, for all structural elements, to the relevant values for all of Germany in 1994.

- The structural elements' percentage shares of the activity rates, for each fuel, are considered to be the same in each case for the old and new German Länder, and they correspond to the relevant values for all of Germany in 1994.

With these assumptions, the aforementioned conditions are met. A third condition is not met, however: the plausibility of emissions results in the time series, in each case, for the old/new German Länder. For this condition to be fulfilled, the 1994 should be remodelled in TREMOD; this should be done via separate derivation of vehicle stocks and mileages for the old and new German Länder, followed by recalculation of emissions on the basis of this data.

14.1.4 Fugitive emissions from solid fuels (1.B.1)

14.1.4.1 Activity rates and emission factors in coal mining (1.B.1a)

In the framework of verification, various data sources for activity rates in coal mining, and the relevant EF used, were compared with the corresponding sources and EF of other countries.

The potential data sources include:

- Statistik der Kohlenwirtschaft e.V. ("silver book") (www.kohlenstatistik.de)
  ⇒ The data from Statistik der Kohlenwirtschaft e.V. are used as basic statistics for the Energy Balance of the Federal Republic of Germany and for statistics of the Federal Statistical Office
- BMWA - Der Bergbau in der Bundesrepublik Deutschland 1990-2002 (mining in Germany, 1990-2002; "blue book")
- Europäisches Handbuch der Energie- und Rohstoffwirtschaft (Glückauf Verlag)
- Energy Balance for the Federal Republic of Germany (www.ag-energiebilanzen.de)
  ⇒ Secondary statistics on the basis of the Statistik der Kohlenwirtschaft (coal-industry statistics).
- Federal Statistical Office (DESTATIS)
  ⇒ Secondary statistics on the basis of the Statistik der Kohlenwirtschaft.

Comparison of data sources' usefulness relevant to AR for hard-coal mining

Figures on production of both hard coal and lignite are published by Statistik der Kohlenwirtschaft e.V. and then become the basis for the Energy Balance, the Jahrbuch der Energiewirtschaft (energy sector handbook), the "blue book" of the Federal Ministry of Economics and Labour (BMWA) and the publications of the Federal Statistical Office. This data is still recent when published.

Table 112 Comparison of activity rates for 2002

Data source	Hard coal [millions of tonnes]	Lignite [millions of tonnes]
Statistik der Kohlenwirtschaft (coal-industry statistics) Total	**26,363**	**181,747**
Not including small mines	26,088	
Small mines	0,275	
Jahrbuch Energiewirtschaft (energy sector yearbook) Total	**26,363**	**181,8**
Not including small mines	26,088	
Small mines	0,275	
DESTATIS	**26,363**	**177.714**
"Blue book" (Federal Ministry of Economics and Labour (BMWA))	**26,363**	**181,778**

Detailed statistical data for 2003 will be collected later

Primary data of Statistik der Kohlenwirtschaft e.V. are used for emissions reporting.

Verification of results via by-country comparisons

For verification of results for methane emissions from coal mining, the results were compared with default values of the IPCC Workbook (IPCC, 1997a, Chapter 1.5, p. 1.26) and with values of countries that neighbour Germany and that, presumably, have similar parameters with regard to geological circumstances and their coal's chemical composition. The countries selected for the comparison were the Czech Republic, Poland and France. The reference year for the comparison is 2002; the data was taken from these countries' published CRF tables[179].

Table 113: Data for by-country comparison of methane emissions from coal mining

	UNFCCC-Default		Czech Republic			Poland			France *)		
	EF (low) CH_4 [kg/t]	EF (high) CH_4 [kg/t]	AD [Mt]	IEF CH_4 [kg/t]	E CH_4 [Gg]	AD [Mt]	IEF CH_4 [kg/t]	E CH_4 [Gg]	AD [Mt]	IEF CH_4 [kg/t]	E CH_4 [Gg]
1. B. 1. a. Coal Mining and Handling			59,95		237,48	161,92		568,48	2,63		62,87
i. Underground Mines (Sum)	10,90	29,00	14,47	13,78	199,39	103,71	5,47	567,74	1,63	38,55	62,83
Mining Activities	10,00	25,00		12,16	175,92		5,47	567,74		38,55	62,83
Post-Mining Activities	0,90	4,00		1,62	23,47		IE	IE			IE
ii. Surface Mines (Sum)	0,30	2,20	45,48	0,84	38,09	58,21	0,01	0,74	1,00	0,04	0,04
Mining Activities	0,30	2,00		0,77	35,04		0,01	0,74		0,04	0,04
Post-Mining Activities	0,00	0,20		0,07	3,05		NE	NE			IE
1. B. 1. b. Solid Fuel Transformation						NE	NE	NE	4,55	0,35	1,59
1. B. 1. c. Other					0,00			0,00			5,01
Post Mining Activities (Sum)									1,63	3,07	5,01
Abandoned Mines											

*) Post-mining activities in France are allocated to 1.B.1.c

A by-country comparison of specific emission factors for underground coal mining shows a broad range, with Germany in the lower part of the range, in a position comparable to that of the Czech Republic. France's EF lies considerably higher within the range, while Poland's is considerably lower. Both of these countries' EF lie outside of the UNFCCC's recommended range.

[179] Cf. the Website http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/2761.php

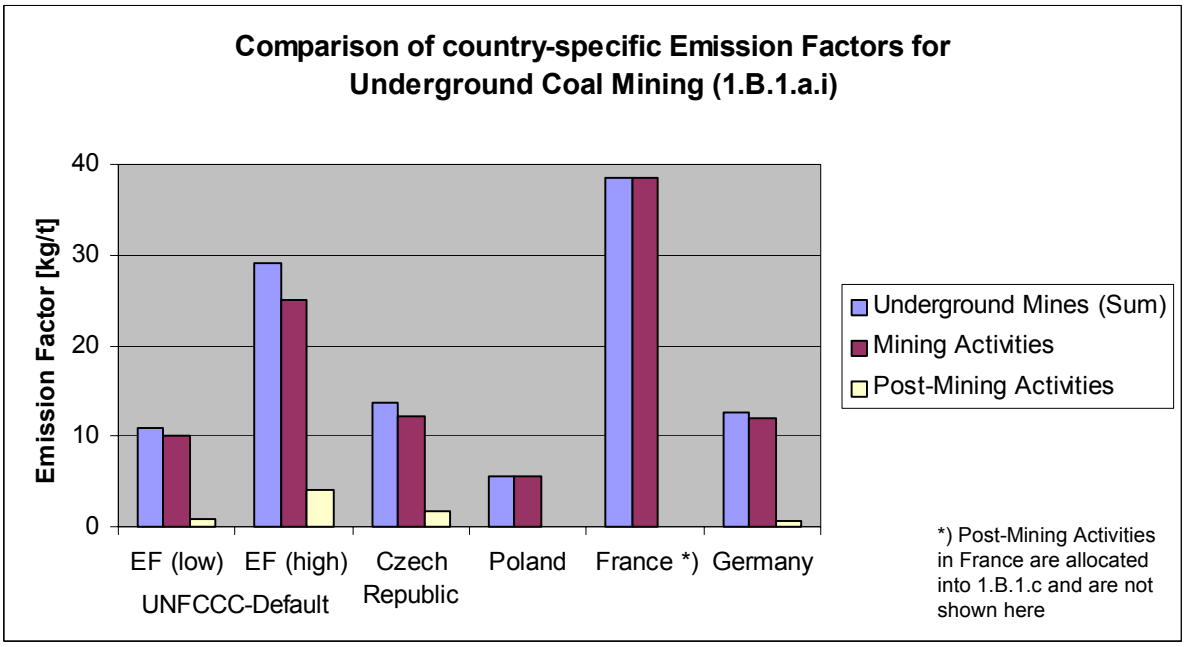


Figure 63: Comparison of country-specific emission factors for underground coal mining

A by-country comparison of specific emission factors for surface coal mining shows that Poland, France and Germany have relatively low emission factors that are below the UNFCCC default values. The reason for this is that the relevant coal in these countries has a very low methane content, as a result of its degree of coalification and its geological history. Consequently, suitably low emission factors have to be applied to it. The comparison value for the Czech Republic is considerably higher, since its coal is not the "lignite" found in Germany, which has a low degree of coalification; instead, its coal is largely "sub-bituminous coal", which has a higher degree of coalification and higher methane content.

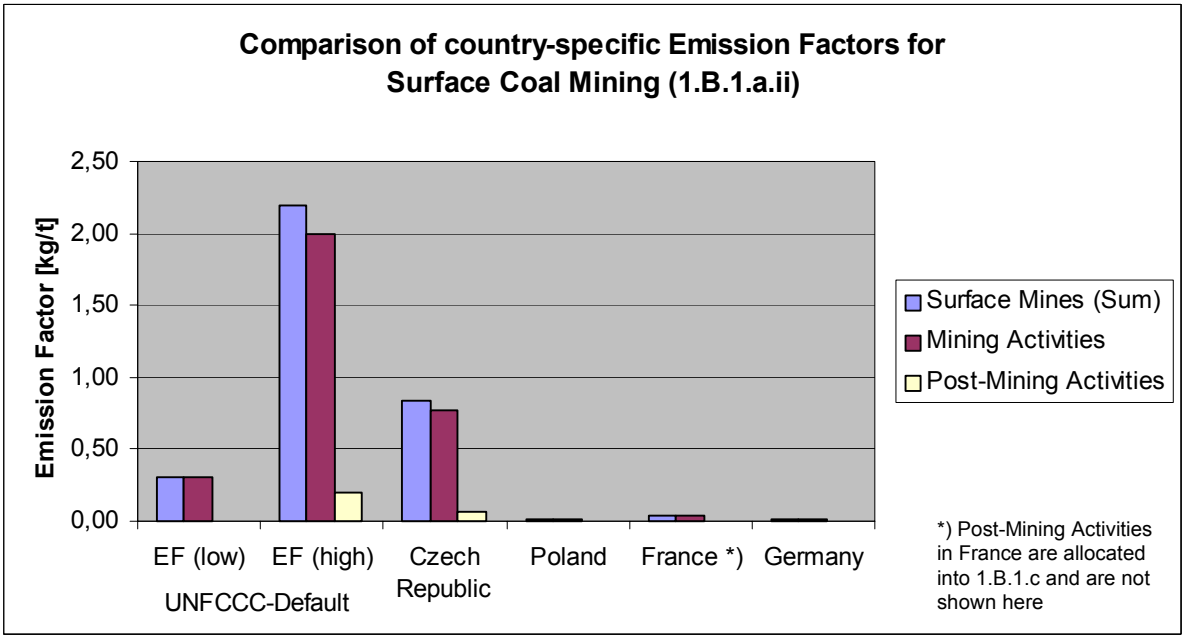


Figure 64: Comparison of country-specific emission factors for surface coal mining

14.1.5 Oil and natural gas (1.B.2)

14.1.6 Aviation and marine (1.BU.1/1.BU.2)

14.2 Other detailed methodological descriptions for the source category "industrial processes" (2)

14.2.1 Mineral products (2.A)

14.2.2 Chemical industry (2.B)

14.2.2.1 Chemical industry: Nitric acid production (2.B.2)

14.2.2.1.1 IPCC requirements pertaining to emissions calculation

Nitrous oxide emissions E_{N2O} [kg] are calculated from the activity rate [t HNO_3], a pertinent emission factor [kg N_2O/t HNO_3] and, if applicable, the efficiency and relative operating time of a system for N_2O emissions reduction, with:

$$E_{N2O} = AR \times EF \times (1 - N_2O\text{-reduction factor} \times \text{rel. operating time of reduction system})$$

The relative operating time of the N_2O-reduction system was included so that down time could be taken into account. Alternatively, the entire last term can be included within the EF.

Since EF depend strongly on plant type and on N_2O-reduction method used, emissions for main source groups should be determined at the plant level. To this end, the activity rate and emission factor must be determined in each case, or emissions must be measured in each plant. If the operator provides the data, it must be ensured that adequate QC/QA measures are carried out.

The EF listed in the IPCC Guidance (2000: Tab. 3.8) range from less than 2 to 19 kg N_2O/t HNO_3, and they depend strongly on plant age, plant design and type of NO_x-reduction equipment used. If production data, but no emissions measurements, are available for each plant type, adequate IPCC default values should be used. Activity rates that have been aggregated across different plant types should be used only if more detailed data cannot be obtained.

In determination of plant-specific EF, regular measurements, carried out at different types, are normally able to prevent systematic errors and to provide the desired degree of precision. Normally, it is a good practice to carry out measurements and analyses whenever significant changes in a plant's processes occur that affect the rate at which N_2O is produced. In addition, such measurements should serve the purpose of ensuring that the operational conditions have remained constant. Plant operators should be queried annually regarding their reduction technologies, and they should confirm that they have indeed used the technologies they have described. For precise determination of emissions rates and efficiencies of N_2O-reduction systems, measurements of both controlled and uncontrolled waste-gas flows must be carried out. Where measurement data is available only for controlled waste gases, it is good practice to base emissions figures on this data. In such cases, estimates of the efficiency of N_2O-reduction systems should be used only for information purposes and should not be used in emissions calculations.

For European systems ("dual pressure, double absorption"), 8-10 kg N_2O/t is proposed as the default value; for older systems dating from before 1975, 10-19 kg N_2O/t is proposed. Non-selective catalytic reduction (NSCR) for reducing NO_x emissions also destroys N_2O, and the relevant reduction rate is given as 80-90%. Other methods for NO_x reduction either have no impact on N_2O emissions or can even increase them.

14.2.3 Metal production (2.C)

14.2.3.1 Metal production: Iron and steel production (2.C.1)

14.2.3.1.1 Source-category description (2.C.1)

CRF 2.C.1					
Key source by level (l) / trend (t)		**Gas (key source)**	**1990 – contribution to total emissions**	**2003 – contribution to total emissions**	**Trend**
	- / -				

Gas	CO_2	CH_4	HFCs	PFCs	SF_6	N_2O	NO_X	CO	NMVOC	SO_2
Emission factor[180] (EF)	D	NO	NO	NO	NO	NO	NE	NA	NE	NE
EF uncertainties in %										
Distribution of uncertainties[181]	N									
Method of EF determination[182]	T2									

In 2003, a total of 28.8 million t of raw steel, from ore, was produced in Germany in six integrated steel works. Electric steel production in 2003 amounted to 13.4 million t.

All steel works use sintering systems for agglomeration of charges (ore and aggregates).

14.2.3.1.2 Methodological issues (2.C.1)

The CO_2 emissions are determined in accordance with Tier 2.

For determination of process-related emissions, the mass of the reducing agent used in the blast furnace is multiplied by the relevant carbon content. The carbon fraction that remains dissolved in the pig iron is then deducted from this. The resulting carbon mass is multiplied by 44/12, for calculation of the corresponding amount of CO_2. The CO_2 emissions from electric steel production are added to process-related emissions; they are obtained by multiplying the standard emission factors for electrode consumption with the relevant standard amount of electrode consumption.

The energy-related CO_2 emissions (1.A.2a; cf. Annex, Chapter 14.1.2.1) result as the difference between a) the total amount consisting of inputs of reducing agent, liquid fuels, other fuels, natural gas and coking duff and b) the previously determined process-related emissions.

The input substances can be allocated as follows to energy-related and process-related emissions:

180 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
181 N = Normal, L = Log-normal, T = Triangular, U = Uniform (even distribution)
182 D = IPCC default, RA = Reference approach, T1= IPPC Tier 1, T1a/ T1b/ T1c = IPPC Tier 1a/ 1b/ 1c, T2 = IPPC Tier 2, T3 = IPPC Tier 3, C = CORINAIR, CS = Country-specific, M = Model

Energy: coking duff (sintering plant), 4% of liquid fuels, natural gas

Process (blast furnace): coal, coke, other fuels, liquid fuels

Since in the Tier 2 approach complete transformation of carbon to CO_2 is assumed, no CO emissions can be assigned to this sector.

The database consists of Fachserie 4 Reihe 8.1 of the Federal Statistical Office (DESTATIS, Fachserie 4 Reihe 8.1, 1991-2004: 4. Vierteljahr 2003) in conjunction with Statistisches Jahrbuch der Stahlindustrie (statistical yearbook of the steel industry; Wirtschaftsvereinigung Stahl, VDEh, 2003).

The following table shows process-related / energy-related emissions, and total emissions, for CO_2, in millions of tonnes per year.

Table 114: Process-related and energy-related emissions, and total emissions, per year [Mt CO_2 / a]

Year	Emissions [Mt CO_2 / a]		
	Process	**Energy**	**Total**
1990	46,27	9,11	55,38
1991	45,45	9,88	55,33
1992	44,48	10,03	54,51
1993	41,19	9,49	50,68
1994	44,94	9,92	54,86
1995	44,54	10,32	54,86
1996	40,72	10,35	51,07
1997	44,91	10,89	55,80
1998	43,66	10,87	54,53
1999	40,37	10,20	50,57
2000	45,34	10,61	55,95
2001	43,30	10,13	53,43
2002	43,88	9,82	53,70
2003	45,25	9,67	54,92

14.2.3.1.3 Uncertainties and time-series consistency (2.C.1)

The time series is consistent, since the data is collected on a plant-specific basis and since it has been compiled according to the same method for all years concerned. The uncertainties are very small, since the calculations were carried out with collected – rather than calculated – data.

14.2.3.1.4 Source-specific quality assurance / control and verification (2.C.1)

Measures for standardisation of QC and QA are currently being established.

14.2.3.1.5 Source-specific recalculations (2.C.1)

No recalculations were carried out.

14.2.3.1.6 Planned improvements (source-specific) (2.C.1)

The data obtained with the Tier 2 approach is to be entered into the CSE. This will require cross-checks between the sectors 1.A.2.a and 2.C.1. Emissions of the other relevant gases,

apart from CO_2, remain to be determined. The uncertainties will be quantified when the new approach has become established.

14.2.4 Other production (2.D)

14.2.4.1 Pulp and paper (2.D.1)

The fibre for paper production is produced, via chemical or mechanical processes, either from fresh fibre or from processed recycled paper. A distinction is made between integrated and non-integrated pulp and paper mills. Non-integrated pulp mills (that produce pulp for the market) solely produce pulp for sale on the open market. On the other hand, integrated mills produce both pulp and paper, at integrated sites. A paper mill can either produce paper from fibre material produced at other locations or be integrated within complete pulping processes set up at one site.

Sulphate pulp mills normally operate in both integrated and non-integrated modes, whereas sulphite pulp mills are normally only integrated – i.e. part of paper-production chains. In most cases, paper production includes both mechanical pulping and used-paper processing, although in some cases such processes are carried out separately.

14.2.4.1.1 Fibre production processes

The **sulphate process** is the world's most common pulping process, since it yields higher pulp strengths and can be used with all types of wood. In the two German plants, carbonate is extracted from the circulation of lye via bonding with calcium (causticising) and then, in a separate lime oven, is burned to burnt lime, a process that releases CO_2; the burnt lime is then reused for causticising. Pursuant to the *IPCC Good Practice Guidelines*, CO_2 released from $CaCO_3$ is assigned an emission factor of "0", since all of its carbon comes from pulped wood. Calcium loss from the cycle is compensated for solely via addition of burnt lime and thus, for the present purposes, also does not lead to report-relevant CO_2 emissions (the CO_2 released in production of burnt lime is already included in the figures for the lime industry (CRF 2A2)).

This process produces atmospheric emissions in lye recovery (boilers), in bark combustion, in wood-chip storage, in pulp digestion, in pulp washing, in bleaching, in bleach-chemical processing, in evaporation, in sorting and washing, in processing of circulating water and in operation of various types of tanks. Such emissions include fugitive emissions that occur at various processing points – primarily in lye-recovery boilers, lime ovens and auxiliary boilers. The main components of emissions include nitrogen oxides, sulphur-containing compounds, such as sulphur dioxide, and foul-smelling reduced sulphur compounds.

The German system is fitted with a system for post-incineration of foul-smelling sulphur compounds and with a system for NO_x-reduced combustion in lye-recovery boilers (>20% NO_x reduction).[183]

Other types of emissions-reduction equipment are not yet being used in Germany:

- Scrubbers downstream from recovery boilers (>85% SO_2 reduction)
- SNCR equipment for NO_x reduction downstream from the auxiliary boiler (>30% NO_x reduction)

- SNCR equipment for NOx reduction downstream from the recovery boiler (>30% NOx reduction)
- NOx-reduction systems for combustion in auxiliary boilers (>20% NO_x reduction) [183]

Sulphite pulp is produced in 4 of 5 systems in Germany. In such plants, pulping is carried out with various chemicals. The sulphate process and the sulphite process have numerous similarities, including similarities with regard to possibilities for using various internal and external measures to reduce emissions. From the standpoint of environmental protection, the main differences between the two pulp-production processes have to do with chemical aspects of the boiling process, with aspects of preparation and post-processing of chemicals and with bleaching intensity – bleaching in sulphite plants is less intensive, since sulphite pulp is whiter than sulphate pulp.

Atmospheric emissions occur especially in lye recovery (boilers) and in bark combustion. Waste-gas emissions with less-concentrated SO_2 are released in washing and sorting processes, and they are released by ventilation shafts of evaporators and by various tanks. Such emissions escape – in part, as fugitive emissions – at various points of the process. They consist primarily of sulphur dioxide, nitrogen oxides and dust.

A number of measures are available for reducing consumption of fresh steam and electrical energy and for increasing internal generation of steam and electricity at plants. Sulphite pulp mills can generate their own heat and electricity by using the thermal energy in concentrated lye, bark and waste wood. Integrated plants require additional amounts of steam and electricity, however; these additional amounts can be generated in either in on-site facilities or at off-site locations. Integrated sulphite pulp and paper mills consume 18 - 24 GJ of process heat, and 1.2 – 1.5 MWh of electrical energy, per tonne of pulp.

All four plants in Germany are operated with SO_2 scrubbers fitted downstream from recovery boilers (>98% SO_2 reduction). One plant is fitted with equipment for NO_x-reduced combustion in recovery and auxiliary boilers (total of >40% NO_x reduction)[183].

Other types of emissions-reduction equipment are not yet being used in Germany:

- SNCR equipment for NO_x reduction downstream from the auxiliary boiler (>30% NOx reduction)
- SNCR equipment for NOx reduction downstream from the recovery boiler (>30% NO_x reduction)[183]

Wood pulp

Wood pulp is produced in 9 plants in Germany. In mechanical pulping, wood fibres are separated from each other via mechanical energy applied to the wood matrix. This process is designed to conserve most of the lignin in the wood, in order to maximise yields while ensuring that the pulp has adequate strength and whiteness. Two main processes are differentiated:

- The wood-grinding process, in which wood logs are wettened and pressed against a rotating grinder, and
- The refiner process, in which wood chips are broken down into fibres in disk refiners.

[183] Figures of the Verband Deutscher Papierfabriken (VDP; German Pulp and Paper Association), September 2004

Wood-pulp properties can be influenced by increasing the process temperature and, in the case of the refiner process, by chemical pre-treatment of the wood chips. The pulping process in which wood is chemically pre-softened and then broken down into fibres, under pressure, is known as chemical-thermal-mechanical pulping (CTMP).

In most cases, the waste-gas emissions consist of emissions from heat and energy generation in auxiliary boilers and of emissions of volatile organic carbon (VOC). VOC emissions occur in storage of wood chips, in air removal from containers for washing wood chips and in air removal from other containers. They also occur in connection with condensates that are produced in recovery of steam from refiners and contaminated with volatile wood components. Some of these emissions are released as fugitive emissions, from various parts of mills.

The best available technologies for reducing waste-gas emissions include effective recovery of heat from refiners and reduction of VOC emissions from contaminated steam. Along with VOC emissions, mechanical pulping produces waste-gas emissions from on-site energy generation (i.e. non-process-related emissions). Heat and electricity are generated through combustion of various fossil fuels and wood residues (the latter is a renewable resource). The best available technologies for auxiliary boilers are described below.

Recycled fibre

In general, processes that use recycled fibres (processes for processing used paper) can be divided into two main categories:

- Processes that use solely mechanical cleaning, i.e. processes that use no de-inking. Such processes are used for production of test liners, fluting, carton and cardboard.
- Processes that use mechanical and chemical technologies, i.e. that include de-inking. Such processes are used for production of newsprint, tissue, printing and copier paper, magazine papers (SC/LWC) and for some types of carton and commercial DIP (de-inked recycled paper).

The raw materials for paper production from recycled fibre include recycled paper (main component), water, chemical additives and energy in the form of steam and electricity. Waste-gas emissions occur primarily in energy generation through fossil-fuel combustion, in power stations.

Waste-gas emissions from mills that process recycled paper occur primarily in systems for heat production; in some cases, they are also produced by combined heat/power generation (CHP) systems. For this reason, energy efficiency is closely linked to reductions of waste-gas emissions. The energy-generation systems in such mills normally use standard boilers, and thus they may be considered truly similar to all other such power plants. The following measures are considered the best available techniques for reducing energy consumption and emissions into the atmosphere: heat-power cogeneration, modernisation of existing boilers and retrofits (in connection swith replacement investments) with more energy-efficient systems.

Energy-efficient mills for processing recycled paper consume about the following amounts of process heat and electrical energy:

- Integrated mills that process recycled paper, without de-inking (for example, for production of test liners and fluting): 6 – 6.5 GJ/t process heat and 0.7 – 0.8 MWh/t electrical energy;

- Integrated mills for tissue production, with DIP systems: 7 -12 GJ/t process heat and 1 – 1.4 MWh/t electrical energy;
- Integrated mills for production of newsprint, and integrated mills for production of printing and writing paper, and including DIP systems: 4 – 6.5 GJ/t process heat and 1 – 1.5 MWh/t electrical energy.

14.2.4.1.2 Paper and carton production

Paper is made from fibre materials, water and chemical additives. The entire paper-making process consumes large amounts of energy. Electricity is required primarily for operation of various motors and for grinding of fibres. Process heat is used primarily for heating water, other liquids and air, for evaporating water in dry areas of paper machines and for converting steam into electrical energy (with heat/power cogeneration). Large amounts of water are required as process water and for cooling. Various additives are used in paper production, as process aids and to enhance product properties (paper additives).

Most of the waste-gas emissions produced by non-integrated paper mills are emitted by steam-production and energy-generation systems. The boilers used in such systems are standard boilers that do not differ from those of other combustion systems. It is assumed that such systems are operated in the same manner as other auxiliary boilers of the same capacity (see below).

Energy-efficient, non-integrated paper mills consume about the following amounts of heat and energy:

- Non-integrated mills for production of uncoated fine paper consume process heat at a rate of 7 – 7.5 GJ/t and energy at a rate of 0.6 – 0.7 MWh/t;
- Non-integrated mills for production of coated fine paper consume process heat at a rate of 7 – -8 GJ/t and energy at a rate of 0.7 – 0.9 MWh/t;
- Non-integrated mills for production of tissue from fresh fibre consume process heat at rate of 5.5– 7.5 GJ/t and electrical energy at a rate of 0.6 – 1.1 MWh/t.

Auxiliary boilers

In considering waste-gas emissions from auxiliary boilers, one must take account of the actual energy balance of the pulp or paper mill concerned, the nature of the fuels that are supplied to the facility and any use of biomass fuels such as bark and waste wood. Pulp and paper mills that produce fibre materials from primary fibres normally use bark-fired boilers. Non-integrated paper mills, and mills that process recycled paper, generate waste-gas emissions primarily via their steam-production and/or energy-generation systems. Such systems normally consist of standard boilers that do not differ from those of other combustion systems. It is assumed that such systems are operated in the same manner in which all other systems of the same capacity are operated. The technologies involved include:

- Heat/power cogeneration, where the prevailing heat/power ratio permits;
- Use of renewable fuels, such as wood and any waste wood that is produced, in order to reduce emissions of fossil CO_2;
- Reduction of NO_x emissions from auxiliary boilers, via control of combustion conditions and installation of burners with low NO_x emissions;
- Reduction of SO_2 emissions through use of bark, gas and low-sulphur fuels, and via waste-gas scrubbing to remove sulphur compounds;

- Use of effective electrical filters (or tube filters) to separate dust in auxiliary boilers fired with solid fuels.

Overall, most product-specific waste-gas emissions are site-dependent (for example, they depend on the type of fuel used, the size and type of the relevant facility, whether the plant is integrated or non-integrated, whether it generates electricity). The auxiliary boilers used in Germany cover a wide spectrum of different sizes (from 10 to more than 200 MW). With smaller boilers, the only useful approach is to use low-sulphur fuels and the pertinent combustion technologies, while secondary reduction measures can also be effective with larger boilers.

14.2.5 Refrigeration and air-conditioning systems (2.F.1)

14.2.5.1 Procedure for calculating emissions from the sub-categories pertaining to "refrigeration and stationary air-conditioning systems"

The "household" refrigeration model

1. Determination and aggregation of annual HFC additions since introduction of HFCs (1993)
2. Calculation of annual HFC emissions on the basis of the average size of stocks and of the relevant EF
3. Production and disposal: NO

Refrigeration model for "commercial refrigeration systems"

1. The entire sub-category of commercial refrigeration is divided into numerous system categories. Divisions are based on areas of application (for example, small supermarket) and on system type (for example, central system).
2. For each system category, the number of systems and installed refrigeration output, divided into the categories of low-temperature refrigeration and normal refrigeration, are determined and used as constants. The percentages of systems that are filled with CFCs, HFCs and halogen-free refrigerants are also assumed to be constant. This yields the numbers and installed refrigeration output of all systems that are operated, in the long term, with HFCs (following complete conversion/replacement of old CFC-based systems).
3. For each system category, the relevant refrigerant type, and the refrigerant amount per unit of refrigeration output, are determined.
4. From the data obtained via 1 to 3 above, the target stocks for each refrigerant are determined. Due to the large differences involved, a distinction is made between target stocks for the category "food sales" and those for "other commercial refrigeration".
5. The target stocks, in connection with the average system service lifetimes (10 years), can then be used to calculate, for both areas, how much refrigerant must be filled annually into new systems (new additions) in order to maintain stocks in the face of removals of old systems (1/10 of stocks). The "average yearly stocks" can also be determined for both areas.
6. Replacement of CFC-based systems is considered separately.

7. Production emissions are calculated by multiplying "new additions" by $EF_{production}$. Production normally takes place at the relevant sites.

8. Emissions from stocks are obtained by multiplying the "average yearly stocks" by the relevant EF_{use}.

9. Disposal emissions occurred for the first time in 2003. $EF_{disposal}$ = 0.3-0.5.

The EF on which the emissions data is based (except for $EF_{disposal}$) are shown in Table 51.

Except for $EF_{disposal}$, the emission factors used are the result of surveys of experts and of evaluations of the literature. It should be noted that emission factors have been adapted in line with technical developments for the various reporting years.

"Transport refrigeration / refrigerated vehicles" refrigeration model

1. The entire sub-category of transport refrigeration / refrigerated vehicles is divided into four size classes of refrigerated vehicles: 2-5t, 5-9t, 9-22t and > 22t total vehicle weight.

2. Fixed amounts of refrigerants (types), and fixed fill amounts in refrigeration units, are assigned to the various size classes. A fixed share of the market is also assigned to each size class.

3. The number of newly licensed refrigerated vehicles, and the number of refrigerated vehicles filled within the country (broken down by refrigerants), are determined for each year.

4. The annual new additions of refrigerants result from the numbers of newly licensed refrigerated vehicles and the above assumptions.

5. When one knows the existing stocks, one can calculate the average yearly stocks and the year-end stocks.

6. Production emissions are calculated by multiplying the "domestically filled refrigerated vehicles" (for each refrigerant type) by the relevant $EF_{production}$.

7. Emissions from stocks are obtained by multiplying the "average yearly stocks" by the relevant EF_{use}.

8. Disposal emissions occurred for the first time in 2003. $EF_{disposal}$ = 0.3.

The EF on which the emissions data is based (except for $EF_{disposal}$) are listed in Table 51.

Except for $EF_{disposal}$, the emission factors used are the result of surveys of experts. It should be noted that emission factors have been adapted in line with technical developments for the various reporting years.

Refrigeration model for "industrial refrigeration systems"

1. The entire sub-category of industrial refrigeration is divided into numerous system categories. Division is in accordance with industrial sectors and refrigeration levels (normal refrigeration, low-temperature refrigeration and freezing).

2. For each system type, the numbers of systems in service, and the pertinent installed refrigeration output, are assumed to be constant. The percentages of systems that are

filled with CFCs, HFCs and halogen-free refrigerants are also assumed to be constant. This yields the numbers and installed refrigeration output of all systems that are operated, in the long term, with HFCs (following complete conversion/replacement of old CFC-based systems).

3. For each system type, the relevant refrigerant type, and the refrigerant amount per unit of refrigeration output, are determined.

4. From the data obtained via 1 to 3 above, the target stocks for each refrigerant are determined.

5. The target stocks, in connection with the average system service lifetimes (10 years), can then be used to calculate how much refrigerant must be filled annually into new systems (new additions) in order to maintain stocks in the face of removals of old systems (1/10 of stocks). The "average yearly stocks" can also be determined.

6. Replacement of CFC-based systems is considered separately.

7. Production emissions are calculated by multiplying "new additions" by $EF_{production}$. Production normally takes place at the relevant sites.

8. Emissions from stocks are obtained by multiplying the "average yearly stocks" by the relevant EF_{use}.

9. Disposal emissions occurred for the first time in 2003. $EF_{disposal} = 0.3$.

The EF on which the emissions data is based (except for $EF_{disposal}$) are listed in Table 51.

Except for $EF_{disposal}$, the emission factors used are the result of surveys of experts. It should be noted that emission factors have been adapted in line with technical developments for the various reporting years.

Refrigeration model for "stationary air-conditioning systems"

1. Stationary air-conditioning systems are divided into three categories. The number of new systems in each category is determined each year via surveys of experts: Turbo-compressor, screw-compressor, and scroll-compressor and piston-compresor systems. Imports of systems already filled with refrigerant are assumed to be zero.

2. For each category, a certain fill amount and refrigerant composition is assumed.

3. The annual new additions of refrigerant result from the new additions of systems and the above assumptions.

4. When one knows the existing stocks, one can calculate the average yearly stocks and the year-end stocks.

5. Production emissions are calculated by multiplying "number of new systems" by $EF_{production}$.

6. Emissions from stocks are obtained by multiplying the "average yearly stocks" by the relevant EF_{use}.

7. No disposal emissions have occurred to date.

The factors on which the emissions data is based are listed in Table 51.

The emission factors used are the result of surveys of experts. It should be noted that emission factors have been adapted in line with technical developments for the various reporting years.

Refrigeration model for "room air-conditioners"

1. There is no domestic production of room air-conditioners. Room air-conditioners, all of which are imported, are divided into three categories. Annual sales in each category are determined via surveys of sellers: mobile devices, split devices, multi-split devices.
2. For each category, a certain fill amount and refrigerant composition is assumed.
3. The annual new additions of refrigerant result from the sales statistics and the above assumptions.
4. When one knows the existing stocks, one can calculate the average yearly stocks and the year-end stocks.
5. There are no production emissions (losses in installation of split and multi-split devices have not been considered in the model to date).
6. Emissions from stocks are obtained by multiplying the "average yearly stocks" by the relevant EF_{use}.
7. No disposal emissions have occurred to date.

The factors on which the emissions data is based are listed in Table 51.

14.2.5.2 Procedure for calculating emissions of "mobile air-conditioning systems"

The following procedure is used to calculate HFC emissions (only HFC-134a) from mobile air-conditioning systems:

1. Determination of annual numbers of newly licensed vehicles, for the classes of automobiles, trucks, buses and agricultural machines.
2. Determination of the average rates of installation of air-conditioners in automobiles, trucks buses and agricultural machines. For automobiles, the average rate is based on figures for each vehicle type; these are supplemented as appropriate with figures of industry experts.
3. Determination of the average fill amounts (refrigerant), from figures for each vehicle type (automobiles) and from figures provided by industry experts.
4. Determination of numbers of air-conditioning systems newly installed each year on ships (on the basis of statistics on new ship construction for the German fleet) and in railway vehicles (on the basis of new procurements by German Railways / Deutsche Bahn), and determination of the relevant fill amounts involved.
5. Determination of the annual new additions of 134a, for each pertinent area, from previous figures.

6. Determination of average yearly stocks, and of year-end stocks, for each relevant area, from 5. and the pertinent amounts for the previous year.

7. Emissions from stocks are obtained by multiplying the "average yearly stocks", for each area, by the relevant EF_{use}.

8. Determination of domestic consumption of 134a for production of mobile air-conditioning systems.

9. Production emissions are calculated by multiplying the "domestic consumption" by $EF_{production}$.

10. Disposal emissions occurred for the first time in 2003. $EF_{disposal}$ = 0.25-0.3.

The factors on which the emissions data is based are listed in Table 51.

The emission factors used were obtained from the literature (e.g. Clodic and Yahia, 1997; Fischer, 1997; Öko-Recherche, 2001; Öko-Recherche / Ecofys 2003; Preisegger, 1999; Siegl et al., 2002), as well as via measurements (automobiles), evaluations of workshop documentation and comprehensive surveys of experts. (In addition to regular emissions during operation, emissions also arise as a result of accidents and other external influences.)

14.3 Other detailed methodological descriptions for the source category "solvent and other product use" (3)

14.4 Other detailed methodological descriptions for the source category "agriculture" (4)

14.4.1 Agriculture (4) – Information on steps for improving future inventories

- Collection of regional data, especially with regard to frequency distribution in connection with keeping of farm animals
- Collection of regional data on use of mineral fertilisers
- Enhancement of spatial resolution of data on emissions of reactive gases (CH_4,NO)
- Development of procedures, adapted to German data sets, for determining CH_4 emissions from enteric fermentation as a function of yields and feeding, for the most important animal categories
- Inclusion of immobilisation and mobilisation of N-species in manure management in connection with straw-based procedures
- Inclusion of procedures for biogas collection
- Enhancement of chronological resolution, to one month, of data on emissions of reactive gases (especially NH_3)

14.4.2 Agriculture (4) – information on forecasts of agricultural emissions

At a meeting in Luxembourg on 26 June 2003, the ministers of agriculture of the European Union approved a far-reaching reform of the Common Agricultural Policy. This reform permits numerous options. At the time the present report was prepared, the various degrees of national latitude could not yet be estimated. Several months are expected to pass before

administrative directions are issued. Extension income redistributions are expected; these are likely to lead to considerable changes, especially in numbers of cattle. In light of the importance of cattle farming with regard to methane and ammonia emissions, neither any scenario modelling nor extrapolation of the *status quo* seems at all useful.

14.4.3 Calculation of losses of gaseous N-species using the mass-flow procedure (4.B)

The mass-flow procedure traces the flow of all nitrogen deposited in manure and urine – as total N, as total ammoniacal nitrogen (TAN) and as organically bound nitrogen (N_{org}) (cf. Figure 65). The substance flow is divided into flows for pasturing and stabling. The flow for stabling takes into account the keeping procedures commonly used in Germany for liquid-manure and straw-based systems and assumes that the relevant quantities occurring with both types are stored in the storage facilities commonly used in Germany. All N in straw is N_{org}. In stalls, straw immobilises some TAN. In stalls, liquid manure and manure are produced. These products are stored separately, in liquid-manure storage facilities and in solid-manure storage facilities. During storage, part of the N_{org} is mineralised to TAN. Emissions from stalls, from storage and from spreading (broad red arrow) are fed solely from the TAN stocks. Where animals are integrated in liquid-manure systems, the left side of the diagram applies by analogy, with no immobilisation.

The periods required for working manure into the soil are taken into account. The TAN fraction (total ammoniacal nitrogen) is considered as the source for NH_3, N_2O, NO and N_2.

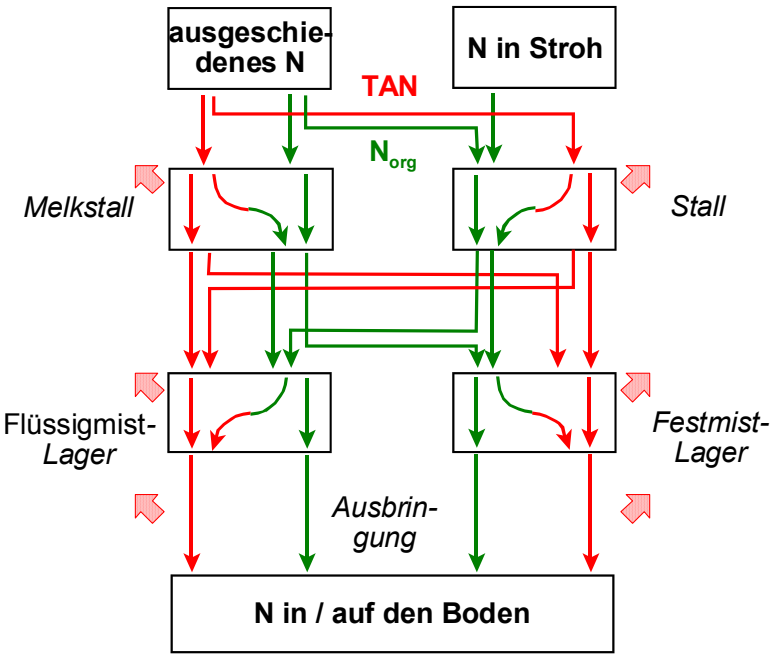


Figure 65: Nitrogen flows in animal husbandry[184]

[184] Translation (clockwise from top left): excreted N; N in straw; Stall; Solid-manure storage; N in/on the soil; Spreading; Liquid-manure storage; Milking stall]

14.5 Other detailed methodological descriptions for the source/sink category Land-use change and forestry (5)

14.5.1 Land-use changes and forestry (5.A)

The C stocks in forest biomass, and their changes, were derived, under commission to the Federal Ministry of Consumer Protection, Food and Agriculture (BMVEL), by the Biometry and Information Science department of Baden-Württemberg's Institute for forestry experimentation and research (Forstliche Versuchs- und Forschungsanstalt (FVA), from Federal Forest Inventory data and are in keeping with the provisions of the Good Practice Guidance relative to Land-Use, Land-Use Change and Forestry (GPG-LULUCF, IPCC, 2003).

The C-stock changes in dead wood, debris and forest soils, and the other greenhouse-gas emissions from forests and forest conversion, were not estimated, since complete relevant data and evaluations are not yet available. The provisional assessments made in this regard have been made by the Federal Ministry of Consumer Protection, Food and Agriculture (BMVEL).

14.5.1.1 Forest

The basis for reporting consists of the definition of "forest" used by the Federal Forest Inventory (Bundeswaldinventur - BWI)[185].

The BWI's survey instructions differentiate between the following sub-categories of forest:

- Productive forest, wooded ground
- Unproductive forest, wooded ground
- Forest, opening
- Forest, non-wooded ground

In calculations for greenhouse-gas inventories, the categories **unproductive forest** and **openings** were included with forest, while **non-wooded ground**, in keeping with the definition of "forest" used in decision 11/CP.7 of the 7th Conference of the Parties in Marrakesh (UNFCCC, 2002: p. 58) was excluded, as non-forest.

Unproductive forest areas are fields of dwarf pines and green alders, areas of shrubs (but not openings) and other forest areas which are sparsely covered or which have low productivity (≤1 m³ average total growth (dGZ)/hectare).

[185] Forest within the meaning of the FFI is any area of ground covered by forest vegetation, irrespective of the information in the cadastral survey or similar records. The term forest also refers to cutover or thinned areas, forest tracks, firebreaks, openings and clearings, forest glades, feeding grounds for game, landings, rides located in the forest, further areas linked to and serving the forest including areas with recreation facilities, overgrown heaths and moorland, overgrown former pastures, alpine pastures and rough pastures, as well as areas of dwarf pines and green alders. Heaths, moorland, pastures, alpine pastures and rough pastures are considered to be overgrown if the natural forest cover has reached an average age of five years and if at least 50% of the area is covered by forest. Watercourses up to 5 m wide do not break the continuity of a forest area. The cultivation of Christmas trees and ornamental brushwood in the forest is forest within the meaning of the Federal Forest Inventory (BWI). Areas with forest cover in open pasture land or in built-up areas of under 1000 m², coppices under 10 m wide and the cultivation of Christmas trees and ornamental brushwood as well as parkland attached to country houses are **not forest** within the meaning of the FFI.

The **wooded-ground area** is that part of the forest that is covered with trees used in forestry and that is used for wood production.

Non-wooded ground includes forest tracks, rides and firebreaks over 5 m wide, landings, tree nurseries, seed and plant nurseries, wood-pastures and fields for game, the areas of yards and buildings used for forestry purposes, recreational facilities linked to the forest and rocks, boulders, gravel and water located in the forest. In addition, if they are not overgrown, swamps and moors located in the forest come under non-wooded ground.

In the GPG-LULUCF (IPCC, 2003), and in the official reporting tables for the greenhouse-gas inventories sent to the Climate Secretariat (CRF), the category "forest" is divided into "Forest Land remaining Forest land" (forest that remains forest during the period covered by the report) and "Land converted to Forest Land" (new forest created, via afforestation or natural succession, on areas previously used for other purposes). Pursuant to IPCC GPG-LULUCF (2003), new forest remains for at least 20 years within this category, after which it is transferred to the "remaining forest land" category.[186]

In Germany, with existing data, new forest additions in the old German Länder can be traced only back to 1987; for the new German Länder, it has been possible only to derive the net new forest since 1993.

14.5.1.1.1 Forest Land remaining Forest Land

14.5.1.1.1.1 Source-category description

14.5.1.1.1.1.1 Changes in biomass

For the old German Länder, data is available from two federal forest inventories (key dates: 1 October 1987 and 1 October 2002). Between the two forest inventories, C stocks in forests of the old German Länder underwent a net increase of 1.52 Mg/ha/a. The increase in stocks is a result of low use, in comparison to growth. For the new German Länder, data from the Federal Forest Inventory II (BWI II) was compared with forest-establishment data, given the lack of an initial inventory comparable to BWI I. The comparison showed a marked net C-stock increase of 3.01 MgC/ha/a.

The forest-establishment data is not completely suited for comparison with the Federal Forest Inventory (BWI). It seems clear that the forest-establishment data underestimates stocks. If the initial value for total stocks is assumed to be 10 % higher (and evenly distributed among all tree species), a marked net C-stock increase of 2.32 MgC/ha/a results.

Overall, the forests of the Federal Republic of Germany are thus a net sink for C.

14.5.1.1.1.1.2 Dead wood, debris and soils

The deadwood stocks of 11.5 m^3/ha found by the BWI II correspond to C stocks of some 2.6 Mg C /ha. Federal Forest Inventory I (BWI I) did not collect data on dead wood, and thus no conclusions can be drawn regarding changes in stocks.

[186] Countries may choose to remain for longer periods of time in this category, if that seems appropriate to them in light of the time required, under their typical local conditions, for all compartments, including soil, to achieve "typical" forest conditions relative to carbon stocks and its changes.

On the whole, more dead wood is now left in forests than was left in the 1950s to 1980s. The reasons for this include changes in demand in the wood market, changes in wood-harvesting methods and an interest in protecting forest biotopes. Storm damage in 1990 and 1999 sharply increased dead wood stocks in some regions. For this reason, it may be assumed that dead wood stocks tended to increase, rather than decrease, between 1990 and 2002.

The inventories did not include a complete survey of debris. Finer debris fractions are part of the humus layer, which was surveyed by the forest-soil-condition survey (BZE).

The BZE estimated the carbon stocks in the humus layer, and in the first 30 cm of mineral soil lying beneath the humus layer, as amounting to about 0.858 Pg C. No conclusions can be drawn regarding changes in stocks, since a subsequent inventory remains to be carried out.

For purposes of greenhouse-gas inventories, therefore, changes in dead wood, debris and soil were neglected, in keeping with the Tier 1 assumption that such stocks do not change in existing forests.

14.5.1.1.1.1.3 Other greenhouse-gas emissions from forests

Figures for CO_2 emissions from liming of forest floors are provided in category 5.G (Other). They range between 130 and 210 Gg CO_2 per year, and are tending to decrease.

BUTTERBACH-BAHL (2003), using the PnET-N-DNDC model, estimated total nitrous oxide (N_2O) emissions from forest soils for the years 1990-1999 as amounting to about 14 Gg per year. This includes the effects of considerable nitrogen discharges from deposition of nitrogen compounds, from emissions of industry, and from the energy, residential, transport and agriculture sectors.

These "indirect" N_2O emissions, which must be assigned to sources outside of the forestry sector, are outside the scope of greenhouse-gas inventories in the area of land-use changes and forestry, however. Reporting in this area includes only N_2O emissions from nitrogen fertilisation of forest soils and from drainage of forest soils.

Forests in Germany are not normally given nitrogen fertilisers. In CRF Table 5(I), therefore, this activity has been marked "NO".

In the 19th and early 20th centuries, many wet locations were drained and afforested, and forested wet locations were "ameliorated", via drainage, in order to increase yields. Some of the drainage ditches from that era are still present in today's forests. In addition, in the second half of the 20th century, areas were afforested that had previously been drained as a means of obtaining or enhancing agricultural land. There is a lack of reliable data for reporting on this category, however (CRF 5(II)).

N_2O, CH_4, NO_x, CO and other gases are released in forest fires and in controlled burning of biomass (for example, in burning-off of logged areas following wood harvesting).

The areas in which forest fires occur in Germany are small and, since surveys commenced, have decreased markedly as a result of improved forest-fire prevention and response. Only in 2003, a year with months of continuing dryness and extreme heat, did they increase again.

Table 115: Areas affected by forest fires [ha]

1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
3.267	1.493	1.114	592	1.381	599	397	415	581	122	122	1.315

Forest-fire statistics (BML 1992 ff., Part G., Table „Waldbrände und ihre Ursachen“ ("Forest fires and their causes")) unfortunately include no data on the amounts of biomass effectively burned; such data would at least support rought estimates, in keeping with "Tier 1", of the relevant amounts of gases released. In light of the small size of the areas in question, this source is considered negligible, and "NO" has been entered in Table 5 (V) "Biomass burning" next to N_2O and CH_4.

This also applies to controlled burning of biomass. Burning-off of vegetated areas is prohibited in Germany. Burning of unusable crown parts and branches is carried out in exceptional cases, in combatting of bark beetles. Increasingly, other methods (chopping, crushing) are also being used for this purpose.

As a result of use of the "stock-change method" (cf. Chapter 7.1.1.2.3), CO_2 from biomass combustion has already been taken into account in changes of biomass stocks; the entry for this category is thus "IE".

14.5.1.1.1.2 Methodological issues

14.5.1.1.1.2.1 Data sources

The basis for the biomass and area calculations consists of the data from the two Federal Forest Inventories. Pursuant to provisions of the IPCC GPG-LULUCF (2003), this data is processed in keeping with requirements pertaining to international reporting obligations.

The Federal Forest Inventory is a terrestrial random-sampling inventory with permanently marked sampling points. Data collection is carried out at the corners of about 44,000 quadratic plots, with side lengths of 150 m, that are distributed systematically throughout the entire country. As in the first Federal Forest Inventory, random sampling is distributed throughout a 4 x 4 km basic grid whose resolution may be increased, at Länder request, on a regional basis. A double random-sampling density is used in parts of Bavaria, Lower Saxony and Thuringia, and a quadruple sampling density is used in the Länder Baden-Württemberg, Mecklenburg-West Pomerania, Schleswig-Holstein and Rhineland-Palatinate[187].

The first Federal Forest Inventory, BWI I, covered only the territory of the Federal Republic of Germany in its pre-1990 boundaries and West berlin. For the new German Länder, therefore, forest-establishment data has to be taken from another source – the publication "The Forest in the New German Länder" ("Der Wald in den neuen Bundesländern" (BML, 1994)).

Due to the differences in the data situations for the two areas, and to the resulting need to use different calculation methods, reporting in the CRF tables is broken down by old and new German Länder.

The Federal Forest Inventory II (BWI II) took a first accounting of dead wood, and thus no information can yet be provided regarding changes in dead-wood stocks. The dead-wood stocks of 11.5 m^3/ha found by the BWI II correspond to C stocks of some 2.6 Mg C /ha.

[187] Further information: http://www.bundeswaldinventur.de

The first soil condition survey, which was carried out from 1987 to 1993 (BMELF, 1997), supports estimates of carbon stocks in humus layers and mineral soils; it does not support estimates regarding changes in such stocks, however. These carbon stocks (humus layer and the first 30 cm of mineral soil) were estimated at about 0.858 Pg C (BMELF, 1997).

Data on liming of forest soils was derived from fertiliser statistics (Düngemittelstatistik) (DESTATIS, 2003). Until 1992/93, the results published by the Federal Statistical Office referred to the territorial status of the former Federal Republic of Germany. For the territory of the former GDR, the Federal Ministry of Consumer Protection, Food and Agriculture (BMVEL) adapted data for the years 1950 to 1989, based on GDR statistics, to the fertiliser-statistics categories of the Federal Republic of Germany, to facilitate comparison. Due to a lack of relevant surveys, data on fertiliser consumption in the former GDR during the years 1990-1992 was extrapolated linearly. From 1993/94 onwards, the results have been collected and published for unified Germany.

Since 1992, data on areas on which forest fires have occurred is available in official forest-fire statistics pursuant to Council Regulation (EEC) No. 2158/92 of 23 July 1992 on protection of the Community's forests against fire.

14.5.1.1.1.2.2 Forest land remaining as forest land

Forest-area data is not required for calculation of biomass stocks pursuant to the "stock-change method", but it must be reported in the CRF. The area data for individual years is based on linear interpolation.

For the old German Länder, such data can be derived from the results of the two Federal Forest Inventories. In that region, the total forest area (not including non-wooded ground) increased by 54.12 kha, to 7,693.72 kha. Pursuant to IPCC GPG-LULUCF (2003), new forest must be classified as "new forest" for a period of 20 years, and thus each year the category "forest land remaining forest land" is reduced by that forest area converted to other land uses. As a result, the category "forest land remaining forest land" decreased from 7,626.14 kha (1990) to 7,572.27 kha (2002).

The only recourse for the new German Länder, therefore, is to compare BWI II data and forest-establishment data from the publication "The Forest in the New German Länder" ("Der Wald in den neuen Bundesländern" (BML, 1994)).

According to forest-establishment data, in the new German Länder, the forest area (not including non-wooded ground) in 1993 amounted to 2,852.5 kha; by BWI II it had increased to 3,027 kha. As a result, the first of these values can assigned to the category "forest land remaining forest land".

14.5.1.1.1.2.3 Derivation of stock changes pursuant to the "stock-change method" (difference method)

The Federal Forest Inventories provide an outstanding database for calculating C stocks and their changes. They provide such good data for calculation – measuring about 230,000 trees in key year 1987 (BWI I) and some 377,000 trees in key year 2002 (BWI II) – that it was possible to use the "stock-change method" instead of the "default method" (incremental extrapolation, as carried out for previous inventories) (IPCC, 2003: p. 3.24). For use of the "stock-change method", the categories: standing-timber volume, branch wood volume and

root mass were separated. Above-ground volumes were converted into masses using specific basic densities for the various tree species in question. The basic equation (Equation 16 and Equation 17) for C-stock determination via the stock-change method was thus converted into a form pursuant to Equation 18. The first part of Equation 18 (standing timber, branch wood) was applied to each tree, while the second part was applied to stands. The total value was then extrapolated from the stand values.

Equation 16

$$\Delta C = \left(C_{t_2} - C_{t_1}\right)/\left(t_2 - t_1\right)$$

Equation 17

$$C = \left[V \bullet D \bullet BEF\right] \bullet \left(1 + R\right) \bullet CF$$

Equation 18

$$C = \underbrace{[V \bullet D_D}_{\text{Standing timber}} + \underbrace{V \bullet D_A \bullet (VEF - 1)]}_{\text{Branch wood}} \bullet \underbrace{(1 + R)}_{\text{Root wood}} \bullet CF$$

where:
C = carbon stocks
V = volume of standing timber
D_D = basic density of standing timber
D_A = basic density of branches
BEF = biomass-expansion factor
VEF = volume-expansion factor[188]
R = root / sprout relationship
CF = carbon fraction

14.5.1.1.1.2.4 Procedure

For central European conditions, there are no generally valid biomass functions that could have been applied to the inventory's measured data (a function for spruce is one exception). These functions directly yield tree dry masses, usually with the input quantities breast-height diameter (BHD) and height (H). Unfortunately, existing biomass studies comprise only small numbers of random samples, and they represent only local growth and site conditions, along with relevant variations in management. Use of such data would distort extrapolations.

For this reason, a procedure was applied whereby the standing-timber volume, as determined in the inventory, is converted into the above-ground tree volume. The above-ground tree volume includes branches and, for evergreen trees, the leaf organs. To estimate tree wood volumes from standing timber volumes, linear regression equations are used that describe the relationship between above-ground standing-timber volume and the above-ground tree wood volume. These equations (volume-expansion functions) were derived from

[188] The biomass-expansion factor (BEF) is used here in keeping with IPCC. In the literature, the term "BEF" is used in a variety of very different ways. For this reason, in the following, the term "volume-expansion factors" (VEF) is used, which describes the relationship above-ground volume / standing-timber volume.

the tables of GRUNDNER & SCHWAPPACH (1952), which are based on an extensive database comprising 71,051 trees.[189]

In a next step, the trees' above-ground mass was calculated from tree wood volume, via basic density data. A range of different basic density figures were used. Among these are the basic densities of KNIGGE & SCHULZ (1966), as they are used, for example, by BURSCHEL et al. (1993). Other wood-science handbooks, such as BOSSHARD (1984), use density figures of KOLLMANN (1982). The default values pursuant to IPCC (2003) also provide basic densities for many native tree species. Since densities have a direct influence on total carbon stocks, 3 different density extrapolations were used for the individual-tree calculations.

Since above-ground expansion of standing-timber volume into tree wood volume was carried out, the various wood categories can be separated in order to take the higher basic densities of branches (HAKKILa, 1972) into account. Such separation was carried out for densities pursuant to KOLLMANN (1982) and IPCC GPG-LULUCF (2003). In the third extrapolation, the procedure pursuant to BURSCHEL et al. (1993) was methodically applied, with constant basic densities, to above-ground volumes, in order to permit comparison with other scenarios.

The underground living biomass was taken into account via stock-mass relationships. To this end, the above-ground biomass, broken down by tree species, was extrapolated to hectare values for each random-sample point. This value was then used to derive root biomass. Root masses were calculated with the help of two sources (DIETER & ELSASSER, 2002; IPCC, 2003). Overall, three extrapolations for above-ground C stocks, and 6 calculations of underground C stocks, are thus available. In addition, results for spruce can be compared with the general biomass function of WIRTH et al. 2004b. The various calculations may be seen as scenarios that approximate the actual circumstances and that can reveal the range of deviations and their sensitivity.

For the new German Länder, forest-establishment data is available in aggregated form. For this reason, the C-balancing method pursuant to BURSCHEL et al. (1993), in conjunction with basic densities pursuant to KOLLMANN (1982), was used for C-stock determination.

14.5.1.1.1.2.5 Total stocks of remaining forest land

The results described here refer, in connection with individual-tree calculations for BWI I and BWI II, to basic densities pursuant to KOLLMANN (1982), whereas branch volumes, with their greater densities, were extrapolated pursuant to HAKKILA (1972). Above-ground tree volume was estimated with the function coefficients from Table 119. Root biomass was calculated using default values from IPCC GPG-LULUCF (2003). In the extrapolation for the new German Länder for 1993, the biomass-expansion factors (BEF) of BURSCHEL et al. (1993) were separated into above-ground and below-ground components, and the upper branch volume was estimated from the difference between above-ground volume and standing-timber volume. In the interest of comparability between the extrapolation of forest-

[189] Since the regressions describe the relationship between rounded table values, the actual variation is not taken account of, and no true prediction error can be given. Such an error could be given if the original data were available as a base for calculating new tree wood-volume functions.

establishment data and individual-tree calculation pursuant to BWI, the same basic densities were used throughout this process.

Table 116: Total C stocks, remaining forest

Gg C		1987 (BWI I)	1993 (BML)	2002 (BWI II)
Old German Länder	below ground	174.670	-	212.849
	above ground	604.474	-	740.481
	Total	**779.144 (± 8%)**	**-**	**953.330 (± 7,55%)**
New German Länder	below ground	-	34.723	63.690
	above ground	-	161.766	218.667
	Total	**-**	**196.489 (±12,71 %)**	**282.357 (± 10,02 %)**

14.5.1.1.1.2.6 Total stocks in various scenarios

The scenario calculations were carried out only for the individual-tree calculations. The error bar shows the simple standard error. For determination of the 95% confidence interval, this range must be doubled. The bars on the left in each approximately correspond to the values in Table 116, since in these cases the entire forest area (not including non-wooded ground) was considered. The abbreviations are to be understood as follows: the first refers to the above-ground basic density assumptions (Table 117), while the second refers to the underground density assumptions (Table 120, Table 121).

The last scenario in each case is also considerably below the other extrapolations. This is due to an underestimation of basic densities, since, pursuant to Burschel et al. (1993), no separation was made between branch volume and standing-timber volume; such separation would lead to correspondingly higher basic densities for branches.

Figure 66: Total stocks in various scenarios [Gg C] [old German Länder, new German Länder]

14.5.1.1.1.2.7 Basic density of stem (trunk) wood

In light of basic densities' strong influence on carbon balance, various basic densities (i.e. the relationship between dry weight and fresh-wood volume) were used. In two scenarios, the basic densities from KOLLMANN (1982) and IPCC GPG-LULUCF (2003) were used and linked with higher branch densities (see above).

The raw densities pursuant to KOLLMANN (1982: Annex, tables V) give the raw-density ranges and their average values for the most important tree species. These ranges were also used as a basis for error calculation. The basic densities were calculated from the raw densities, via relevant volume-loss measures.

Equation 19

$$R = r_0 * \left(1 - \frac{\beta_V}{100}\right)$$

R= basic density (g/cm^3)
r_0= raw density (g/cm^3)
$ß_V$= volume-loss measure

For comparison, an extrapolation without this branch-wood correction, and with the basic densities used by Burschel et al. (1993) from Knigge & Schulz (1966), was carried out. The resulting basic densities differ only between tree-species groups.

Table 117: Basic densities

		Basic density (R) [g/cm³]					
Genus	**Species**	**Stem (IPCC)**	**Branch (IPCC)**	**Stem (Kollmann)**	**Branch (Kollmann)**	**Knigge Schulz (Branch and stem)**	**βV (%) (Kollmann)**
Picea	**abies**	0,40	0,54	0,3788	0,5093	0,3771	11,9
Picea	**(other)**	0,40	0,54	0,3788	0,5093	0,3771	11,9
Pinus	**sylvestris**	0,42	0,56	0,4307	0,5790	0,4307	12,1
Pinus	**strobus**	0,32	0,43	0,4307	0,5790	0,4307	12,1
Pinus	**(other)**	0,42	0,56	0,4307	0,5790	0,4307	12,1
Abies	**alba**	0,40	0,54	0,3629	0,4878	0,3700	11,5
Abies	**(other)**	0,40	0,54	0,3629	0,4878	0,3700	11,5
Pseudotsuga	**menziesii**	0,45	0,60	0,4141	0,5567	0,4124	11,9
Larix	**decidua**	0,46	0,62	0,4873	0,6551	0,4873	11,4
Larix	**kaempferi**	0,49	0,66	0,4873	0,6551	0,4873	11,4
Thuja	**spec.**	0,31	0,42	0,3788	0,5093	0,3771	11,9
Tsuga	**spec.**	0,42	0,56	0,3788	0,5093	0,3771	11,9
Nadelbäume	**(other)**	0,40	0,54	0,3788	0,5093	0,3771	11,9
Fagus	**sylvatica**	0,58	0,64	0,5583	0,6119	0,5543	17,9
Quercus	**robur**	0,58	0,62	0,5707	0,6056	0,5611	12,2
Quercus	**petraea**	0,58	0,62	0,5707	0,6056	0,5611	12,2
Fraxinus	**exelsior**	0,57	0,60	0,5642	0,5987	0,5642	13,2
Carpinus	**betulus**	0,63	0,69	0,6415	0,7031	0,5642	18,8
Acer	**spec.**	0,52	0,57	0,5222	0,5723	0,5642	11,5
Tilia	**spec.**	0,43	0,47	0,4170	0,4571	0,5642	12,1
Robinia	**pseudoacacia**	0,58	0,64	0,6468	0,7089	0,5642	11,5
Ulmus	**spec.**	0,51	0,54	0,5555	0,5895	0,5642	14,9
Castanea	**sativa**	0,48	0,51	0,5583	0,5924	0,5642	11,4
Betula	**spec.**	0,51	0,56	0,5264	0,5770	0,3768	13,2
Alnus	**spec.**	0,45	0,49	0,4283	0,4694	0,3768	17,9
Populus	**spec.**	0,35	0,38	0,3538	0,3878	0,3768	13,7
Salix	**spec.**	0,45	0,49	0,4618	0,5061	0,3768	13,7
Prunus	**spec.**	0,49	0,54	0,5583	0,6119	0,3768	12,6
Deciduous	**(other)**	0,58	0,64	0,5583	0,6119	0,3768	13,7

14.5.1.1.1.2.8 Basic densities of branches

Pursuant to Equation 18, other basic densities are assumed for branches. Due to the stresses it is subject to, branch wood is denser than trunk/stem wood. Separation into various categories makes it possible to use different densities. The necessary data was derived by analogy to HAKKILA (1972), who divides trees by physiological groups, into conifers, ring-porous broadleaves and diffuse-porous broadleaves.

Table 118 shows average values for 8 conifers, 8 ring-porous broadleaves, 4 diffuse-porous broadleaves. A relationship for these physiological tree-species groups was derived, and the basic densities were correspondingly increased.

Table 118: Basic densities, branches

	Stem wood [g/cm^3]	Branch wood [g/cm^3]	Ratio Brandh/stem density
Conifers	0,363	0,488	1,3444
Diffuse-porous broadleaves	0,489	0,536	1,0961
Ring-porous broadleaves	0,54	0,573	1,0611

14.5.1.1.1.2.9 Volume-expansion factors

For above-ground expansion, BURSCHEL et al. (1993) used the brushwood percentages of GRUNDNER & SCHWAPPACH (1952). They have the advantage of being generally valid for central European conditions and of representing a large number of sample trees. This extrapolation has often been criticised for being too coarse, since the brushwood percentages are shown in the tables only as aggregated values. What is more, WIRTH et al. (2004a) note that use of BEF (remark: this refers to volume-expansion factors, i.e. the relationship between standing-timber volume and total tree volume) pursuant to BURSCHEL et al. (1993) probably results in underestimation of biomass stocks, since the various categories (compartments) were not separated, to permit use of different basic densities.

For this reason, a different approach was selected for these calculations. First, a compartment-oriented calculation was carried out, divided into three tree-part categories (standing timber, tree wood, root wood). In addition, in preparation of generally valid volume-expansion factors (VEF) for above-ground expansion, brushwood tables were not used; instead, data from the tables of GRUNDNER & SCHWAPPACH (1952), for standing timber and tree wood, was placed into a linear regression. These factors provide a functional relationship between standing timber and tree wood; this relationship is shown in the tables. This relationship makes it possible to estimate tree wood from the size of standing timber, which itself depends on the measured values BHD, height and D7. In addition, the tables call for separation, by age classes, for the tree species spruce, fir, beech and pine, since for these trees it was found that, for trunks with the same dimensions, older trunks have a greater volume than younger trunks; the older trunks have a greater wood fraction. This separation was retained, since the tables on based on separate basic totalities.

First of all, various models were tested for predicting tree-wood volume from standing timber, models with varying terms for diameter and height. It emerged that the models could be improved somewhat via inclusion of diameter and height (as BHD^2*height) as predictors. Unfortunately, use of these models has shown that the Federal Forest Inventory (BWI) database includes trees that depart sharply from the normal allometry. This produced tree-wood volumes that were smaller than the corresponding standing-timber volumes. As a result of this implausibility, these models were not used; instead, models with simple linear regression were used. The relevant relationships are shown in the following Table 119:

Table 119: Above-ground expansion functions

Model	a	b
Birch	0,017493	1,121933
Beech, age 61 to 100	0,008184	1,196184
Beech, age at least 101	0,030255	1,128104
Beech, age to 60	0,011942	1,207371
Oak	0,101879	1,051529
Alder	0,004825	1,068903
Spruce, age at least 61[1]	0	1,177947
Spruce, age to 60	0,036697	1,148143
Pine, age at least 81	0,036883	1,076103
Pine, age to 80	0,009946	1,156659
Fir, age to 80	0,019457	1,168262
Fir, age 81 to 120[190]	0	1,228069
Fir, age at least 121 **Fehler! Textmarke nicht definiert.**	0	1,219492
Larch	0,063265	1,057712

Tree-wood volume = a + b * standing-timber volume

This leads to the following relationship for volume-expansion factors:

Equation 20

$$VEF = \frac{B}{D} = \frac{a + bD}{D}$$

B=Tree-wood volume
D=Standing-timber volume
VEF=Volume-expansion factor

14.5.1.1.1.2.10 Root biomass

In contrast to derivation of above-ground biomass, the root dry substance was not calculated via a volume and the basic density; instead, it was established directly from the above-ground mass. Dry-root substance was estimated using the root/shoot ratio, with values pursuant to IPCC GPG-LULUCF (2003). To obtain stand values, the above-ground biomass, differentiated by tree-species groups, was extrapolated to the hectare level for each sampling point, and then the underground biomass was derived.

Because root studies are so difficult to carry out, few root-biomass functions are available. For this reason, the relationships derived in "meta-analyses" were used. For example, DIETER & ELSASSER 2002 published a function for estimating root biomass. In the main, this function is based on data, for temperate forests, of CAIRNS et al. (1997), KURZ et al. (1996) and VOGT et al. (1996). They achieved a random-sampling set of 272 root studies.

[190] Here, a negative constant was calculated; for this reason, the model was used without a constant.

Equation 21

$$\sqrt{rb} = \beta * \sqrt{ab} + \delta_{treespecies} + \varepsilon$$

where:
ab = Above-ground biomass
rb = Root biomass

It must be remembered that this derived function is oriented to stand values that always refer to one hectare.

Table 120: Root biomass, Dieter & Elsasser 2002

Tree Species	β	δ	Degrees of freedom	Sig.-level	r^2
Abies	0,4259	1,8114	266	**	0,8
Picea		1,169		**	
srb		0,691		**	
Pseudotsuga		0,4738		*	
Pinus		0,2864		*	
Fagus and Quercus		0			

For below-canopy and "selection forest" (Plenterwald), the authors assumed an average R/S (biomass) value of 0.18.
srb = short rotation broadleaves (in BWI= ALN)
* Significant α< 5%, ** Significant α<1%.

Since these calculations are subject to a great deal of uncertainty, a scenario with the values pursuant to IPCC (2003) was also calculated. The advantage of the IPCC table is that it includes the standard error in the estimates; this is not included in the study of DIETER & ELSASSER 2002. The values entered into the CRF tables were derived pursuant to IPCC (2003.

Table 121: Root mass (IPCC 2003)

Vegetation type	Above-ground-biomass [t/ha]	Mean	SD	lower range	upper range
Conifer plantation	<50	0,46	0,21	0,21	1,06
Conifer plantation	50-150	0,32	0,08	0,24	0,5
Conifer plantation	>150	0,23	0,09	0,12	0,49
Oak forest	>70	0,35	0,25	0,2	1,16
Other broadleaf	<75	0,43	0,24	0,12	0,93
Other broadleaf	75-150	0,26	0,1	0,13	0,52
Other broadleaf	>150	0,24	0,05	0,17	0,3

The following Figure 67 shows the R/S values for fir and spruce, along with the average R/S relationship pursuant to DIETER & ELSASSER 2002. In addition, the relevant values pursuant to IPCC GPG-LULUCF (2003: "Conifer Plantation") are included for comparison.

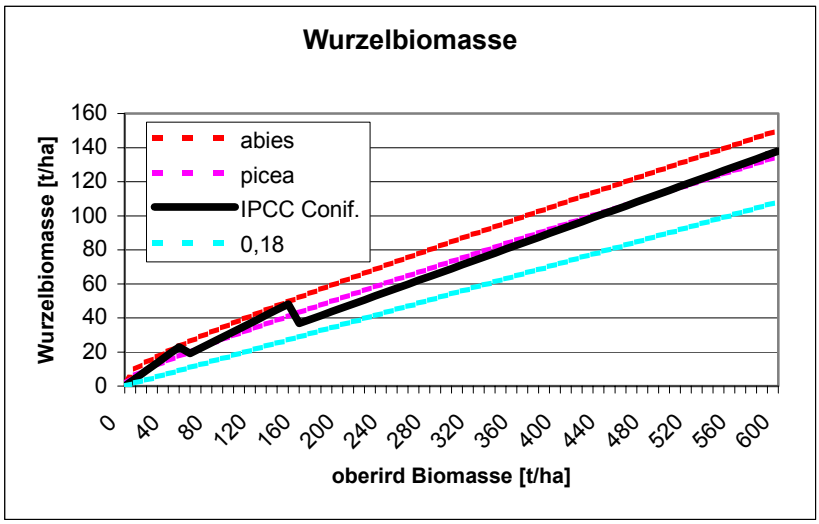


Figure 67: Root biomass [root biomass; above-ground biomass]

14.5.1.1.2 Derivation of CO_2 emissions from liming of forest soils

The data for liming was derived from the overall calculation for fertilisers. For this reason, sampling errors cannot be specified. Because companies have a statutory duty to supply information, the data collection is complete.

The data describes deliveries, by producers and importers, to wholesalers and end users. It does not provide direct information on the annual use of fertilizers in agriculture and forestry. Deviations from actual fertiliser use are possible

- due to changes in commercial stocks
- due to use of fertiliser outside of agriculture and forestry, e.g. on private land, gardens, sports facilities

The relevant emissions were derived using equation 3.3.6 from IPCC GPG-LULUCF (2003: p. 3.80).

14.5.1.1.2.1 Uncertainties

Within the available time, it was not possible to determine uncertainties at the individual-tree level, using Monte Carlo simulation. Presumably, the advantage of Monte Carlo simulation would be that the total error would shrink, due to the enormously high number of individual samples involved. Due to the situation of the 1990 data for the new German Länder, it cannot be carried out, however.

For the old German Länder, stratification was carried out in accordance with tree-species groups pursuant to BWI (ALH[191], ALN[192], beech, douglas fir, oak, spruce, pine, larch, fir). To this end, the relative standard error is estimated or calculated for each input item (standing-timber volume, basic density, above-ground biomass expansion, root biomass and carbon

[191] ALH = all other deciduous trees with high life expectancies
[192] ALN = all other deciduous trees with low life expectancies

fraction). This relative standard error is then extrapolated using the extrapolation procedure in question – additive error propagation or multiplicative error propagation. The calculation does not take account of every possible error source (divergence of allometry, model errors in standing-timber calculation). For this reason, the following assumptions must always be seen as a way of approximating the actual error values. Where assumptions had to be made, they tended to be made carefully (with higher error).

As a result, the relative standard error for the total stocks was obtained. The 95% confidence interval for this estimate corresponds to double the relative standard error.

Equation 22

$$U_{tot} = \frac{\sqrt{\sum_i (U_i \bullet x_i)^2}}{\sum_i x_i}$$

where
Ui Uncertainty in quantity i
xi Quantity

For the new German Länder, C stocks can be calculated only as estimates, based on aggregated values; this is accomplished pursuant to the publication "The forest in the new German Länder" ("Der Wald in den neuen Bundesländern" (BML 1994)). The calculations continue to be carried out separately with respect to Federal Forest Inventory I (BWI I), BWI II new German Länder and BWI II old German Länder.

14.5.1.1.2.1.1 Uncertainties, standing-timber stocks

For BWI I, random-sampling errors can be taken from the publication "Bundeswaldinventur" ("Federal Forest Inventory", BMELF 1990). The random-sampling errors for BWI II were taken (separated by tree-species group and German Länder) from the Internet[193]. For error extrapolation from the Länder level to the level new/old German Länder, error propagation by sums was used (Equation 22). The model errors cannot be calculated via estimation of standing timber, since relevant studies for this are lacking.

Table 122: Relative standard error, standing-timber stocks

Tree-species group	**BWI II New German Länder** rel. s (stocks)	**BWI II Old German Länder** rel. s (stocks)	**BWI II total** rel. s (stocks)	**BWI I Old German Länder** rel. s (stocks)
EI[194]	4,31%	2,24%	2,1%	2,5%
BU	4,23%	1,96%	1,8%	2,0%
ALH	4,85%	2,61%	2,4%	3,1%
ALN	3,84%	2,94%	2,4%	3,3%
FI	3,48%	1,59%	1,5%	1,4%
TA	40,40%	3,76%	3,8%	3,3%
DGL	13,94%	4,14%	4,0%	6,0%
KI	2,46%	2,28%	1,7%	2,0%
LÄ	5,87%	3,65%	3,2%	3,7%

14.5.1.1.2.1.2 Uncertainties, basic density

[193] http://www.bundeswaldinventur.de/testergebnisse/
[194] EI oak, BU beech, FI spruce, TA fir, DGL Douglas fir, KI pine, LÄ larch

Wood basic densities differ from species to species and can fluctuate within one and the same tree. KOLLMANN (1982) gives variation ranges for raw densities. With the held of these variation ranges, the standard error can be estimated pursuant to SACHS (1984). For left-leaning and right-leaning distributions (approximations of triangular distributions) of basic densities, distributions that are actually seen in trees (BOSSHARD 1984; KOLLMANN 1982), the range is divided by 4.2. It was not possible to take account of the error arising in conversion of raw density into basic density, since no relevant data is available. In this case, it was assumed that this error would not affect the basic-density range.

Table 123: Relative standard error, basic density

Tree species	Average raw density	min. raw density	max. raw density	Standard error, estimated	Rel. standard error
BU[195]	0,68	0,49	0,88	0,0929	13,66%
DGL	0,47	0,32	0,73	0,0976	20,77%
EI	0,65	0,39	0,93	0,1286	19,78%
LÄ	0,55	0,4	0,82	0,1000	18,18%
ES (ALH)	0,65	0,41	0,82	0,0976	15,02%
FI	0,43	0,3	0,64	0,0810	18,83%
KI	0,49	0,3	0,86	0,1333	27,21%
PA (ALN)	0,41	0,37	0,52	0,0357	8,71%
TA	0,41	0,32	0,71	0,0929	22,65%

For secondary tree-species groups that are relatively unimportant in terms of numbers, including broadleaves with high life expectancies (4.4 % of total standing-timber volume) and broadleaves with low life expectancies (5.2 %), the values for ash and poplar were used.

14.5.1.1.2.1.3 Uncertainties for volume expansion

The natural variability of above-ground allometry is not included here. This error cannot be calculated, since the original figures of GRUNDNER & SCHWAPPACH (1952) are not available. The tables contain only averaged values. These smoothed values systematically underestimate the actual variance.

This error consideration thus calculates only the error for conversion of standing-timber volume into tree-wood volume. The standard error of residues of the models is shown in the following Table 124:

[195] ES ash, PA poplar

Table 124: Relative standard error, VEF model

Model		Average (calculated tree wood)	s(residues)	Rel. standard error
Oak		4,688483	0,1921357	4,10%
Birch		0,6871404	0,007478048	1,09%
Alder		0,6902273	0,006260212	0,91%
Beech	**Age to 60**	0,3631021	0,01984793	5,47%
Beech	**Age 61 to 100**	1,253777	0,05095927	4,06%
Beech	**Age at least 101**	2,665235	0,06851797	2,57%
Spruce	**Age to 60**	0,4466276	0,05036626	11,28%
Spruce	**Age at least 61**	3,595929	0,1637905	4,55%
Pine	**Age to 80**	0,6035531	0,01861142	3,08%
Pine	**Age at least 81**	2,112509	0,06913789	3,27%
Fir	**Age to 80**	0,8898365	0,05534219	6,22%
Fir	**Age 81 to 121**	3,526363	0,2644826	7,50%
Fir	**Age at least 121**	6,980293	0,6241895	8,94%
Larch		3,209294	0,07115059	2,22%

Since the errors for a given tree species, with respect to age classes, can vary considerably, the errors from the extrapolation are amount-weighted with the stocks from BWI I and BWI II. The following values were thus determined:

Table 125: Errors VEF model, tree-species groups

	BWI IRSE	BWI II, a.Bl. RSE	DS Waldfonds RSE	BWI II, n.Bl. RSE
BU	3,55%	3,47%	3,40%	3,41%
ALH	4,22%	4,37%	4,55%	4,37%
ALN	5,01%	5,10%	5,01%	4,94%
FI	7,08%	7,16%	6,89%	7,06%
TA	7,32%	7,70%	6,91%	7,49%
DGL	9,63%	9,89%	10,01%	9,94%
KI	3,16%	3,18%	3,14%	3,14%

RSE = relative standard error

14.5.1.1.2.1.4 Uncertainties, root biomass and carbon content

The standard errors in root-biomass calculation can only be obtained from the tables pursuant to IPCC GPG-LULUCF (2003). Here as well, amount-weighted error extrapolation was carried out. To carry out error propagation by sums (IPCC, 2000: Equation 6.3), the sums of above-ground mass calculations were calculated for each stratification of the table; it was then possible to derive the total errors for conifers, oak, and other broadleaves.

The following values then resulted:

Table 126: Relative standard error, root

	BWI I	BWI II
Conifers	25,34%	25,45%
Oaks	58,11%	59,17%
Broadleaves	19,34%	19,07%

The relative standard error for carbon content in wood is given by BURSCHEL et al. (1993) as 1-2%; WEISS et al. (2000) use 2 %. WIRTH et al. (2004a) report that the differences between compartments, within one and the same tree species, are larger than the

differences between tree species. They obtain a range of 0.5-0.56 gC/g in conifers. Overall, therefore, a mean C content of 0.5 gC/g, as a good assumption for average content, and with a relative standard error of ±2 %, seems appropriate.

14.5.1.1.2.1.5 Error estimation for the new German Länder, 1993

Since C-stock calculation for the new German Länder was possible only with the method pursuant to Burschel et al. 1993, taking account of data in the publication: "Der Wald in den neuen Bundesländern" ("The Forest in the New German Länder", BML, 1994), the procedure for the old German Länder can be adopted here only partially.

On p. 9 of this publication, the following statement about errors relative to stocks is made: "The stocks on the sub-area were determined, in the framework of the forest-establishment procedure, with a mean standard error of ±12.5 %." Assuming that this error has had a systematic impact on extrapolation, a value of ±12.5 % may be assumed for tree-species groups.

The basic densities pursuant to BURSCHEL et al. (1993) exhibit no range; for this reason, the basic-density variations pursuant to Table 117 are used.

The biomass-expansion factors of Burschel et al. (1993) were divided into above-ground and below-ground components. As an approximation for above-ground expansion, therefore, the values from Table 125 can be accepted, with a small addition for aggregation in the brushwood-percentage class averages. Since the data situation for underground root percentages is unclear, as an approximation the standard errors of IPCC GPG-LULUCF (2003), as derived in 4.4, are used.

Following multiplicative error propagation

Equation 23

$$U_{tot} = \sqrt{\sum_i U_i^2}$$

for above-ground parts, and summing (Equation 22) of tree-species groups, the following overall value was derived:

Table 127: Error estimation, new German Länder, 1993

	RSE standing timber	RSE density	RSE VEF above-ground	RSE VEF aggr. (+ 1%)	above ground total RSE	below-ground total RSE	RSE above-ground + below-ground	RSE C content	RSE C calculation	RSE dead wood
Ei	12,50%	19,78%	4,10%	5,10%	23,95%	59,17%	22,35%	2,00%	22,44%	
Bu	12,50%	13,66%	3,40%	4,40%	18,76%	19,07%	15,79%	2,00%	15,92%	
Alh	12,50%	15,02%	4,55%	5,55%	19,91%	19,07%	16,80%	2,00%	16,92%	
Aln	12,50%	8,71%	5,01%	6,01%	15,97%	19,07%	13,65%	2,00%	13,80%	
Fl	12,50%	18,83%	6,89%	7,89%	23,40%	25,45%	19,38%	2,00%	19,48%	12,78%
Ta	12,50%	22,65%	6,91%	7,91%	26,45%	25,45%	22,28%	2,00%	22,37%	
Dgl	12,50%	20,77%	10,01%	11,01%	26,26%	25,45%	21,73%	2,00%	21,82%	
Ki	12,50%	27,21%	3,14%	4,14%	30,13%	25,45%	25,17%	2,00%	25,25%	
Lä	12,50%	18,18%	2,22%	3,22%	22,30%	25,45%	18,85%	2,00%	18,96%	

RSE = relative standard error

Many of these values are estimates and thus cannot be considered true errors.

14.5.1.1.2.1.6 Total error

For estimation of the total errors for BWI I, old German Länder, and BWI II, new and old German Länder, the values for the tree-species groups can be combined, for each individual calculation factor. For the above-ground error propagation (standing-timber volume, biomass expansion, density), the multiplicative error propagation can be (Equation 23). Since calculated underground C stocks are added to the above-ground stocks, error propagation by sums must again be assumed (Equation 22). The same applies for the summation over all tree-species groups. The following Table 128 summarises the various individual rel. standard errors:

Table 128: Error overview

BA		RSE Standing timber	RSE Density	RSE BEF	above ground RSE	below-ground RSE	RSE above-ground + below-ground	RSE C content	RSE pursuant to C calculation	RSE dead wood
BWI I old German Länder	Ei	2,50%	19,78%	4,10%	20,35%	58,11%	21,55%	2,00%	21,65%	8,16%
	Bu	2,00%	13,66%	3,55%	13,96%	19,34%	11,74%	2,00%	11,91%	
	Alh	3,10%	15,02%	4,22%	15,58%	19,34%	12,63%	2,00%	12,78%	
	Aln	3,30%	8,71%	5,01%	10,19%	19,34%	9,07%	2,00%	9,28%	
	Fl	1,40%	18,83%	7,08%	19,56%	25,34%	16,36%	2,00%	16,49%	
	Ta	3,30%	22,65%	7,32%	23,33%	25,34%	18,82%	2,00%	18,93%	
	Dgl	6,00%	20,77%	9,63%	23,26%	25,34%	18,70%	2,00%	18,81%	
	Ki	2,00%	27,21%	3,16%	27,38%	25,34%	21,92%	2,00%	22,02%	
	Lä	3,70%	18,18%	2,22%	18,69%	25,34%	15,43%	2,00%	15,56%	
New German Länder	Estimate 1993									12,78%
BWI II old German Länder	Ei	2,24%	19,78%	4,10%	21,03%	59,17%	22,08%	2,00%	22,17%	7,70%
	Bu	1,96%	13,66%	3,47%	14,72%	19,07%	12,29%	2,00%	12,46%	
	Alh	2,61%	15,02%	4,37%	16,78%	19,07%	13,52%	2,00%	13,67%	
	Aln	2,94%	8,71%	5,10%	12,12%	19,07%	10,26%	2,00%	10,45%	
	Fl	1,59%	18,83%	7,16%	19,86%	25,45%	16,61%	2,00%	16,73%	
	Ta	3,76%	22,65%	7,70%	23,98%	25,45%	19,37%	2,00%	19,47%	
	Dgl	4,14%	20,77%	9,89%	24,76%	25,45%	20,00%	2,00%	20,10%	
	Ki	2,28%	27,21%	3,18%	27,79%	25,45%	22,29%	2,00%	22,38%	
	Lä	3,65%	18,18%	2,22%	20,05%	25,45%	16,41%	2,00%	16,53%	
BWI II new German Länder	Ei	4,31%	19,78%	4,10%	22,39%	59,17%	22,80%	2,00%	22,89%	10,08%
	Bu	4,23%	13,66%	3,41%	16,53%	19,07%	13,67%	2,00%	13,81%	
	Alh	4,85%	15,02%	4,37%	18,76%	19,07%	14,99%	2,00%	15,12%	
	Aln	3,84%	8,71%	4,94%	12,28%	19,07%	10,37%	2,00%	10,57%	
	Fl	3,48%	18,83%	7,06%	20,72%	25,45%	17,18%	2,00%	17,30%	
	Ta	40,40%	22,65%	7,49%	61,51%	25,45%	46,55%	2,00%	46,60%	
	Dgl	13,94%	20,77%	9,94%	26,80%	25,45%	21,48%	2,00%	21,57%	
	Ki	2,46%	27,21%	3,14%	31,37%	25,45%	25,14%	2,00%	25,22%	
	Lä	5,87%	18,18%	2,22%	20,49%	25,45%	16,83%	2,00%	16,95%	

14.5.1.1.2.2 Source-specific quality assurance / control and verification

The calculated data is based on ACCESS queries of Federal Forest Inventory data. With regard to the quality assurance developed for the Federal Forest Inventory, the reader's attention is called to the literature for the Federal Forest Inventory.

First, an estimate was carried out using the BURSCHEL et. al. (1993) method, to provide an indication of the orders of magnitude of the extrapolation. This estimate, which is based on aggregated values (average stocks, by tree-species groups), was carried out by two different persons, using two different methods (published BWI results and ACCESS queries). The results obtained with the two methods agreed.

In the individual-tree calculations, a "Burschel" scenario (cf. Annex 14.5.1.1.1.2.6) using the same basic densities used for the estimate (using aggregated values), was calculated. The resulting values agreed with the calculations using the aggregated values. Consequently, it is clear that the ACCESS queries, in general, provide correct values; on the other hand, their results can deviate depending on what assumptions are made for basic densities and root-shoot ratios.

One systematic error persists, however: It was not possible to estimate rejuvenation below the standing-timber threshold, and the relevant figure is not found in the stock data, because the volume-expansion function is based on standing-timber volumes. The lack of rejuvenation stocks results in a systematic underestimation of total stocks.

14.5.1.1.2.3 Source-specific recalculations

The 2002 Federal Forest Inventory II provided new random-sample data. For the old German Länder, this was a repeat inventory using the same random-sample points. As a result, it was possible to derive, from its data, the C-stock changes for these countries, with the "stock-change method". For the new German Länder, this was possible only to a limited extent, since only forest-establishment data is available for that region for 1993.

In addition, for the first time the calculation took account of underground biomass as well as above-ground biomass (cf. methods 14.5.1.1.1.1.2).

The "stock-change method" was applied for the new and old German Länder, and linearly interpolated and extrapolated for the relevant period.

The greenhouse-gas inventory for 2005 presents newly calculated data for all years since 1990. Time-series consistency is thus assured.

At the same time, reporting has been converted in keeping with the new CRF tables adopted at the 9th Conference of the Parties in Milan.

Pursuant to this recalculation, stock increases are twice as high as listed in previous inventories. The main reason for this is the wood-stock increase determined in BWI II, an increase that far exceeds existing yield-table estimates. Other factors include inclusion, for the first time, of underground biomass, improved methods of calculation and, possibly, underestimation of the outset stocks in the new German Länder.

14.5.1.1.3 Land converted to Forest Land

14.5.1.1.3.1 Source-category description

Forest is created through succession, afforestation and reforestation; new forest areas begin storing C equivalents as soon as they are converted. In a rigorous approach, the C-stocks of previous land uses should be deducted. But no data is available on previous plant coverage (for example, individual trees, hedges or long-lived woody cultivations) and its biomass. Overall, such stocks are considered negligible, especially since the total area of new forest land is very small in comparison to the total forest area (old German Länder 2002: 121 kha to 7,694 kha).

14.5.1.1.3.2 Methodological issues

14.5.1.1.3.2.1 New forest land

Pursuant to IPCC GPG-LULUCF (2003), new forest lands must remain in the category "new forest lands" for 20 years. No land-use-change data that could support comparisons is available prior to BWI I. For the old German Länder, direct comparison between BWI I and BWI II makes it possible to separate new forest land and deforested land since 1987. The new forest lands occurring between BWI I (key year 1987) and BWI II (key year 2002), and amounting to 121.45 kha (not including the non-wooded ground) can be categorised as follows in keeping with their existing uses:

Table 129: New forest lands, old German Länder

Category	Area [kha]	Annual increase in area [kha/a]
Cropland and permanent cultivations	30,57	2,04
Permanent grassland	45,46	3,03
Wetlands	15,67	1,04
Settled areas	29,75	1,98

For derivation of area figures for the various years in question, it was assumed that new forest land increased linearly between BWI I and II. In the CRF tables, these area increases are shown beginning with the key year for BWI I (1987).

When these areas are considered in comparison to the entire forest area of the old German Länder, 7693.72 kha, then the increases seem marginal – 1.58% over 15 years (both figures not including non-wooded ground).

For the new German Länder, only the net forest-land increase between 1993 and 2002 can be determined; it amounts to 174.56 kha. This difference is considered the new forest land. Its annual rate of increase is 17.46 kha/a; the data does not permit any allocation into outset categories. The area increases were assumed to progress linearly between 1993 and 2002.

14.5.1.1.3.2.2 Biomass stocks, new forest land

For the old German Länder, an individual-tree calculation was carried out for the new forest land (cf. 14.5.1.1.1.2.6). The distribution of stocks by outset categories (Table 130) is weighted by areas, however.

Table 130: Stocks, new forest lands, end of 2002

Outset category	Stocks [Gg C]
Cropland and permanent cultivations	922
Permanent grassland	1.372
Wetlands	473
Settled areas	897

For the new German Länder, assumptions had to be made relative to these figures. The area increase was seen solely as a net increase; for this reason, area losses are not considered.

The area increases were assumed to progress linearly between 1993 and 2002. The wood stocks on this area must be considered to be only stocks of the 1st age class (0-20 years, BWI II, new German Länder). For determination of the stocks on these areas, the standing-timber stocks of tree-species groups of the 1st age class were converted into C stocks. The average C stocks in the biomass of these areas, as of the end of 2002, was assumed – due to its young age – to be half of the average C stocks of the 1st age class. This produces a value of 18.01 t C/ha, or total stocks of 3,144 Gg C, for these areas at the end of the 2002 vegetation period.

The biomass stocks at the end of the 2002 vegetation period correspond to the biomass stock increases throughout the entire period under consideration since 1987 (old German Länder) and 1993 (new German Länder), as long as any possible previous plant cover is ignored. These stock increases were weighted with the new forest areas produced in the relevant report years, and then they were linearly interpolated throughout the entire period under consideration.

14.5.1.1.3.2.3 Stocks in dead wood, debris and soils on new forest areas

In our latitudes, it takes decades for typical forests stocks to form in these compartments. The annual rates were considered negligible – also in light of the small size of the new forest area overall – and not taken into account in the greenhouse-gas inventory.

14.5.1.1.4 Forest Land converted to Other Land

14.5.1.1.4.1 Source-category description

Forest areas converted to other forms of land use are smaller overall than the new forest areas. At the same time, they had higher average biomass stocks prior to conversion. In conversion, such stocks are normally removed, and thus they are considered C emissions.

The C-stock losses from dead wood, debris and soil, and relevant emissions of other greenhouse gases, cannot be precisely determined. The CRF tables thus contain only the C losses from above-ground and underground biomass. The IEF derived from biomass losses, and from the areas achieved in each relevant year since 1987, decreased continuously from 1990 to 2003. This does not reflect any true trend, however; it results simply in that areas have not been listed separately only since 1987, and not for the past 20 years, as called for by the IPCC (2003). As a result, the area has increased in each report year.

In addition to biomass, C stocks in dead wood and debris, and part of the carbon in the soil, are lost in deforestation. Burning of biomass, in conversion of forest, as well as mineralisation processes occurring via plowing and turning of topsoil, can cause both CO_2 emissions and additional greenhouse-gas emissions.

14.5.1.1.4.2 Methodological issues

14.5.1.1.4.2.1 Deforested areas

The total deforested area in the old German Länder (not including non-wooded ground) is about half as large (67.33 kha and 4.49 kha/a) as the new forest area. The C emissions that

must be assigned to these areas are higher, as a result of their stock accumulations, than C binding by new forest lands.

The corresponding figures for the new German Länder cannot be derived from the available data.

14.5.1.1.4.2.2 Stock losses on deforested land

In the old German Länder, individual-tree-based extrapolation was carried out for this category (cf. 14.5.1.1.1.1.2). The C emissions that must be assigned to these areas are higher, as a result of their stock accumulations, than C binding by new forest lands. All in all, total stocks of 4,035 Gg C were lost from biomass in this category. Applying linear interpolation, this corresponds to an annual loss of 269 Gg C. For the sake of simplicity, it was assumed that these C stocks are emitted into the atmosphere in the year in which they are converted.

As to C-stock losses from dead wood, debris and soil, only a first, very rough estimate, based on average stocks identified by the Federal Forest Inventory (BWI) and the soil-condition survey (BZE; BMELF 1997), can be provided. In this estimate, it was assumed that dead wood and the humus layer decompose completely, while about 30% of the C stocks in the uppermost 30 cm of the mineral soil are lost. The results are reported here as a memo item, but they have not been included in the CRF tables.

In light of the great variability, by area, of dead-wood, humus and soil stocks, these figures are subject to very large uncertainties. The total relevant emissions could be more precisely estimated by linking the BWI points affected by deforestation with soil maps or with the nearest BZE points.

Table 131: Losses from dead wood, humus layer and soil upon deforestation

Category	Stocks [Mg C/ha]	Stock loss [Gg C]
Dead wood	2,6	11,7
Humus layer	18,0	80,8
Mineral soil (0-30 cm)	62,2	83,8
Total	**82,8**	**176,3**

Stock losses from deforestation cannot be calculated for the new German Länder.

14.5.2 Cropland, grassland, other areas and land-use changes (5B/5C/5F)

14.5.2.1 Land-area distribution and allocation of usage categories

14.5.2.1.1 Data sources and their adaptation

The following official German statistics were used as sources:

1. Bodennutzungshaupterhebung (BOHE; main survey of soil use) 1991, 1999, 2001 (DESTATIS, Fachserie 3, Reihe 2.1.2, Jg. 1993; DESTATIS, Fachserie 3, Reihe 2.1.2, Jg. 2000; DESTATIS, 2003a)

2. Flächenerhebung nach Art der tatsächlichen Nutzung (FE; area survey by types of actual uses) 1993, 1997, 2001 (DESTATIS, Fachserie 3, Reihe 5.1, Jg. 1994, 2002a & 2003)
3. Verteilungsschlüssel Kreisreform 1998 (distribution key for 1998 district reform)

Agricultural areas and their usage categories were determined via BOHE and FE data. The basis for designation of areas and land-use categories consists of definitions for the usage-type key of the Working group of surveying administrations of the Länder of the Federal Republic of Germany (Arbeitsgemeinschaft der Vermessungsverwaltungen der Länder der Bundesrepublik Deutschland - AdV), in the "Directory of area-based usages in the property cadastre and their definitions" ("Verzeichnis der flächenbezogenen Nutzungsarten im Liegenschaftskataster und ihrer Begriffsbestimmungen" - AdV, 1991), and on the "Ground-cover nomenclature" ("Nomenklatur der Bodenbedeckungen") of the CORINE LAND COVER project (DESTATIS, 1989).

The agricultural area was divided into the following usage categories:

1. Cropland with annual crops (rye, summer and winter barley, oats, triticale, feed plants, silo corn, potatoes, sugar beets, non-food crops – especially winter rape)
2. Long-lived crops (Fruit crops, osiers, poplars, Christmas tree farms, nurseries)
3. Vineyards
4. (Permanent) grassland
5. Untilled land

These categories were used for calculation of carbon and biomass stocks, as well as of shifts of areas between the various usage categories. For the CRF, categories 1.-3. were combined into "cropland", while categories 4. and 5. were combined into "grassland".

In compilation of land-use data, problems arose that are due to the political development in Germany after 1989. Since German reunification did not take place until October 1990, the first standardised statistical survey of agricultural area and land use for all of Germany was not carried out until 1991; this is why land use in 1991 served as the basis for calculations. In addition, the administrative boundaries between districts were redrawn, especially in the new German Länder, as a result of reunification. As a result, data from BOHE 1999 was not comparable with that of BOHE 1991 – some districts had "disappeared", while some had been created and others had simply changed. To provide a basis for comparison, therefore, the district areas used in the 1991 main survey of soil use (Bodennutzungshaupterhebung) were "redrawn", with the district-distribution key for the 1998 district reform, and the pertinent land-use categories, in their relevant shares, were shifted and adapted as necessary.

Due to differences in survey principles, the absolute difference between the agricultural area shown in FE 1993 and that shown in BOHE 1991 amounts to 8.4 % (cf. Chapter 14.5.2.5.1). To compensate for this, the BOHE area sum was proportionally related to the entire agricultural area shown by FE (this was adjusted via removal of bogs and heaths which by definition are uncultivated land), since FE, as a cadastre survey, shows the actual areas involved, by types of uses. The adjustment was made under the assumption that distribution of land-use classes and of soil units on the approximately 10 % of the area that was "missing" would correspond to that of the remaining area. Since BOHE 2001 was only a representative survey (100,000 farms) – i.e. not a complete survey – it provided no area data on vineyards and untilled land at the district level. This data was estimated, for the various districts, on the basis of the Länder data. It was assumed that the pertinent areas, in all

districts, had changed in proportion to the Länder total. In each case, the reference basis consisted of the values from 1999. The changes were very small. In another complication, the BOHE data has been available in computerised form only since 1999, and the computerised differs, in format and extent, from the corresponding printed data. Consequently, extensive manual data collection and conversions had to be carried out in order to produce a usable, standardised set of data.

To obtain the entire agricultural area for the pertinent years, the areas for the various use categories of BOHE 1991 and 1999 were adapted, proportionally, to Germany's total area in 2001. This norming was necessary, since the FE of 1993, 1997 and 2001 differ in their figures for Germany's total area.

14.5.2.1.2 Determination of land-use changes, and of use-related area shifts

The data made it possible to determine the net changes in use categories for the periods 1991 – 1999 and 1999 – 2001. More current data is not yet available. The area increases and decreases within the five categories were determined, at the district level, by subtracting areas from their corresponding areas at the relevant subsequent date.

This "net" consideration does not show land-use changes on individual areas, however. Since no records of such changes are kept in Germany, Heinemeyer/Gensior developed a procedure for estimating land-use changes. From a range of assumptions and prerequisites (including legal stipulations), they derived basic assumptions and a priority list. They then translated this list into an algorithm that describes a very "probable" direction of area shifting. The algorithm was incorporated into a computer programme that mades the allocation procedure fully transparent and always consistent.

Basic assumptions:

1. Emerging differences are always compensated for first within the agricultural area
2. Category amounts, in keeping with the priority list, are compensated for within the agricultural area until one of the two categories reaches an amount of zero.
3. When the "area changes" exceed the "ability of agriculture to compensate", the supernumerous land areas are shifted into the pool of the remaining district area (settlement and transport, water…).
4. When the "area changes" are smaller than the "ability of agriculture to compensate", land area is shifted from the pool of the remaining district area and into the pool of the agricultural usage category that had shown a deficit following the algorithmic run.

When no differences between the years under consideration emerge, no changes have occurred in the relevant (or in all) categories and in the pools subject to reporting obligations.

The pool serves as a reservoir for compensation, and it appears only in the sum of all districts; it contains the summed relevant remaining areas for the Federal Republic of Germany ("settlement and transport area", "forest area", "water area" and "areas with other uses", pursuant to FE). This approach in keeping with the survey principle used for the BOHE (farm-operation principle). For example, when an agricultural area category in a district grows or shrinks simply as a result of the survey principle being applied, the pertinent difference can be compensated for nationally from the pool, since Germany's total area does not change. The following example illustrates this principle: A farmer with a farm in the Braunschweig district leased and worked 100 ha of cropland in the Magdeburg district in

1991 (the area in question is counted with the Braunschweig district); in 1999, the pertinent land is again being worked by the owner, whose farm operation is located in Magdeburg (the area is counted with the Magdeburg district). In this case, it is assumed that the previous use is being continued, without any changes.

Where areas enter the pool, it is also assumed that the relevant land-use changes do not lead to any reduction of the carbon stocks in the soil or in the biomass in question.

In the authors' opinion, the following priority list (Table 132) is based on the most probable directions of usage changes. The list is also based on assumptions and legal provisions. The following considerations are applied to vineyards, for example: Vineyards that are abandoned are usually located in steep, terraced areas that are difficult to work. Such land is thus most likely to lie fallow. According to legal provisions, such areas must be completely vacated. Normally, every other row between vine rows is covered with grass. After the vines have been removed, grass will also grow in their place.

Logically, therefore, the programme processes "vineyards" first. The area lost is always allocated to fallow land. The vines' biomass is lost completely, and discontinuation of cultivation enables the soil to add carbon on every second row.

Table 132: Priority list, use changes

Priority list					
Vineyards (R)	Decrease	R → B			
	Increase	B → R			
Permanent cultivations (D)	Decrease	D → B	D → A	D → G	
	Increase	B → D	A → D	G → D	
Grassland (G)	Decrease	G → A	G → D	G → B	
	Increase	A → G	D → G	B → G	
Cropland (A)	Decrease	A → B	A → G	A → D	
	Increase	G → A	B → A	D → A	
Fallow land (B)	Decrease	B → R	B → D	B → A	B → G
	Increase	R → B	D → B	A → B	G → B
Surplus		D/A/G/B → Pool			
Deficit		Pool → D/A/G/B			

Areas that change from forest to agriculture, or change vice-versa, have been identified via the Federal Forest Inventory data (cf. Chapter 7.1). These areas will be included in the calculation only after all district results have been summed. Following use of the above-mentioned algorithm, forest areas are part of the "pool". For this reason, the forest areas are removed from the "original" pool area (in cases of usage changes from agriculture to forest) or are offset with the pool areas in the various categories (usage changes from forest to agriculture).

The thus-determined areas were entered into the relevant columns of CRF tables 5A, 5B and 5C. Since "wetlands" and "settlement areas" are not reported and differentiated, the excess agricultural area is listed completely in Table 5 F, and additions to the agricultural area are shown, in Tables 5B and 5C, in the line "Other Land converted to…".

14.5.2.1.3 Organic soil area

Since agriculturally used organic soils are not listed separately in statistical surveys (they are subsumed under the relevant usage categories (BOHE) or under agriculture (FE)), such

areas (fens and raised bogs (lead-soil associations (Leitbodenassoziation) 6 and 7 (BUEK 1000)), and the relevant usage categories, were determined via the soil overview map drawn to a scale of 1 : 1,000,000 (BUEK 1000) and via CORINE – Landcover (cf. Chapter 14.5.2.2). Via their area ratios to other soil types, at the district and national levels, the bog areas were proportionally allocated to the agricultural areas shown by BOHE 1991/1999. In the CRF tables, they appear subsumed within the columns for the relevant usage categories.

14.5.2.2 Determination of carbon stocks and their changes as a result of land-use changes

Data on spatial distribution of soil communities in Germany is available in the form of a digital soil map on a scale of 1: 1 000 000 (BUEK 1000). The soil map has been prepared via proportionate allocation of discrete profile data (obtained at individual points in the landscape) on land units (polygons) within the map area. The profiles provide quantitative information on a range of key factors measured. This information provided the basis for estimating the carbon stocks in agricultural soils. Calculation was carried out using the map's/legend's data for the lead profiles of the 72 lead soil units, data that included specific C_{org} content measurements, humus, raw-density and skeleton classes and profile and horizon descriptions. With this data, and under the assumption that the map's values, in each case, are representative of the entire relevant legend/map unit, C_{org} stocks were calculated. To this end, the C_{org} content figures were multiplied by the relevant raw densities and horizon depths and the relevant skeleton portions were deducted. The horizon stocks were added to a depth of 30 cm. The range of carbon stocks was determined via the figures in the relevant legend/map unit pursuant to KA 4 (ARBEITSGRUPPE BODEN, 1994). In each case, the aforementioned algorithm was used to calculate a minimum value (lowest possible C_{ORG} content for the class, lowest possible storage density, maximum skeleton content) and a maximum value (highest possible C_{ORG} content for the class, highest possible storage density, minimum skeleton content).

A geo-information system (GIS) was used to assign the individual soil units to rural districts and to the relevant land-use units. BUEK 1000 was overlaid with polygons of district boundaries and with the CORINE Landcover land-use classes. For each of the resulting polygons, carbon stocks were calculated to a depth of 30 cm and then summed, in keeping with land use (farmland, grassland, heterogeneously structures agricultural land), at the district level. Division by the area sum then produced a weighted carbon-stock figure (and minimum and maximum values) – relative to soil unit and expressed in t/ha * 30 cm – for each land-use class, at the district level; for the sake of comparison, stocks were summed at both the district and national levels. The CORINE nomenclature was translated as follows into the usage-type key of AdV (1991):

Cropland → Cropland

Grassland → Grassland

Agricultural land with heterogenous structure → Garden land + fallow land

Since the forest-conversion areas for Germany were available only in aggregated form, specific carbon stocks, averaged over all districts and soil types, were assumed for these soils.

14.5.2.3 Changes in carbon stocks in the soil and in biomass

14.5.2.3.1 Derivation of EF for mineral soil as a result of land-use changes

The emission factors for changes in carbon stocks in the soil, resulting from use changes, were drawn from the literature. To this end, a number of studies, including several reviews, were evaluated. From these studies, those studies were selected that directly considered carbon stocks following land-use changes, or whose data permitted relevant derivation. Of these studies, in turn, only those were used for EF derivation that apply criteria, for soil, climate and other parameters (for example, about 30 cm soil depth) that are at least somewhat comparable to those required for German reporting (ANKEN et al 2004, BLANK & FORSBERG, BOUMA & HOLE 1971, BOWMAN et al. 1990, BURKE et al 1995, BUYANOVSKY 1987, CAMBARDELLA et al 1992 & 1993, CAMPEL et al.1989, CHAN AND MEAD 1988, CONANT ET AL. 2001, DAVIDSON & ACKERMANN 1993, DEGRYZE et al. 2004, FRANZLUEBBERS et al. 1999, FRANZLUEBBERS et al. 2000, GEBHART et al 1994, GUO & GIFFORD 2002, HART et al. 1988, HORNE et al 1992, IHORI et al 1995, JASTROW & LUSSENHOP 1998, LARIONOVA et al 2003, LAWS & EVANS 1949, LIEBIG et al. 2004, MANN 1986, MARTENS et al. 2003, MURTY et al. 2002, POST & KWON 2000, POTTER et al 1999, REEDER et al. 1998, ROSS AND HUGHES 1985, SKEMSTAD et al 1994, TIESSEN et al 1982, VORNEY et al 1981 etc.)

In spite of the wide distribution of absolute results it shows, the literature review supports the oft-heard assumption that conversion of grassland to cropland leads to losses of soil carbon stocks, and that conversion of cropland to grassland enriches soil carbon stocks. Nonetheless, results can be adduced that support the opposite assumption. The breadth of the spectrum of results complicates evaluation, although very close relationships can be found via simple or multiple regression ($r^2 > 0.9$). The results that are produced in this manner, however, show little plausibility and always include 0 within their 95 % confidence intervals.

For this reason, the annual carbon losses and additions, measured in percent of original stocks, and calculated via the difference between outset and final stocks and via the duration of the relevant study, were compared to the relevant values for the overall study duration, in order to obtain annual loss percentages, as a function of study duration and total loss from, or additions to, the original stocks. The relevant data is shown in Figure 68 and Figure 69.

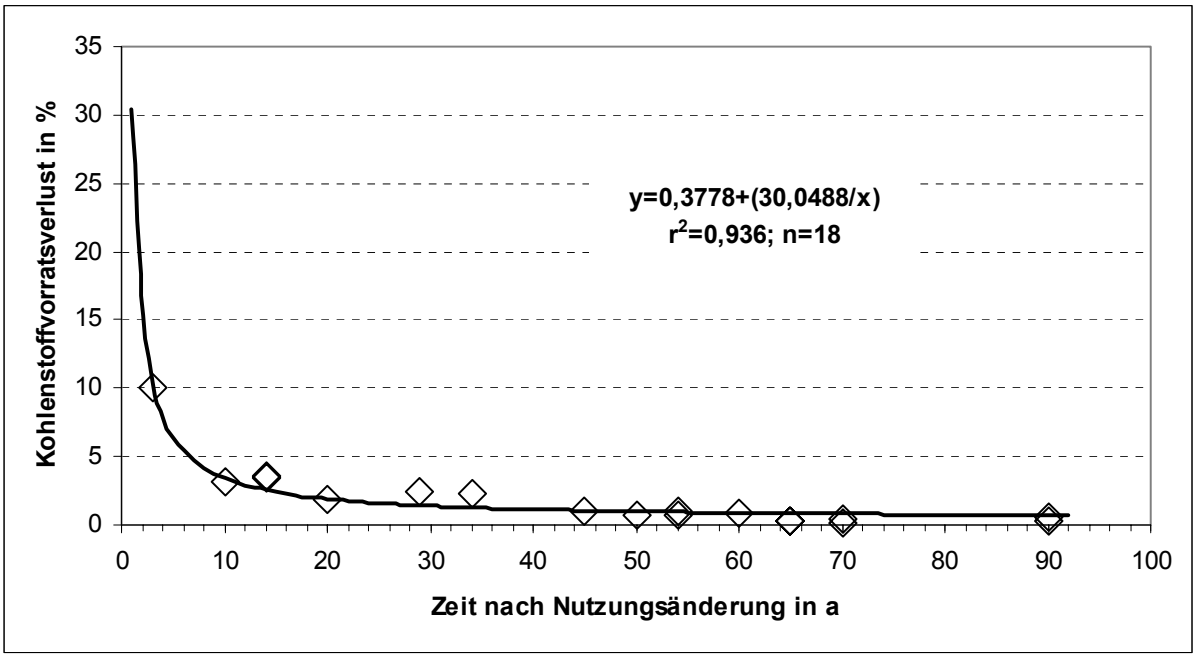


Figure 68 Relationship between annual losses from outset carbon stocks (in percent) and study duration following land-use changes (grassland, permanent cultivations, fallow land or forest to cropland (annual crops))[196]

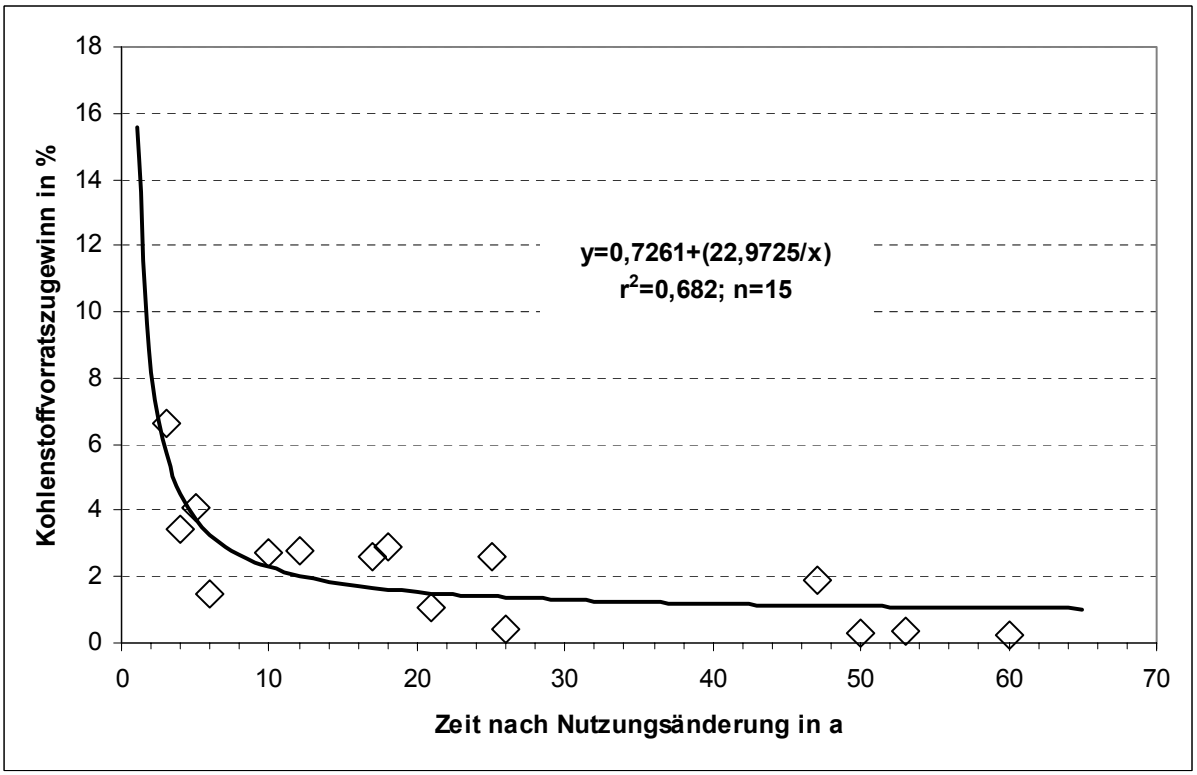


Figure 69 Relationship between annual additions to outset carbon stocks (in percent) and study duration following land-use changes (cropland (annual crops) to grassland, permanent cultivations, fallow land or forest).[196]

The highly significant inverse functions show that the largest changes in carbon stocks resulting from land-use changes occur in the first years – and mostly in the first year –

[196] Translation: vertical: Carbon-stock losses [%]; horizontal: Time after use change [a]

following the land-use changes. This means that in subsequent years changes in soil cropland are small in comparison to those of the first year. This applies both to carbon losses (normally, from conversion of cropland to grassland) and to carbon additions (normally, grassland to cropland). Only the levels concerned differ. These results, along with other calculations (using multiple regression) also show that changes in carbon stocks, in respect to 20-year periods, and after the first year, amount to only about 5 % of the original stocks in the case of additions, and to only about 1% in the case of losses.

This implies that the time period specified by IPCC GPG LULUCF (2003) as a basis for calculation of additions and losses is too long in the case of losses and much too short in the case of additions. The contribution from stock changes is thus applied in the first year following the relevant land-use change, and it is applied only once, for the year in which it is determined. As a result, German reporting does not include the floating average for 20 years (pursuant to IPCC, 2003); the average does not seem relevant, for technical reasons, and unreasonable effort would be required to obtain the necessary high degree of spatial disaggregation of changes over 20 years. Apart from these considerations, usage changes in agriculture tend to take place in the short-to-medium term, so that further changes prior to establishment of the "final balance" may be assumed (cf. Chapter 14.5.2.5.1), and thus the procedure approximates the real situation, considered generally.

The formulae shown in Figure 68 and Figure 69 thus yield the following emission factors for soil carbon:

Cropland to grassland / forest / fallow land:	15,5554	% (original stocks *1.155554)
Cropland to permanent cultivations:	15,5554	% (original stocks *1.155554)
Vineyards to fallow land:	7,777	% (original stocks *1.07777)
Fallow land to vineyards:	15,2133	% (original stocks *0.847867)
Grassland / forest / fallow land to cropland:	30,4266	%(original stocks * 0.695734)

For vineyards, the above factors result from the fact that normally every other row between vine rows is allowed to have a grass cover. For conversion of grassland to permanent cultivations and vice-versa, no changes in soil carbon stocks are assumed, since permanent cultivations normally have a grass cover. Since no nation-wide data is available on tilling of grassland, this aspect is excluded from the inventory.

14.5.2.3.2 Derivation of calculation figures (emission factors) for biomass

14.5.2.3.2.1 Permanent cultivations, fruit plantations and vineyards:

The default factor from IPCC GPG-LULUCF (2003) was used as a basis for estimating the biomass.

14.5.2.3.2.2 Grassland and non-perennial crops:

Emission factors for carbon stocks in above-ground biomass of grassland and non-perennial crops were derived on the basis of results of the 1999 main survey on soil use (Bodennutzungshaupterhebung) and of figures from the literature. The calculation was

carried out at the district level for wheat, rye, winter barley, summer barley, oats, triticale, silo corn, feed plants, potatoes, sugar beets, non-food crops (primarily rape) and grass. The figures for the areas under cultivation with the various relevant crops (ha), and those for harvests (t/ha), were taken from the 1999 main survey of soil use (Bodennutzungshaupterhebung; DESTATIS, 2000 & 2003). In some instances, harvest data for individual districts was lacking. In such cases, the data was replaced with average annual values for Germany, drawn from the Statistical Yearbook (Statistisches Jahrbuch (Tab. 105, BMVEL, 2003). The biomass, in t/district, was obtained by multiplying the area under cultivation with the applicable harvests. The harvest figures given by the main survey of soil uses (BOHE) were adjusted to take account of residual moisture content. For grain, a residual moisture content of 14 % was assumed. The corresponding figures for other crops were as follows: silo corn, 28%; potatoes, 78 %; and sugar beets, 77 %.

Biomass consisting of straw, leaves and stems was calculated with factors and dimensioned figures from harvests of grain, potatoes, sugar beets and rape. These factors were averaged from figures given in the literature:

Straw production:	Wheat:	1,2	
	Rye:	1,7	
	Winter barley:	1,05	
	Summer barley:	1,05	
	Oats:	1,4	
	Triticale:	1,7	(value for rye)
	Rape:	1,9	
Stems and foliage:	Potatoes:	0,4	t/ha
Leaves:	Sugar beets:	0,8	t/ha

Source: Die Landwirtschaft 1998; FISCHER 1988; OEHMICHEN 1990; RUHR-STICKSTOFF AG 1985

Grassland biomass was determination by multiplying the area under cultivation by the following average yields:

Grass:	8,46	t/ha	(BMVEL 2003)
Feed plants:	8,83	t/ha	(BMVEL 2003)

For calculation of biomass carbon stocks, average carbon stocks of 45 % were assumed (carbon content of individual plant parts and types 37 – 60 %, whole plants 44 – 48 % (OSOWSKI et al., 2004)). The sum of all parameters yiels the carbon stocks for above-ground biomass on agricultural land, at the district level. From these stocks, and the arable agricultural land, a district-specific, average value for biomass carbon stocks was determined (in t/ha). As EF, this value then serves as a basis for all other calculations in connection with land-use changes. Biomass calculations were carried out pursuant to IPCC GPG LULUCF (2003).

14.5.2.4 Liming

The annual figures for liming were taken from official statistics (DESTATIS, Fachserie 4, Reihe 8.2). The methods by which they were obtained are described in DÄMMGEN et al. 2004. The emissions are derived from figures for product sales. Because companies have a statutory duty to supply information, the data collection is complete. The data does not provide direct information on the annual use of fertilizers in agriculture and forestry. For this reason, figures cannot be differentiated with regard to types of application (dolomite or lime) or to the spreading sites (cropland or grassland). Differences can occur between amounts sold and amounts actually used:

- due to changes in commercial stocks
- due to use of fertiliser outside of agriculture and forestry, e.g. on private land, gardens, sports facilities.

14.5.2.5 Uncertainties

14.5.2.5.1 Area designation

The land-use categories required for allocating soil types, cropland, grassland and heterogeneously structured agricultural land, were taken from the CORINE Landcover data. The area values differ, in absolute terms, from those of the area survey (Flächenerhebung) and those of the main survey of soil use (Bodennutzungshaupterhebung). With respect to the 1993 area survey, the agricultural area is estimated to be about 11 % larger; with regard to the 1991 main survey of soil use, it is estimated to be about 21 % larger (GENSIOR, 2004). The ratio of grassland to cropland, with regard to that shown by the main survey of soil use, has remained relatively constant in the various rural districts, however: the mean deviation is 6.6 %; this means that the relative cropland area, with respect to the agricultural area, is overestimated, while the grassland area is underestimated.

The absolute difference between the agricultural area in the 1993 area survey and the agricultural area in the 1991 main survey of soil use is 8.4 %. The reasons for this difference include:

- The survey principle (operational principle (BOHE), usage principle (FE))
- The time lag between the surveys (2 years)
- Differences in definitions
- The intervals at which the cadastre areas are updated and, especially
- The cut-off boundaries (pursuant to the amended Agricultural Statistics Act (Agrarstatistikgesetz – Federal Law Gazette 1992), farms are exempted from BOHE if they have fewer than a certain minimum number of animals or if they have less than 2 ha of land).

Studies of ERHARD et al. (2002) have shown that the main survey of soil use misses some 10 % of the relevant area as a result. It is assumed that distribution of any district's remaining area corresponds to the distribution in the rest of the district, and that the remaining area cannot exceed 10 % of the district area. Via harmonisation of BOHE values with FE values, the error from this assumption cannot exceed the same level.

To estimate the error resulting from calculation of land-use changes from net data of the modified BOHE, the data on which the NIR is based, for the Gifhorn rural district, was compared with that from a study showing the results of a "satellite-imaging analysis of land-

use changes, illustrated with the example of grassland use in the Gifhorn rural district" (LAGGNER, 2003).

The net data from evaluation of the satellite imagery, and the net BOHE data, both show a decrease of grassland and cropland areas between 1991 and 2001, along with an increase in fallow areas. Consideration of the net differences shows that the satellite data and the BOHE data differ only slightly with regard to cropland and grassland (cropland: 782 ha (sat.) to 658 ha (BOHEmod.); grassland: 4,622 ha (sat.) to 2,677 ha (BOHEmod.). The larger difference for the satellite imagery in the area of grassland is due to inadequate identification of grassland in the 1991 evaluation (LAGGNER, 2003)).

Differentiation of this data, with application of the aforementioned model for conversion of grassland to cropland, yields 136 ha, and 9,152 ha for the satellite imagery (ATKIS, about 4,600 ha). For conversion of cropland to grassland the model calculation yields a value of 0 ha, while evaluation of the satellite imagery yields 6,278 ha (ATKIS, about 8,500 ha).

It becomes clear that consideration of summed data fails to take account of the majority of actual changes. As a result, the error for estimation of area shifts can be enormous and, consequently, the error in estimation of changes in carbon stocks can also be enormous. In the present case, with regard to cropland to grassland, and vice-versa, it amounts to about 6,000 – 7,000 %. This means that land-use changes are being underestimated by a factor of at least 60 – 70. In actuality, the discrepancy is likely to be even larger, since the work of LAGGNER (2003) evaluated the period 1991 – 2001 without any intermediate stages. Inclusion of an image for 1984 increases the factor to 100. It is highly unlikely that changes in carbon stocks vary to the same degree, since a "state of balance", in keeping with usage conditions, has likely been attained on these areas over centuries of agricultural use (further studies in this area are urgently required!). Nonetheless, it is clear that the CRF tables' figures for changes in carbon stocks in mineral soils, as a result of land-use changes, are underestimations. The example shows that:

- Land-use changes can be identified precisely only with the use of spatial references (for example, InVeKoS data, remote sensing, ATKIS, ALKIS)
- Changes in soil carbon stocks can be reliably determined only via inventories, or via a basic understanding of the applicable processes and "states of balance", in connection with highly complex models – models that must be suitably calibrated and validated.

14.5.2.5.2 Soil

The provisional C_{org}-stock estimates for agriculture are based on the only existing complete-coverage soil map for all of Germany, which is drawn to a scale of 1: 1,000.000 (BUEK 1000). This map integrates soil information over large areas and aggregates indexes within classes. Consequently, the scattering for data on changes in carbon stocks, as estimated from these figures, is very wide. The potential error for changes in carbon stocks is 70 % of the average.

The curve corrections for determining emission factors (Figure 68 and Figure 69) are highly significant; they explain 93.6 % and 68.2 %, respectively, of the variance. For grassland / forest / fallow land to cropland, the standard error for the estimate is 0.6 $\%_{*}a^{-1}$ of the original carbon stocks; for cropland to grassland / forest / fallow land, it amounts to 1.01 $\%_{*}a^{-1}$.

14.5.2.6 Planned improvements

It is still the case that not all of the data required for reporting for the Framework Convention on Climate is available, and that existing data cannot always be accessed in the manner required (regularly, within a reliable legal framework). What is more, the data varies in quality, and conversion of data into a common format, for compatibility, can be a laborious process. In addition, staffing levels and IT systems are inadequate for the task of proper, regular reporting in the manner described below. For this reason, decisions and action are urgently required in the following areas, if reporting is to be complete, chronologically consistent, transparent and of sufficient quality:

- Transposition of obligations into national law that governs specific execution – for example, framework laws, an "act on implementation of climate reporting" or provisions governing specific individual case – in order to clarify the following points:
- The design, implementation and execution of periodic, complete-coverage monitoring of soil carbon stocks (survey of soil condition in the agricultural sector – Bodenzustandserhebung Landwirtschaft, BZEL)
- Implementation of a system for surveying land-management / cultivation activities, or for expanding existing surveying systems (for example, InVeKoS)

Creation of the financial and material basis for the ongoing task "reporting"

14.6 Other detailed methodological descriptions for the source category "Waste and wastewater" (6)

Source category 6 Waste is divided into the sub-categories 6.A, 6.B, 6.C and 6.D. CSE sub-category 6.D Other waste includes spread sewage sludge.

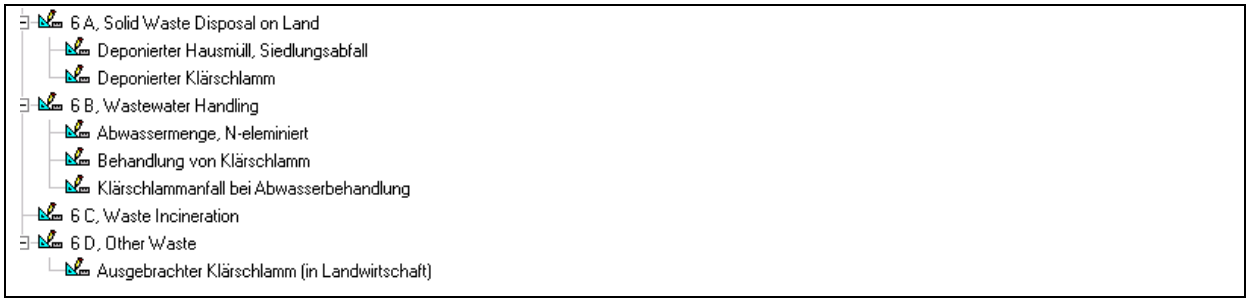


Figure 70: Structural allocation, 6 Waste and wastewater

14.6.1 Solid waste disposal on land (6.A)

14.6.1.1 Information relative to the Tier 2 approach used

Activity data for the relevant quantities of municipal waste, and for the quantities landfilled, was collected for the following fractions:

- Household waste, commercial waste similar to household waste and collected via public waste collection
- Commercial waste similar to household waste, but not collected via public waste collection (not including household waste and bulky waste)
- Mixed municipal waste and other types of such waste
- Bulky waste

- Compostable waste collected in "Biotonne" bins / compostable waste delivered separately
- Separated waste (glass, paper, plastics, electronic components)
- Road sweepings (including waste from public wastepaper baskets)
- Market waste
- Garden and park waste

The new Environmental Statistics Act (UstatG) permits collection of statistics on all key components of managed waste; in contrast to earlier procedures, however, waste quantities and waste origins must now be estimated on the basis of waste delivered to waste-management facilities. As a result, findings from statistical waste surveys carried out as of 1996 are only partly comparable with published figures for 1993 and earlier.

14.6.1.2 Uncertainties for the source category "solid waste disposal on land"

To date, emissions from source category CRF 6.A.1 Managed waste disposal on land have been modelled via the default method (Tier 1). In this simplified method, it is assumed the entire amount of methane in landfilled waste is emitted in the year in which the waste is landfilled. Since waste disposal on land is a key source for methane, in terms of emissions levels and trend, this method does not conform to requirements pursuant to IPCC-GPG.

For this reason, in future the First Order Decay (FOD) method will be used to calculate methane emissions, in keeping with provisions of the IPCC GPG. The FOD method considers the dynamic course of methane emissions from the landfill.

The following section describes the FOD method and the parameters used. The FOD method calculates in accordance with

Equation 24:[197]

Equation 24: FOD method for determination of methane production from landfills

$$CH_4 \ produced \ in \ year \ t \ (Gg / year) = \sum_x [(A * k * MSW_T(x) * MSW_F(x) * L_0(x) * e^{-k(t-x)}]$$

$$with: L_0(GgCH_4 / kgWaste) = MCF * DOC * DOC_F * F * 16/12$$

$$for \ x = first \ year \ to \ t$$

where

t = inventory year

x = Year as of which the consideration begins and amounts data is collected

MSW_T (x) =Total amount of municipal waste

MSW_F (x) = Percentage of municipal waste that is landfilled

$A = (1-e^{-k})/k$ = Normalisation factor for sum correction

k = Constant methane-formation rate (1/year)

L_0 = Potential methane formation

MCF (x) = Methane-correction factor for year x

DOC (x) = Degradable organic carbon in year x (percentage)

DOC_F = Proportion of DOC converted into landfill gas

F = proportion of CH_4 in landfill gas

16/12 =Factor for conversion from C to CH_4

To obtain the final CH_4-emissions result, methane that is collected and 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 25:

Equation 25*: Determination of CH_4 emissions*

$$CH_4 \text{ emitted in year } t \text{ (Gg/year)} = (CH_4 \text{ produced in year } t - R(t)) * (1 - OX)$$

Where

R(t) = CH_4 collection in year t

OX = Oxidation factor (proportion)

The following uncertainties were estimated by the responsible Federal Environmental Agency expert on 23 February 2004. The uncertainties must be considered provisional for the time being, since no national experience has yet been gained with the FOD method. In addition, an effort is being made to hold an expert hearing that will adjust the estimated uncertainties as necessary, thereby placing them on a broader, more reliable basis.

[197] A detailed description of the FOD method and its parameters is presented in the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, in the Greenhouse Gas Inventory Reference Manual, known as the "IPCC Guidelines" , and in the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, known as "GPGAUM".

	Definition of time series						Uncertainties data					
		Source description					Base year 1990 [4]		2002			
No.	CRF	For example, module name or suitable aggregate within the listed CRF code [1]	Further source differentia-tion if applicable	CSE time series ID if applicable	Value type (EF / EM / AR)	If EF / EM: Gas	Uncertainty [+/-%] [3]	Distribution type [5]	Uncertainty [+/-%] [3]	Distribution type [5]	Remarks on considerations, literature sources, etc..	Estimated by
1	6A1	Waste landfilling			MSW_T (x)							
2	6A1	Waste landfilling			MSW_F(x)		+/-20%	N	+/-10%	N	For 1990: low reliability in ABL, no data for NBL	
3	6A1	Waste landfilling			DOC(x)	CH4	+/-20%	N	+/-20%	N	No reliable results from studies of raw waste in MB-waste-treatment facilities	
4	6A1	Waste landfilling			DOC_F	CH4	+/-30%	N	+/-30%	N		
5	6A1	Waste landfilling			MCF(x) (bei MCF=1)	CH4	+ 0% -10%	L	+0% -10%	L	Pursuant to IPCC-GPG	
6	6A1	Waste landfilling			F	CH4	+10% -0%	L	+10% -0%	L		
7	6A1	Waste landfilling			k	CH4	+50% -35%	L	+50% -35%	L		
8	6A1	Waste landfilling			R(t)	CH4	+/-10%	N	+/-10%	N	Pursuant to IPCC-GPG, low with respect to other uncertainties	
9	6A1	Waste landfilling			OX	CH4	+50% -35%	L	+50% -35%	L	Corresponds to half-life of 3.5 years (k=0.23) to 8 years (k=0.09)	

[1] If the CSE module name and CSE time-series ID are not available for estimation, or are too detailed, the sources may also be defined via CRF, and another unambiguous description, in the field "further source differentiation".

[2] Pursuant to CSE dimensions, if required for differentiation: e.g. fuel, type of operation, material, equipment, measure

[3] With log-normal distribution: [+x%; -y%]

[4] For F gases, the base year is 1995.

[5] Distribution types: N (normal distribution); L (log-normal distribution); T (triangular); U (uniform)

14.6.2 Wastewater (6.B) – Data for determination of emission factors for wastewater and sewage-sludge treatment (6.B.2)

Under the IPCC method, percentage levels of aerobic and anaerobic wastewater and sewage-sludge treatment should be determined via characterisation of wastewater and sewage-sludge treatment systems at the national level.

Evaluation of national inventory reports shows that the various Länder have used widely differing approaches to determine their Länder-specific emission factors. In some countries, the available data is not adequate to permit direct use of the IPCC method, and thus such countries have used alternative calculation methods or aggregated values. The evaluation reveals the following:

- A few countries list specific methane conversion factors for national treatment systems (Czech Republic, U.S., Finland; cf. Table 133). In addition, sub-categorisation of wastewater systems is not standardised.
- In some countries, it is assumed that wastewater treatment normally occurs, either aerobically or anaerobically, in closed systems with methane collection, but that small quantities of methane can still escape in exceptional situations. In such cases, very low MCF are chosen for treatment of municipal wastewater (Finland, Czech Republic).
- The UK uses a national method based on characterisation of sludge-treatment processes.
- In some countries, emission factors are determined not via organic load, percentage level of anaerobic treatment and MCF – as called for by the IPCC – but via population equivalents (Canada, Austria, Germany).
- Only Austria explicitly differentiates its emission factors by mechanical, biological and other treatment.

Table 133: Reported methane conversion factors in national inventory reports

MCF	Czech Republic	Finland	U.S.
Management of household and commercial wastewater		0,025	0,05
aerobically treated municipal wastewater	0,05		
anaerobically treated municipal wastewater	0,5		
on-site treatment	0,15		
untreated household and commercial wastewater			
discharge into rivers	0,05		
septic tanks			0,5
Industrial wastewater treatment		0,01	
aerobically treated industrial wastewater	0,06		
anaerobically treated industrial wastewater	0,7		
untreated industrial wastewater	0,05		
differs by sector			0,05 - 0,77
Sludge treatment			
aerobic treatment of sludge from municipal wastewater	0,1		
anaerobic treatment of sludge from municipal wastewater	0,5		
aerobic treatment of sludge from industrial wastewater	0,1		
anaerobic treatment of sludge from industrial wastewater	0,3		

Source: National inventory reports

Further information on determination of methane emissions from wastewater and sewage-sludge treatment of other countries is provided by (ÖKO-INSTITUT, 2004b).

14.6.3 Determination of nitrous oxide emissions from wastewater treatment (6.B.2)

The IPCC Guidelines describe a method for estimating nitrous oxide emissions from wastewater treatment (IPCC, 1996a: Chapter 6.5). An evaluation of experience gained by other countries (further information in ÖKO-INSTITUT, 2004b) shows that all countries that determine nitrous oxide emissions from wastewater treatment either use the IPCC method or made country-specific adjustments to the IPCC method:

- One exception is Belgium, which determines emissions on the basis of the EMEP/CORINAIR manual.
- Some countries also determine nitrous oxide emissions from industrial wastewater, although the IPCC does not describe any method for this (Austria, New Zealand, Sweden and, in future, U.S.).
- The most important relevant country-specific adjustments include consideration of industrial wastewater (see above), determination of nitrogen loads in wastewater-treatment systems instead of determination of daily human protein intake (Sweden) and consideration of other nitrogen sources in municipal wastewater (U.S.).
- In those countries in which nitrous oxide emissions are determined, inter alia, via nitrogen fractions in protein, the IPCC default value is used.
- All countries use the IPCC default value in cases in which the emission factor (kg N_2O-N/kg wastewater N) is relevant for determination of nitrous oxide emissions.
- Data on average per-capita protein intake comes either from national studies and data (UK, Australia) or from the FAO database (U.S., Austria, etc.); such data varies widely. The protein intake for the UK, which was determined via a national survey, is much lower than the others; this is due to the method by which the average value was determined. Table 134 lists average daily protein intake, along with the pertinent

data source, for those countries that list this data item explicitly in their national inventory reports.

Table 134: Average daily and annual protein intake

Country	Protein [kg/person & year]	Protein [kg/person & day]	Data source
UK	8,65	0,024	National Food Survey (DEFRA, 2001). The data is based on a survey of food consumption at home and thus is likely to be a low estimate.
Australia	36,28	0,099	Australian Institute of Health and Welfare (de Looper and Bhatia
USA	41 (1996)	0,112	FAO database
	41 x1,75	0,197	Adjustment via comprehensive method
Sweden	32,85	0,090	National data
Canada	40,15	0,110	No data source listed
Germany	34,68	0,095	FAO database (average, 1990-2001)
New Zealand	4,75	0,013	With respect to nitrogen in wastewater
Belgium			FAO database
Czech Republic	25,00	0,068	No data source listed

Source: National inventory reports

15 ANNEX 4: CO_2 REFERENCE APPROACH AND COMPARISON WITH THE SECTORAL APPROACH, AND RELEVANT INFORMATION ON THE NATIONAL ENERGY BALANCE

Information on the CO_2 reference approach, a comparison with the sectoral approach and relevant information on the national energy balance is found in Chapter 3.1.6.

16 ANNEX 5: ASSESSMENT OF COMPLETENESS, AND ASSESSMENT OF POTENTIALLY EXCLUDED SOURCES AND SINKS OF GREENHOUSE GAS EMISSIONS

To date, no detailed information is available on assessment of completeness and of potentially excluded sources and sinks of greenhouse gas emissions.

17 ANNEX 6: ADDITIONAL INFORMATION TO BE CONSIDERED AS PART OF THE NIR SUBMISSION (WHERE RELEVANT) OR OTHER USEFUL REFERENCE INFORMATION

17.1 German National System of Emissions Inventories

Artcle 5.1 of the Kyoto Protocol mandates the establishment of National Systems for preparation of greenhouse-gas emissions inventories. Under this provision, industrialised countries (Annex I Countries) commit themselves to installing, by no later than 2007, **National Systems** that support determination of greenhouse-gas emissions from sources and greenhouse-gas emissions removals via sinks. Via the *Decision of the European Parliament and the Council on a system for monitoring of greenhouse-gas emissions in the Community and for implementation of the Kyoto Protocol of 11 February 2004*, Germany is also obligated to prepare **national inventory systems** under the Kyoto Protocol, with this process to begin no later than 31 December 2005.

17.1.1 Tasks of the National System

The purpose of the National System is to ensure, by means of continual quality management and ongoing inventory improvement, that the methodological provisions of the IPCC uidelines and the GPG are extensively applied. It comprises all institutional, legal and procedural facilities and agreements to be reached and established in Annex 1 countries of the Framework Convention on Climate for emissions calculation reporting and for archiving of all relevant inventory information.

As a result, in preparation of emissions inventories, a National System must involve all those institutions and resources of the relevant country that are able to make highly competent contributions to such inventories. Such efforts include the following tasks:

- Establishment of a national agency for co-ordinating emissions reporting[198]
- Specification / documentation of institutional facilities, legal agreements and procedures on emissions calculation and reporting
- Archiving of all inventory information
- Initiation of measures for improving emissions inventories

Extensive organisational scope is granted to the Parties for the concrete institutionalisation of the National System. Figure 71 provides a schematic overview of the functions that must be provided and of the institutions to be involved in implementing the National System. Germany's National System does not have to be created from scratch; it is being built on existing relevant inventory-preparation structures and procedures and adapted to international requirements, and improved, as necessary.

198 The co-ordinating agency (single national entity – SNE) is charged with serving as the central point of contact for all participants in the National System. It is required to provide a framework for transparent, consistent, complete, comparable and precise inventories.

The National System

In preparation of emissions inventories, the National System should involve all of the state's institutions that can make highly competent contributions to such inventories.

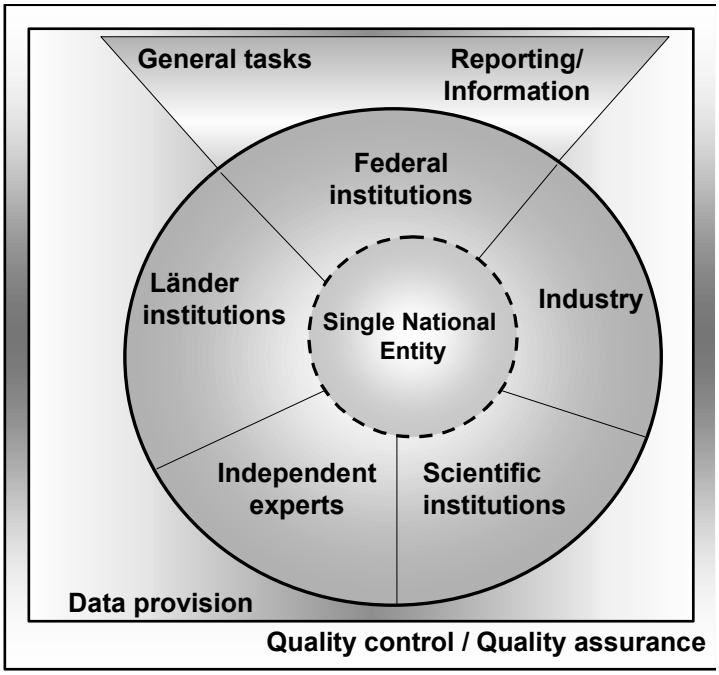


Figure 71: Functions of the National System and the institutions to be involved

17.1.2 Development of the National System

In implementing provisions on establishment of a National System, the Federal Environmental Agency is receiving specialised and technical support from a research project (FKZ: 201 42 258) that will help to formulate an overall concept, for implementation of the National System, which makes allowance for both international requirements and the applicable national framework. The requirement areas of the National System where priority action is needed in future have been identified, so that the bulk of the work for implementing the National System can be completed by the year 2005. The project was launched at the end of 2002 and is being conducted in close collaboration with the UBA until October 2005 (ÖKO-INSTITUT, 2004a).

The ***Coordination Agency for the National System (Single National Entity)*** is sited in the Federal Environmental Agency's Section I 4.6. It acts as a central point of contact, and it coordinates and informs all participants in the National System. During the period 2003-05, the SNE will additionally be identifying new institutional facilities to be incorporated into the National System, as well as checking and initiating the conclusion of legal agreements for ensuring data continuity for the inventories. The SNE will also be responsible for central archiving.

The National System institutions, in addition to the SNE, include the ***Quality System of Emissions Inventories*** (QSE), which is currently being established for management of quality monitoring and assurance, and the ***Central System of Emissions*** (CSE), a central, national database for emissions calculation and reporting (cf. Figure 72).

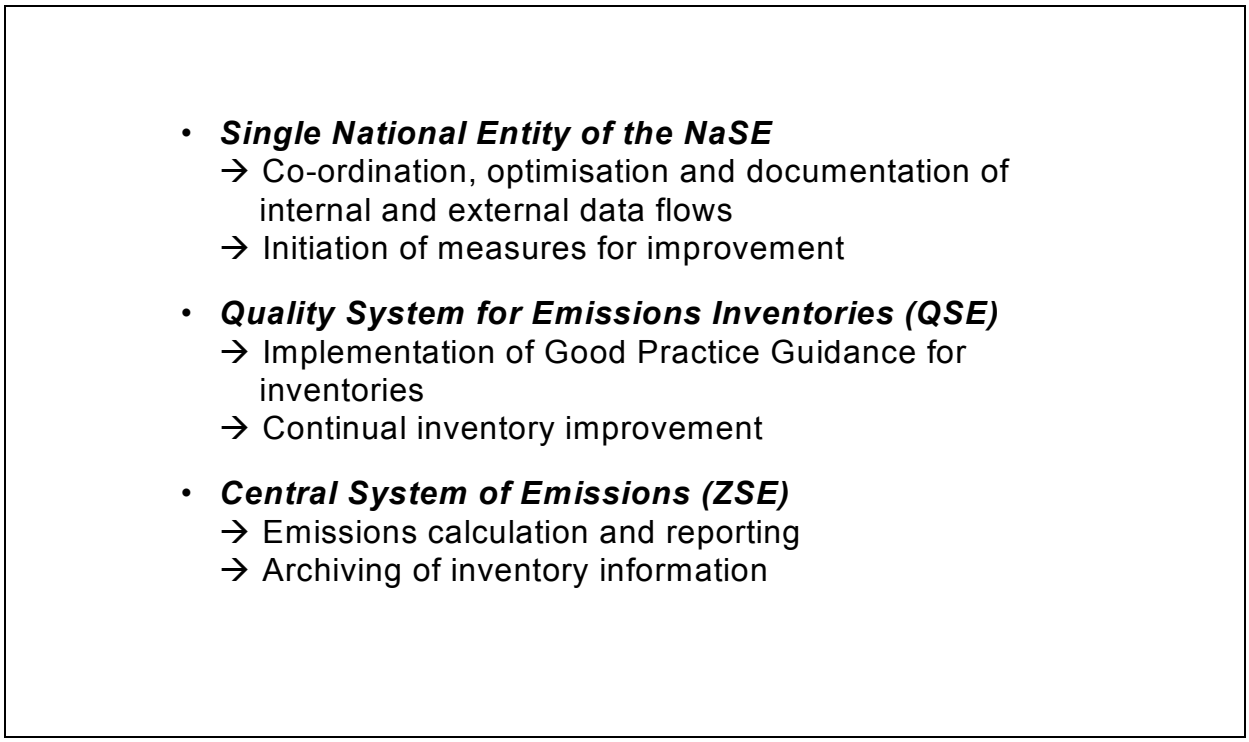


Figure 72: Institutions of the National System of Emissions Inventories

In a first step, the SNE has concentrated its efforts on initiating activities, in the Federal Environmental Agency, in support of establishment of the National System. A *Working Group on Emissions Inventories* has been set up to coordinate relevant work within the Federal Environmental Agency; it will incorporate all of the agency's employees who are involved in inventory preparation. Since the second half of 2002, the national coordination agency (SNE) has held a growing number of information events on the requirements resulting from the Framework Convention on Climate Change and the Kyoto Protocol, and in particular, on the resultant consequences for the UBA's specialised efforts. Since then, internal awareness, at the Agency, of the relevance and scope of this task has risen sharply. The Working Group is charged with facilitating participation of experts in the inventory-preparation, reporting, quality assurance and review processes, as well as with externally communicating relevant requirements via contacts with external data providers. The Working Group's members maintain bilateral contacts within the context of ongoing inventory work. In addition, the Working Group meets three times per year to inform all of its members of progress achieved and of further action required to improve the inventories.

In a second step, the national coordinating agency (SNE) is working to involve additional institutions in the National System. This work as well builds on existing structures.

17.1.3 Workshop on the National System

In November 2004, the Federal Environmental Agency held a workshop on the National System of Emissions Inventories. At this workshop, participants were informed about the status of emissions reporting on greenhouse gases, as well as about relevant requirements. The event also discussed existing problems and weaknesses, and it developed and identified approaches for improving inventories and inventory reporting and for solving relevant problems. The event topics included methods in various areas and for various source categories, databases for the greenhouse-gas inventory, coordinating preparation of a

balanced, harmonised National Inventory Report (NIR) and overarching topics relative to inventory preparation, such as quality assurance and control, uncertainties and data secrecy.

The event was aimed at persons who currently provide, or who may provide, contributions or data to the national greenhouse-gas inventory. This group includes Federal Environmental Agency specialists involved in inventory preparation, participating departments of ministries and of their subordinate authorities, representatives of the Länder, associations, working groups, research institutions and the Federal Statistical Office (DESTATIS).

The workshop provided both overarching, general information and information about specific source categories, with regard to the current status of greenhouse-gas-emissions reporting and relevant requirements. The event's topical emphases included:

1. The main requirements for greenhouse-gas reporting, on the basis of relevant international regulations and provisions;
2. The current status of implementation of such international requirements in Germany;
3. Specification of requirements in light of the SNE's experience with current reporting;
4. Specification of requirements on the basis of experience with, and results of, international reviews of greenhouse-gas inventories;
5. Specification of requirements in light of reporting of other countries;
6. Overarching requirements in implementation (for example, development of new data sources; ensuring provision of at least minimum data sets comprising data, uncertainties, methods and documentation; institutionalisation of data flows; data protection / secrecy, quality assurance /–control, etc..).

The workshop was divided into a general part, aimed at all participants, and sector-specific parts covering the areas of energy, industrial processes, agriculture, forestry and land-use changes. With respect to the area-specific sections, four working groups were formed; these groups worked concurrently, during the workshop, on selected issues relative to individual source categories within the areas. The workshop results will be used directly for inventory improvement, and they are now being summarised in a workshop report that is likely to be completed by the end of March 2005.

17.2 German Quality System for Emissions Inventories

Since 2002, the national coordinating agency (SNE) has been working to develop and implement a QC/QA system (Quality System for Emissions Inventories - QSE). A research project is providing scientific support for the Federal Environmental Agency in implementing requirements from *Good Practice Guidance*. The QSE should serve to meet the requirements of the IPCC, and it should make allowance for the national situation in Germany and for the internal structures and procedures of Federal Environmental Agency (UBA), the reporting institution. The QSE's procedures should be flexible enough to be able to routinely incorporate future changes in requirements. The project will develop a procedural and organisational concept that addresses identified problem areas in emissions reporting and that transparently defines responsibilities for the procedure. At the same time, the

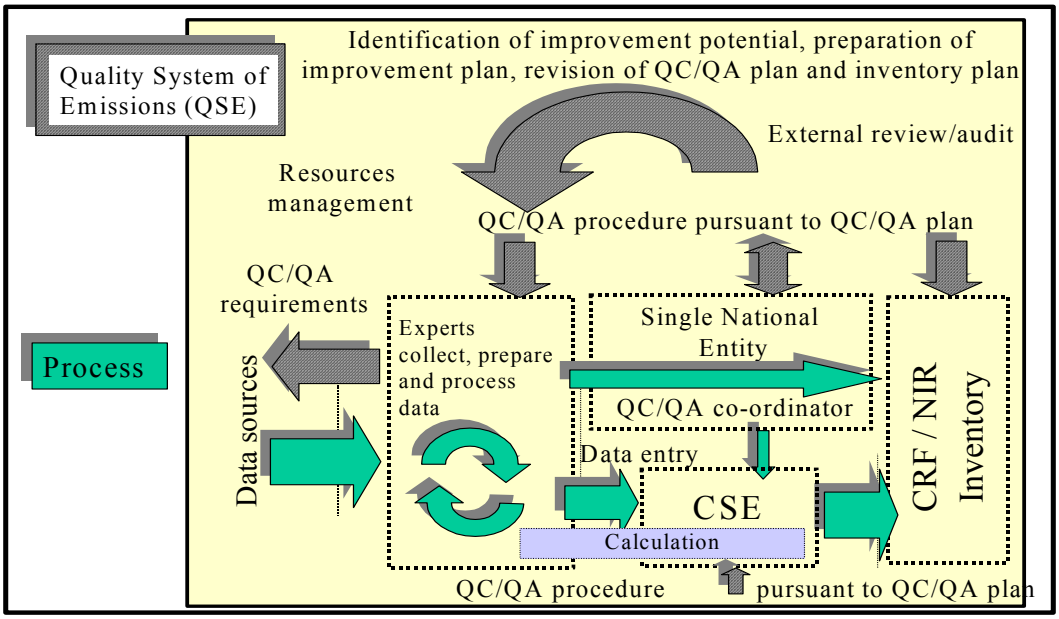
process will link inventory preparation and QC/QA measures in a manner oriented to specific target groups.

17.2.1 Tasks of the Quality System of Emissions Inventories

The national coordinating agency (SNE) is charged with describing, introducing, updating and documenting QC/QA procedures. Such tasks apply both to procedures for quality assurance and control within the Federal Environmental Agency and to work with external data providers and organisations in the framework of the NaSE. The main elements of a QC/QA system that conforms to the minimum requirements of IPCC GPG (2000: Chapter 8.3) include:

- The QC/QA system must have an appointed coordinator. The QC/QA coordinator is responsible for maintaining the system and implementing the QC/QA plan, and he/she serves as a contact person for all of the Federal Environmental Agency's sections and for experts working in the framework of the NaSE;
- Implementation of a start-up organisation, with clearly defined responsibilities and competences,
- Preparation and maintenance of a QC/QA plan,
- Introduction and description of the necessary overarching and source-category-specific QC measures (Tier 1 + Tier 2),
- Introduction and description of the necessary internal and external quality assurance measures reviews, audits),
- Definition of documentation, recording and reporting obligations, and introduction of a procedure for document management,
- Procedures for monitoring, assessing and modifying the QC/QA system within the meaning of continual improvement,
- System documentation, in a suitable form (manual, guide).

The aforementioned QC/QA-system elements represent a concept for an ideal, IPCC-conformal emissions-reporting process (cf. Figure 73). Such a concept has been developed in general form and is currently being tested, in the framework of partial solutions, for practical feasibility.



[B/W arrows: flow of data/text; green arrows : QC/QA elements]

Figure 73: Ideal concept for the emissions-reporting process

The QSE's scope of application comprises the entire emissions-reporting process:

- Data collection, including selection of methods and data sources
- Data preparation and emissions calculation
- Reporting

The term "data" includes figure and number data (activity data, emission factors and uncertainties, as well as material and calculation rules that can be used to obtain such data) and texts and documents, such as those that enter into the national inventory report.

The QSE is binding for all NaSE participants. In the first half of 2004, the Federal Environmental Agency will issue an internal directive / work instructions setting forth the binding nature of the QSE. Details regarding the system's binding applicability for other NaSE participants remain to be defined.

17.2.2 Structure of the Quality System of Emissions Inventories

17.2.2.1 Initial organisation

Within the QSE framework, a concept for initial, start-up organisation was developed that defines binding responsibilities and 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 135).

Table 135: Roles and responsibilities in the QSE

Role	Task	Responsible
QC/QA co-ordinator (QCC)	Overarching QC and QA throughout the entire reporting process Maintenance and further development of the QSE Management and updating of the QC/QA plan and QSE manual Description of quality targets Management and updating of the improvement plan, and management of relevant adoption in the inventory plan	An appointed staff member of the national co-ordinating agency (SNE)
NaSE co-ordinator	Ensuring on-time, requirements-conformal reporting Initiating implementation of overarching measures from the inventory plan Selection of institutions and collection of relevant informational materials, legal agreements Ensuring that all inventory information is archived, carrying out central archiving of inventory information Preparation of execution and post-processing of inventory reviews	An appointed staff member of the national co-ordinating agency (SNE)
Specialised contact person (source-category-specific) in the SNE	Facilitation of specialised and technical support (QC/QA, inventory work and reporting)	An appointed staff member of the national co-ordinating agency (SNE)
Contact persons in Federal Environmental Agency sections	Multipliers in sections and specialised areas with regard to the national co-ordinating agency (SNE) information's and requirements with regard to emissions reporting	An appointed member of each relevant section
QC/QA representative for the specialised area	QC for data and report sections delivered to the national co-ordinating agency (SNE) Approval of report sections Ensuring that necessary inventory work, QC measures and documentation are carried out at the operational level Definition of specialised responsibilities for emissions reporting within the section in question	Heads of all affected sections
Specialised representative at the operational level	Data collection, entry and calculation, in keeping with the prescribed methods Definition of source-category-specific quality and review criteria Execution of QC measures Decentralised archiving of source-category-specific inventory information	All employees appointed by the relevant section head
CSE Administrator (CSE Admin)	Overarching QC and QA throughout the entire inventory process Approval of review criteria for the CSE Ensuring the integrity of databases Emissions reporting and data aggregation into report formats	An appointed staff member of the national co-ordinating agency (SNE)
Report co-ordinator (NIRC)	Contact person for section, for work related to the NIR Coordines support (collects work from section staff and distributes it within the national co-ordinating agency (SNE))	An appointed staff member of the national co-ordinating agency (SNE)

17.2.2.2 Procedural organisation

Procedures for QC/QA measures in the CSE are oriented to the emissions-reporting process described in Chapter 1.3. At the same time, quality must be directly linked with the various steps in the inventory process. In future, suitable QC measures will be allocated to each step of the process; these measures will then be assigned, via the defined initial/start-up organisation, to the various relevant players.

The necessary QC reviews are currently undergoing a coordination process. Beginning with reporting in 2006, they will be sent to the involved experts, in the form of QC checklists containing data requests, and they will have to be completed throughout the course of support work. QC checks are actually defined not as checks but as quality targets; in each case, either compliance with the targets must be confirmed or non-compliance must be justified. By way of example, Table 136 shows relevant checks for definition of requirements. In a first training measure carried out in January 2004, these checks were presented, together with the draft of the concept for the QC/QA plan, to experts of the Federal Environmental Agency and the Federal Agricultural Research Institute (FAL).

No.	Process step/ *Aspect*	Quality target	Documentation	Responsible	Tier 1/ Tier 2	Quality target achieved		Option for action	Option exercised		Not applicable
						yes	no[199]		yes	no	
1.0	**Data collection**										
1.1	**Definition of requirements**										
1.1.1		The general requirements for basic quality control (Tier 1) have been defined and documented.	QKP	QCC	1						
1.1.2		The general requirements pertaining to data and report formats (CSE and NIR) have been defined and documented.	IB	QCC, CSE Admin	1						
1.1.3		The current key sources have been defined and documented.	IB	QCC	1						
1.1.4		The existing data pertaining to the source category has been documented and made available to the responsible expert.	IB	QCC, CSE Admin	1			Where documentation of the data source is incomplete, required actions are described in the improvement plan.			
1.1.5		The general requirements have been defined and documented, taking the information description in 1.1.1-1.1.5 into account.	IB	QCC	1						

Table 136: Example of QC checklist for the process step "definition of requirements"

199 Where a target is not met, the nature and extent of the required corrective measure(s), along with the name of the responsible party, the relevant time frame and any applicable restrictions, must be noted on a separate sheet.

17.2.2.3 Documentation system

The QSE will be used to introduce the necessary QC/QA measures, pursuant to the IPCC, for the entire process of emissions reporting. Execution, description and documentation of QC/QA measures take place largely in conjunction with the relevant inventory contributions. To this end, a documentation system was developed that represents all such measures and related actions in an integrated manner tailoured to the specific parties and tasks concerned. The documentation system will be introduced at the Federal Environmental Agency in 2004. Figure 74 presents the interrelationships between the various elements of the system.

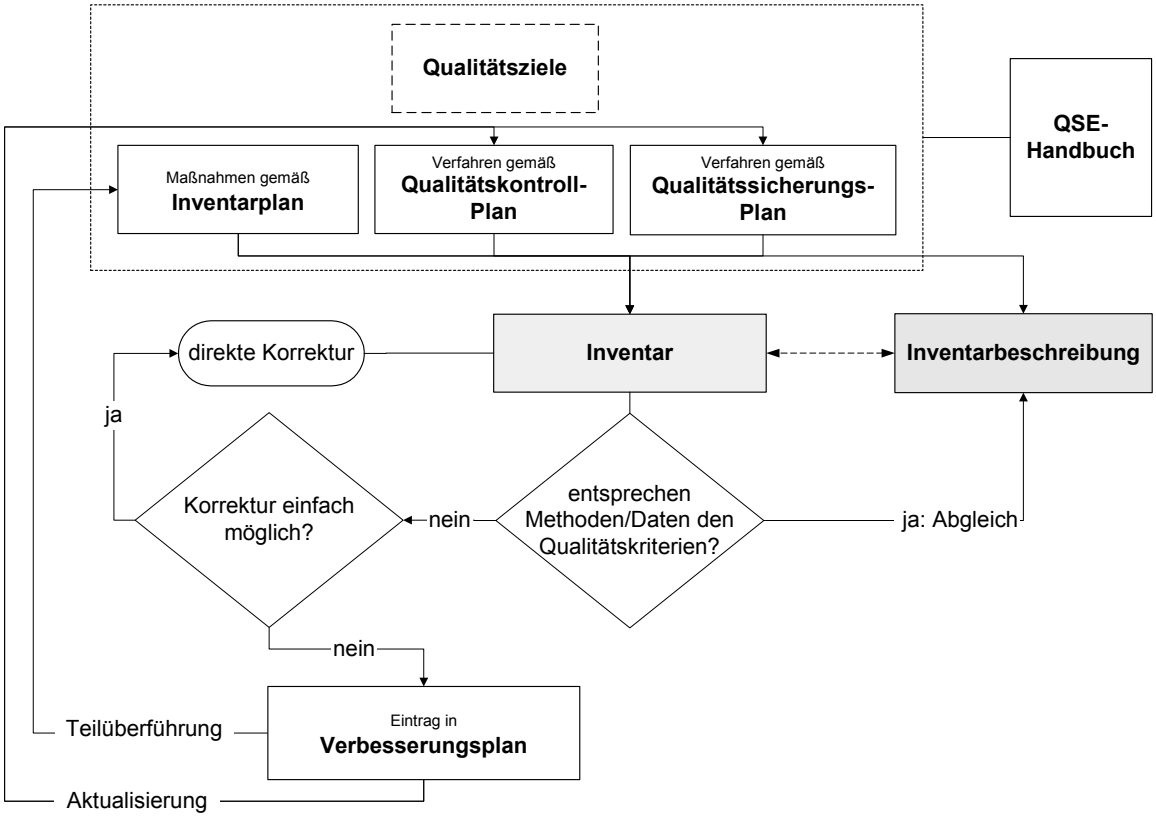


Figure 74: Interrelationship of various elements of the QSE[200]

The ***QC plan*** describes all quality-control procedures; similarly, the ***QA plan*** describes all quality assurance procedures (including review and audit). QC/QA measures are carried out regularly. The plans are updated annually.

By carrying out QC/QA measures, the Federal Environmental Agency, along with other NaSE participants, can identify improvement measures with regard to emissions reporting and to the QSE. Where improvement measures can be easily and promptly carried out, correction takes place right away. Any more time-consuming and complex improvement measures for the inventories, and all improvement measures for the QSE, are first reported by the responsible experts to the Single National Entity, which then summarises them within the **improvement plan**.

[200] Translation (from top and from the left to the right): Quality targets; Measures pursuant to inventory plan; Procedures pursuant to quality-control plan; Procedures pursuant to quality-assurance plan; QSE Manual; Direct correction; Inventory; Inventory description; Simple correction possible?; Do methods / data conform to quality criteria?; Yes: Update; Teilüberführung = Partial transfer; Entry into improvement plan; Updating]

The Single National Entity integrates improvement measures for inventories within the **inventory plan** for the following year, after setting priorities as necessary. In addition to improvement measures, this plan contains short summaries of the goals applying to inventory preparation for each of the source categories. Improvement measures from the inventory plan are published in the NIR, and correction measures in this framework become binding and subject to specific deadlines. Improvement measures affecting other ministries and departments are co-ordinated within the framework of *Working Group VI* of the *CO_2-Reduction* IWG. In each case, specific procedures must be agreed for improvement measures that are to be carried out by National System participants who are not affiliated with any federal institutions. The inventory plan undergoes defined approval processes, as an attachment to the NIR and via UBA's internal co-ordination procedures and interministerial co-ordination.

Inventory description is a central documentation element. In such descriptions, inventory-preparation procedures are described source-category-specifically. In each case, documentation agrees with the relevant current NIR, which is always prepared on the basis of deliveries from the competent experts. Inventory description is supplemented with additional documentation – such as complex calculation models. Such description, which supports the review process, is managed by the Single National Entity, on the basis of contributions by the responsible experts.

All QSE documentation with regard to the system's initial and regular organisation is managed within the framework of the QSE manual. This manual is subject to the approval of the Federal Environmental Agency's top management.

17.2.3 Quality targets

The overarching purpose of the QSE is to ensure compliance with international reporting obligations with respect to transparency, consistency, comparability, completeness and accuracy in inventory preparation (cf. Figure 75).

Figure 75: Requirements, from international reporting obligations, pertaining to inventory preparation

Transparency means that the assumptions and methods used in preparation of emissions inventories must be clearly explained so that users can understand and assess the reported information. Transparency is of fundamental importance with regard to the success of an IPCC-conformal emissions-reporting process.

Consistency means that all elements of an emissions inventory are consistent with inventory elements from other years. An emissions inventory is consistent if the same methods are used for the base year and all subsequent years, and if consistent data records are used to calculate emissions and sinks. Under certain conditions, an emissions inventory may be considered consistent even if different emissions-calculation methods have been used, as long as relevant transparent recalculations have been carried out in conformance with the requirements of IPCC *Good Practice Guidance*. A consistent overall inventory results through avoidance of double counts in the inventory and through establishment, for all source categories, of congruency between the ways activity data and emission factors are delimited.

Comparability means that determined emissions and sinks may be compared across different source categories, and it means that the entire inventories of different states lend themselves to comparison. Comparability is achieved through standardised use of methods – such as that prescribed by *Good Practice Guidance*, for example. Furthermore, sub-elements must be allocated to the appropriate source categories in a standardised way.

Completeness means that the relevant inventory is complete with regard to the relevant gases and pollutants, as well as the relevant source categories and sinks. This also includes spatial/geographical completeness. And completeness also includes adequate documentation.

Accuracy refers to relative measurement of the precision of emissions and sink data. Identified emissions and sinks should be neither systematically overestimated nor systematically underestimated. Uncertainties should be reduced as far as possible. To this end, they must first be quantified.

The special quality targets pursuant to Tier 1 are currently being prepared by the Single National Entity within the framework of development of QC checklists (cf. Chapter 17.2.2.2.). Source-category-specific / sectoral quality targets should be defined, in keeping with the above principles, by the responsible experts, in co-operation with the QC/QA co-ordinator. Targets should be derived, inter alia, from completed QC/QA measures (internal/external reviews, audits, if applicable) and documented within the inventory plan.

17.3 The database system for emissions – Central System of Emissions

Since 1998, the UBA has developed a central national database – the *Central System of Emissions (CSE)* – as a technical tool for inventory preparation. The CSE implements the diverse requirements pertaining to emissions calculation and reporting, and it automates essential work stages. The CSE facilitates inventory planning reporting (e.g. emissions calculation, recalculation and error analysis) as well as inventory management (e.g. archiving, annual evaluation of data) and data-level quality management (cf. UBA 2003a, Decor project manual). The CSE should make it possible to fulfill the key requirements of transparency, consistency, completeness, comparability and accuracy on the data level.

In order to ensure fulfillment of these key requirements, careful attention is given to documentation within the CSE. In the CSE, records are kept of persons responsible for processing, of data sources and calculation procedures, of uncertainties relative to time series, of the date of each last change and of the persons who use such changes. The system has a history-management function that archives deleted entries. This facilitates the tracking and reconstruction of data, thereby also enabling an independent review by third parties. Supporting mechanisms are provided or developed at data level for the performance of quality assurance (e.g. system for detecting uncertainties, plausibility checks). Above all, transparency is accommodated by ensuring that data is recorded in the same structure in which it is provided, and that all processing and transformations into reporting format occur only in the CSE, in the interest of clarity. In this way, the CSE is capable of administering detailed technology-specific activity data and emission factors that can be processed, via calculation rules (calculation methods), into aggregate, source-category-specific values for the reporting formats. Aggregation of individual CSE time series for the CRF report lines is described in Annex 3 and Chapter 14f – in each case, with regard to individual source categories. In addition to aggregation and model formation for calculations, the CSE also supports scenario and forecast calculation.

Data exchange within the framework of the national system – i.e. within the Federal Environmental Agency and with third parties – is also organised via the CSE. In addition to being input directly, aggregate figures may also be imported from existing databases via a standard interface (e.g. TREMOD, GAS-EM). The aim is for technical experts responsible for content to enter inventory data directly into the CSE wherever possible or, at least, for the CSE administrator to import such data via the import interface. This applies to in-house UBA

employees as well as to external parties involved in the National System. In order to achieve this, fundamental preparations have been carried out since 2001:

- Provision of a *standardised import format for CSE* in 2002 has facilitated the direct import of data from other emissions-relevant databases.
- In September 2002, participating technical experts from the UBA were given direct access to the CSE via the UBA intranet. The relevant parties are identified via an annual survey; as a result, virtually all of the responsible experts at the Federal Environmental Agency now have such access. However, write access rights for these experts are normally confined to the database content for which they are technically responsible.
- In November 2002 and 2003, training courses in the CSE were held for relevant UBA staff members.
- Course participants were provided with a description of the database in the form of the *CSE/Point Source User Manual* (UBA, 2002c).

The CSE's operational launch in 2002 fulfilled the principal technical requirements for compliance with the Kyoto requirements for inventories; the next stage now is to bring emissions-calculation and data-collection procedures completely into line with the CSE. In 2005, the CSE will be connected to the Internet. This will enable external experts also to enter data directly into the CSE and conduct searches in it.

Other future tasks for the Central System for Emissions include comprehensive application of the database for:

- Recording of qualitative and quantitative information about data uncertainties,
- Complying with reporting obligations under the Geneva Convention on Long-Range Transboundary Air Pollution and EU legislation (such as the NEC directive),
- Measures-based orientation of emissions calculation to facilitate better quantification of the effectiveness of emission reduction measures in future, and
- Preparation of forecasts and scenarios to facilitate future estimates on compliance with reduction obligations and to facilitate identification of additional measures needed for target attainment.

17.3.1 Documentation of calculations in CalQlator

To support transparent documentation of calculations, the Federal Environmental Agency has developed a calculation tool for the CSE; this tool went into operation at the end of 2003. CalQlator makes it possible to store complex calculation methods in a user-friendly form in the database. It supports derivation of equations for linking entered values within calculations; once a formula has been entered, all calculation steps can be traced, and single changes trigger consistent recalculation of entire time series. Via a function for definition of inequalities, CalQlator can also be used for quality assurance – for example, via definition of checking parameters for maximum deviations. In January 2004, a first group of UBA staff received an introductory training course for CalQlator.

17.3.2 Data transfer between the TREMOD and CSE databases

In 1999/2000, an interface was programmed for transfer of emissions data, for the source category *road transport*, from the TREMOD (Transport Emission Estimation Model) database

into the CSE database; in 2003, this interface was adapted to an upgraded version of the CSE database.

The current CSE import format is shown in Table 137 below.

Table 137: Dimensions in the CSE, and pertinent TREMOD categories

CSE heading	Description	TREMOD categories
SE:Name	Structural element	Vehicle category, vehicle layer, road category
Ts:Name	Time-series name	Like SE:Name
Spatial reference:Name	Germany, old German Länder, new German Länder	Scenario, Land
Value type:Name	Activity rate (energy consumption), emissions	Energy, component
Gas:Name	For example, carbon dioxide, sulphur dioxide	Component
EmiGru:Name	Source category – e.g. municipal road transport	Road category
VwA:Name	Type of use: Propulsion, evaporation	Emissions category (warm-up, ignition, evaporation)
Material:Name	Material (input) – e.g. diesel fuel * Energy Balance	Energy, energy balance, correction factor for energy balance
Measure:Name	Measure: Conventional, reduction equipment	Emission standard (vehicle layer)
Equipment:Name	Equipment – e.g. passenger automobile	Vehicle category
EBZ:Name	Energy Balance source – e.g. Road transport, 95	-
Unit	Units TJ, kg/TJ, t	

The most important category in the CSE is the structure element (SE). For it to be possible to derive activity rates and emission factors from TREMOD, for structure elements, several TREMOD categories have to be combined. A structure element thus consists of

- Road categories (in CSE, as "Emigruppe")
- Vehicle categories (in CSE aggregated to some extent under the "equipment" ("Technik") category)
- Vehicle layer (in the CSE category "Measure", differentiates between "conventional" and "reduction equipment")
- Emissions categories ("warm-up" and "ignition" correspond to the CSE area "propulsion"; "park" and "tank ventilation" correspond to the CSE area "evaporation")
- Energy (CSE category "Material"); the "material types" biodiesel, petroleum and LP gas are currently not included in TREMOD.

Table 138: Allocation of CSE structure elements (first line) and TREMOD category (second line)

SE:Name (ID)	EmiGru	Type of vehicle	Measure	Area	Material
-	SK	FzKat	Vehicle layer	Emissions category	Energy
SV LNFO KOAB	AB	LNF	KO: without reg. cat. conv.	Drive	Gasoline
SV LNFO KOAO	ao	LNF	KO: without reg. cat. conv.	Drive	Gasoline
SV LNFO KOIO	io	LNF	KO: without reg. cat. conv.	Drive	Gasoline
SV LNFO KOVD	io	LNF	KO: without reg. cat. conv.	Evaporation	Gasoline
SV LNFO MTAB	AB	LNF	MT: with reg. cat. conv.	Drive	Gasoline
SV LNFO MTAO	ao	LNF	MT: with reg. cat. conv.	Drive	Gasoline
SV LNFO MTIO	io	LNF	MT: with reg. cat. conv.	Drive	Gasoline
SV LNFO MTVD	io	LNF	MT: with reg. cat. conv.	Evaporation	Gasoline
SV MOPED	io	KKR	KO: All	Drive	Gasoline
SV MOPED VD	io	KKR	KO: All	Evaporation	Gasoline
SV MRAD KOAB	AB	KR	KO: before EURO1	Drive	Gasoline
SV MRAD KOAO	ao	KR	KO: before EURO1	Drive	Gasoline
SV MRAD KOIO	io	KR	KO: before EURO1	Drive	Gasoline
SV MRAD KOVD	io	KR	KO: before EURO1	Evaporation	Gasoline
SV MRAD MTAB	AB	KR	MT: as of Euro 1	Drive	Gasoline
SV MRAD MTAO	ao	KR	MT: as of Euro 1	Drive	Gasoline
SV MRAD MTIO	io	KR	MT: as of Euro 1	Drive	Gasoline
SV MRAD MTVD	io	KR	MT: as of Euro 1	Evaporation	Gasoline
SV PKWO KOAB	AB	Automobile	KO: without reg. cat. conv.	Drive	Gasoline
SV PKWO KOAO	ao	Automobile	KO: without reg. cat. conv.	Drive	Gasoline
SV PKWO KOIO	io	Automobile	KO: without reg. cat. conv.	Drive	Gasoline, LP gas
SV PKWO KOVD	io	Automobile	KO: without reg. cat. conv.	Evaporation	Gasoline
SV PKWO MTAB	AB	Automobile	MT: with reg. cat. conv.	Drive	Gasoline
SV PKWO MTAO	ao	Automobile	MT: with reg. cat. conv.	Drive	Gasoline
SV PKWO MTIO	io	Automobile	MT: with reg. cat. conv.	Drive	Gasoline
SV PKWO MTVD	io	Automobile	MT: with reg. cat. conv.	Evaporation	Gasoline
SV BUS KOAB	AB	RBus, LBus	KO: before EURO1	Drive	Diesel, biodiesel
SV BUS KOAO	ao	RBus, LBus	KO: before EURO1	Drive	Diesel, biodiesel, petroleum
SV BUS KOIO	io	RBus, LBus	KO: before EURO1	Drive	Diesel, biodiesel
SV BUS MTAB	AB	RBus, LBus	MT: as of Euro 1	Drive	Diesel, biodiesel
SV BUS MTAO	ao	RBus, LBus	MT: as of Euro 1	Drive	Diesel, biodiesel, petroleum
SV BUS MTIO	io	RBus, LBus	MT: as of Euro 1	Drive	Diesel, biodiesel
SV LNFD KOAB	AB	LNF	KO: before EURO1	Drive	Diesel, biodiesel
SV LNFD KOAO	ao	LNF	KO: before EURO1	Drive	Diesel, biodiesel
SV LNFD KOIO	io	LNF	KO: before EURO1	Drive	Diesel, biodiesel
SV LNFD MTAB	AB	LNF	MT: as of Euro 1	Drive	Diesel, biodiesel
SV LNFD MTAO	ao	LNF	MT: as of Euro 1	Drive	Diesel, biodiesel
SV LNFD MTIO	io	LNF	MT: as of Euro 1	Drive	Diesel, biodiesel
SV PKWD KOAB	AB	Automobile	KO: before EURO1	Drive	Diesel, biodiesel
SV PKWD KOAO	ao	Automobile	KO: before EURO1	Drive	Diesel, biodiesel
SV PKWD KOIO	io	Automobile	KO: before EURO1	Drive	Diesel, biodiesel
SV PKWD MTAB	AB	Automobile	MT: as of Euro 1	Drive	Diesel, biodiesel
SV PKWD MTAO	ao	Automobile	MT: as of Euro 1	Drive	Diesel, biodiesel
SV PKWD MTIO	io	Automobile	MT: as of Euro 1	Drive	Diesel, biodiesel
SV SNF KOAB	AB	LKW, LZ, SZ	KO: before EURO1	Drive	Diesel, biodiesel
SV SNF KOAO	ao	LKW, LZ, SZ	KO: before EURO1	Drive	Diesel, biodiesel
SV SNF KOIO	io	LKW, LZ, SZ	KO: before EURO1	Drive	Diesel, biodiesel
SV SNF MTAB	AB	LKW, LZ, SZ	MT: as of Euro 1	Drive	Diesel, biodiesel
SV SNF MTAO	ao	LKW, LZ, SZ	MT: as of Euro 1	Drive	Diesel, biodiesel
SV SNF MTIO	io	LKW, LZ, SZ	MT: as of Euro 1	Drive	Diesel, biodiesel
Remarks: FzKat: Vehicle category, SK: Road category, Material: cursive components not included in TREMOD; LKW = Truck					

17.3.3 Next steps

The interface that has been developed is tailoured to the structure and data of TREMOD version 3.0 of 31 October 2002. TREMOD is currently being redesigned and expanded under commission to the Federal Highway Research Institute (BaSt) (IFEU, 2003b). In addition, integration of the new structures and results of the manual "Emissions factors for road transports" (Emissionsfaktoren des Straßenverkehrs) (INFRAS, 2003) is planned. This work will also require the the CSE interface to be adapted.

It currently seems that the manual's new vehicle-layer definitions will necessitate at least a simple updating of the CSE interface. This adaptation will not require a complicated procedure for updating TREMOD.

In future, the fuels biodiesel, petroleum, LP gas and natural gas should be integrated into the TREMOD model. As part of TREMOD enhancement under commission to BASt, by mid-2004 suitable structures will be added to TREMOD that can accept suitable basic data and deliver results to CSE.

The 1994 data was broken down, in a simple manner, into data for the old and new German Länder; this procedure is to be supplanted by differentiation of input data (stocks, mileage) in the TREMOD database, to permit production of plausible time series for emissions of western and eastern Germany.

These changes are to be carried out as concurrently as possible with the updating process based on the new manual, since the emission factors in the new manual will nearly all be changed (changes will include retroactive changes).

17.4 The Web-based German Emission Factor Database (GEREF)

In the GEREF, the Federal Environmental Agency will present all emission factors for Germany that are being used to fulfill reporting obligations to the Secretariat of the Framework Convention on Climate and to the European Union. This database comprises the emission factors for Germany's national reporting.

To enhance the transparency and clarity of German emissions data, the UBA publishes these emission factors in the Internet, and it permits external experts (organisations, industry, research institutions) to submit (to the UBA) and publicise new emission factors and metadata. This will enable the UBA to house a national database for emission factors that includes both emission factors for national reports and other emission factors that are collected. This will facilitate identification and discussion of differences to other emission factors, such as the international emission factors of the Emission Factors Database (EFDB), which the IPCC manages, along with supplementary information. GEREF includes an interface for transmission of German emission factors to the EFDB. Export of selected emission factors to the international EFDB will be managed by the Federal Environmental Agency.

GEREF has been implemented by the firm of Seven2one GmbH, using MESAP, a standard application. GEREF has an Internet Web client (browser) that will enable the public to read-access emission factors. Registered users can also enter new emission factors and their meta-information, including technical data and literature references. Such entry can be

carried out either manually, via the Web client, or automatically, via an Internet upload function.

The GEREF Web application, based on an MESAP solution:

- Is a database for administrating and documenting emission factors in Germany
- Provides Internet access to emission factors
- Enables visitors to search for and research emission factors
- Enables users (registered users) to enter new emission factors
- Is compatible with Federal Environmental Agency's existing databases
- Can easily be expanded to include indirect greenhouse gases and other air pollutants
- Supports data export to EFDB

18 ANNEX 7: TABLES 6.1 AND 6.2 OF THE IPCC GOOD PRACTICE GUIDANCE

Not all of the uncertainties for German greenhouse-gas inventories have been determined. Efforts in this area have begun with determination of uncertainties pursuant to Tier 1; they are being carried out by data-supplying experts of Federal Environmental Agency departments and by external institutions. Systematic and complete experts' estimatess are being hampered by the following issues, however:

- The fact that most activity rates are taken from data sources that are outside the Federal Environmental Agency (DESTATIS, industry associations or other statistics) complicates determination of uncertainties. Experts' judgements must be carried out either by experts outside of UBA, or the data-supplying institutions' own uncertainty figures must be used.
- Furthermore, many activity rates are determined through a process in which UBA carries out a variety calculations, for purposes of adaptation, on an external database (Examples include BEU, TREMOD, etc..). The question arises as to how changes in uncertainties resulting from such calculations, some of which are quite complex, can be determined.
- Furthermore, in some cases no further use of current emission factors and activity rates is planned. It thus must be asked whether it is at all useful to determine uncertainties for such values, which are badly in need of revision, or whether modification of calculation procedures has advanced enough to produce EF and AR for which uncertainties can be estimated.

The results of Tier 1 uncertainties analysis are shown, in keeping with the specifications given in Table 6.1 of IPCC Good Practice Guidance, in Table 139. At present, in light of the current status of relevant work, it is not yet possible to prepare Table 6.2 of the IPCC Good Practice Guidance.

Table 139: Uncertainties calculation pursuant to Tier 1 (in keeping with Table 6.1 GPG)

A		B	C	D	E	F	G	H	I	J	K	L	M	N	O
IPCC Greenhouse Gas Source and Sink Categories	**Fuel Type**	**Direct Greenhouse Gas**	**Base Year emissions, 1990 GWP**	**Current Year emissions, 2003 GWP**	**Uncertainty AD**	**Uncertainty EF**	**Combined uncertainty**	**Combined uncertainty as part of total nat. emissions in 2002**	**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**	**Uncertainty introduced into the trend in total nat. emissions**	**Quality Indicator EF**	**Quality Indicator AD**
			[Gg CO_2-Equivalent]		**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**		
1A1a Public electricity and Heat production	Gaseous Fuels	N_2O	153,7	97,5	7	50	**50,5**	0,004838	-0,000023	0,000078	-0,001135	0,000776	**0,001375**	R	R
1A1a Public electricity and Heat production	Gaseous Fuels	CO_2	18463,3	26118,3	7	3	**7,6**	0,195488	0,008853	0,021002	0,026560	0,207907	**0,209597**	R	R
1A1a Public electricity and Heat production	Gaseous Fuels	CH_4	3,5	7,8	7	50	**50,5**	0,000387	0,000004	0,000006	0,000198	0,000062	**0,000208**	R	R
1A1a Public electricity and Heat production	Liquid Fuels	N_2O	98,5	21,1	7	50	**50,5**	0,001048	-0,000048	0,000017	-0,002391	0,000168	**0,002397**	R	R
1A1a Public electricity and Heat production	Liquid Fuels	CO_2	8474,8	4697,2	7	3	**7,6**	0,035157	-0,001798	0,003777	-0,005395	0,037391	**0,037778**	R	R
1A1a Public electricity and Heat production	Liquid Fuels	CH_4	8,1	4,2	7	50	**50,5**	0,000210	-0,000002	0,000003	-0,000096	0,000034	**0,000102**	R	R
1A1a Public electricity and Heat production	Other Fuels	N_2O	61,3	31,4	**7**	50	**50,5**	0,001557	-0,000015	0,000025	-0,000754	0,000250	**0,000794**	D	R
1A1a Public electricity and Heat production	Other Fuels	CO_2	1251,0	506,1	**7**	3	**7,6**	0,003788	-0,000416	0,000407	-0,001248	0,004029	**0,004218**	**D**	R
1A1a Public electricity and Heat production	Other Fuels	CH_4	12,8	1,3	**7**	50	**50,5**	0,000063	-0,000007	0,000001	-0,000369	0,000010	**0,000369**	**D**	R
1A1a Public electricity and Heat production	Solid Fuels	N_2O	3337,6	3311,1	5	50	**50,2**	0,163520	0,000467	0,002663	0,023334	0,018827	**0,029982**	R	R
1A1a Public electricity and Heat production	Solid Fuels	CO_2	306429,7	291320,9	5	3	**5,8**	1,669451	0,032571	0,234252	0,097713	1,656414	**1,659293**	R	R
1A1a Public electricity and Heat production	Solid Fuels	CH_4	109,1	87,8	5	50	**50,2**	0,004334	-0,000001	0,000071	-0,000062	0,000499	**0,000503**	R	R
1A1a Public electricity and Heat production	Biomass	N_2O	0,1	1,1	2	50	**50,0**	0,000053	0,000001	0,000001	0,000039	0,000002	**0,000039**	R	R

A		B	C	D	E	F	G	H	I	J	K	L	M	N	O
IPCC Greenhouse Gas Source and Sink Categories	**Fuel Type**	**Direct Greenhouse Gas**	**Base Year emissions, 1990 GWP**	**Current Year emissions, 2003 GWP**	**Uncertainty AD**	**Uncertainty EF**	**Combined uncertainty**	**Combined uncertainty as part of total nat. emissions in 2002**	**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**	**Uncertainty introduced into the trend in total nat. emissions**	**Quality Indicator EF**	**Quality Indicator AD**
			[Gg CO_2-Equivalent]		**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**		
1A1a Public electricity and Heat production	Biomass	CO_2		0,0	2	3	**3,6**	0,000000	0,000000	0,000000	0,000000	0,000000	**0,000000**	R	R
1A1a Public electricity and Heat production	Biomass	CH_4	0,0	0,0	2	125	**125,0**	0,000002	0,000000	0,000000	0,000002	0,000000	**0,000002**	R	R
1A1b. Petroleum Refining	Gaseous Fuels	N_2O	8,6	3,7	7	75	**75,3**	0,000271	-0,000003	0,000003	-0,000203	0,000029	**0,000205**	R	R
1A1b. Petroleum Refining	Gaseous Fuels	CO_2	1028,7	725,0	7	1	**7,1**	0,005038	-0,000094	0,000583	-0,000094	0,005771	**0,005772**	R	R
1A1b. Petroleum Refining	Gaseous Fuels	CH_4	0,4	0,3	7	75	**75,3**	0,000026	0,000000	0,000000	0,000003	0,000003	**0,000004**	R	R
1A1b. Petroleum Refining	Liquid Fuels	N_2O	167,4	57,7	5	75	**75,2**	0,004262	-0,000064	0,000046	-0,004783	0,000328	**0,004794**	R	R
1A1b. Petroleum Refining	Liquid Fuels	CO_2	16008,9	18160,4	5	3	**5,8**	0,104071	0,004070	0,014603	0,012210	0,103258	**0,103977**	R	R
1A1b. Petroleum Refining	Liquid Fuels	CH_4	9,9	7,6	5	75	**75,2**	0,000560	0,000000	0,000006	-0,000031	0,000043	**0,000053**	R	R
1A1b. Petroleum Refining	Solid Fuels	N_2O	24,1	4,9	8	75	**75,4**	0,000366	-0,000012	0,000004	-0,000892	0,000045	**0,000894**	R	R
1A1b. Petroleum Refining	Solid Fuels	CO_2	2381,3	487,9	8	1	**8,1**	0,003866	-0,001174	0,000392	-0,001174	0,004439	**0,004592**	R	R
1A1b. Petroleum Refining	Solid Fuels	CH_4	0,8	0,1	8	75	**75,4**	0,000010	0,000000	0,000000	-0,000031	0,000001	**0,000031**	R	R
1A1c. Manufacture of Solid Fuels and Other Energy Industries	Biomass	N_2O	4,6	5,4	**75**	50	**90,1**	0,000478	0,000001	0,000004	0,000064	0,000460	**0,000465**	D	R
1A1c. Manufacture of Solid Fuels and Other Energy Industries	Biomass	CH_4	0,5	1,0	**75**	50	**90,1**	0,000090	0,000000	0,000001	0,000024	0,000087	**0,000090**	**D**	R
1A1c. Manufacture of Solid Fuels and Other Energy Industries	Gaseous Fuels	N_2O	22,5	7,0	7	50	**50,5**	0,000347	-0,000009	0,000006	-0,000458	0,000056	**0,000461**	R	R
1A1c. Manufacture of Solid Fuels and Other Energy Industries	Gaseous Fuels	CO_2	2701,7	1486,6	7	5	**8,6**	0,012568	-0,000582	0,001195	-0,002910	0,011834	**0,012186**	R	R
1A1c. Manufacture of Solid Fuels and Other Energy Industries	Gaseous Fuels	CH_4	2,2	1,2	7	50	**50,5**	0,000061	0,000000	0,000001	-0,000021	0,000010	**0,000023**	R	R

A		B	C	D	E	F	G	H	I	J	K	L	M	N	O
IPCC Greenhouse Gas Source and Sink Categories	**Fuel Type**	**Direct Greenhouse Gas**	**Base Year emissions, 1990 GWP**	**Current Year emissions, 2003 GWP**	**Uncertainty AD**	**Uncertainty EF**	**Combined uncertainty**	**Combined uncertainty as part of total nat. emissions in 2002**	**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**	**Uncertainty introduced into the trend in total nat. emissions**	**Quality Indicator EF**	**Quality Indicator AD**
			[Gg CO_2-Equivalent]		**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**		
1A1c. Manufacture of Solid Fuels and Other Energy Industries	Liquid Fuels	N_2O	4,9	1,2	5	50	**50,2**	0,000062	-0,000002	0,000001	-0,000111	0,000007	**0,000111**	R	R
1A1c. Manufacture of Solid Fuels and Other Energy Industries	Liquid Fuels	CO_2	488,4	216,4	5	5	**7,1**	0,001504	-0,000147	0,000174	-0,000736	0,001230	**0,001434**	R	R
1A1c. Manufacture of Solid Fuels and Other Energy Industries	Liquid Fuels	CH_4	0,4	0,2	5	50	**50,2**	0,000009	0,000000	0,000000	-0,000007	0,000001	**0,000007**	R	R
1A1c. Manufacture of Solid Fuels and Other Energy Industries	Other Fuels	N_2O	3,3	0,2	**7**	50	**50,5**	0,000011	-0,000002	0,000000	-0,000100	0,000002	**0,000100**	D	R
1A1c. Manufacture of Solid Fuels and Other Energy Industries	Other Fuels	CO_2	333,1	4,6	**7**	5	**8,6**	0,000039	-0,000216	0,000004	-0,001078	0,000036	**0,001078**	**D**	R
1A1c. Manufacture of Solid Fuels and Other Energy Industries	Other Fuels	CH_4	2,4	0,0	**7**	50	**50,5**	0,000000	-0,000002	0,000000	-0,000079	0,000000	**0,000079**	**D**	R
1A1c. Manufacture of Solid Fuels and Other Energy Industries	Solid Fuels	N_2O	607,4	248,2	5	50	**50,2**	0,012259	-0,000200	0,000200	-0,010000	0,001411	**0,010099**	R	R
1A1c. Manufacture of Solid Fuels and Other Energy Industries	Solid Fuels	CO_2	56384,0	18858,2	5	5	**7,1**	0,131053	-0,021921	0,015164	-0,109607	0,107225	**0,153333**	R	R
1A1c. Manufacture of Solid Fuels and Other Energy Industries	Solid Fuels	CH_4	19,0	6,5	5	50	**50,2**	0,000323	-0,000007	0,000005	-0,000362	0,000037	**0,000364**	R	R
1A2a-f. Manufacturing Industries and Construction total	Biomass	N_2O	20,3		2	**150**	**150,0**	0,000000	-0,000013	0,000000	-0,002008	0,000000	**0,002008**	R	D

A		B	C	D	E	F	G	H	I	J	K	L	M	N	O
IPCC Greenhouse Gas Source and Sink Categories	**Fuel Type**	**Direct Greenhouse Gas**	**Base Year emissions, 1990 GWP**	**Current Year emissions, 2003 GWP**	**Uncertainty AD**	**Uncertainty EF**	**Combined uncertainty**	**Combined uncertainty as part of total nat. emissions in 2002**	**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**	**Uncertainty introduced into the trend in total nat. emissions**	**Quality Indicator EF**	**Quality Indicator AD**
			[Gg CO_2-Equivalent]		**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**		
1A2a-f. Manufacturing Industries and Construction total	Biomass	CH_4	7,8		2	**75**	**75,0**	0,000000	-0,000005	0,000000	-0,000386	0,000000	**0,000386**	R	**D**
1A2a-f. Manufacturing Industries and Construction total	Gaseous Fuels	N_2O	380,8	239,6	8	50	**50,6**	0,011925	-0,000058	0,000193	-0,002893	0,002180	**0,003623**	R	R
1A2a-f. Manufacturing Industries and Construction total	Gaseous Fuels	CO_2	45751,0	50214,1	8	5	**9,4**	0,465568	0,010274	0,040377	0,051370	0,456818	**0,459697**	R	R
1A2a-f. Manufacturing Industries and Construction total	Gaseous Fuels	CH_4	28,6	37,7	8	50	**50,6**	0,001877	0,000012	0,000030	0,000577	0,000343	**0,000671**	R	R
1A2a-f. Manufacturing Industries and Construction total	Liquid Fuels	N_2O	266,6	103,8	6	50	**50,4**	0,005139	-0,000092	0,000083	-0,004594	0,000708	**0,004648**	R	R
1A2a-f. Manufacturing Industries and Construction total	Liquid Fuels	CO_2	28391,5	19040,6	6	1,5	**6,2**	0,115733	-0,003367	0,015311	-0,005051	0,129915	**0,130013**	R	R
1A2a-f. Manufacturing Industries and Construction total	Liquid Fuels	CH_4	24,9	13,2	6	50	**50,4**	0,000652	-0,000006	0,000011	-0,000291	0,000090	**0,000304**	R	R
1A2a-f. Manufacturing Industries and Construction total	Other Fuels	N_2O	48,8	17,9	**20**	5	**20,6**	0,000362	-0,000018	0,000014	-0,000088	0,000407	**0,000416**	D	R
1A2a-f. Manufacturing Industries and Construction total	Other Fuels	CO_2	1922,7	384,6	**20**	**7**	**21,2**	0,008009	-0,000956	0,000309	-0,006690	0,008747	**0,011012**	**D**	D
1A2a-f. Manufacturing Industries and Construction total	Other Fuels	CH_4	25,4	0,7		50	**50,0**	0,000034	-0,000016	0,000001	-0,000808	0,000000	**0,000808**	R	R

A		B	C	D	E	F	G	H	I	J	K	L	M	N	O
IPCC Greenhouse Gas Source and Sink Categories	**Fuel Type**	**Direct Greenhouse Gas**	**Base Year emissions, 1990 GWP**	**Current Year emissions, 2003 GWP**	**Uncertainty AD**	**Uncertainty EF**	**Combined uncertainty**	**Combined uncertainty as part of total nat. emissions in 2002**	**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**	**Uncertainty introduced into the trend in total nat. emissions**	**Quality Indicator EF**	**Quality Indicator AD**
			[Gg CO_2-Equivalent]		**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**		
1A2a-f. Manufacturing Industries and Construction total	Solid Fuels	N_2O	1017,4	465,6	12	50	**51,4**	0,023531	-0,000295	0,000374	-0,014745	0,006354	**0,016056**	R	R
1A2a-f. Manufacturing Industries and Construction total	Solid Fuels	CO_2	120249,8	59416,9	12	**7**	**13,9**	0,811244	-0,031305	0,047777	-0,219135	0,810809	**0,839900**	R	D
1A2a-f. Manufacturing Industries and Construction total	Solid Fuels	CH_4	173,8	66,1	12	50	**51,4**	0,003342	-0,000061	0,000053	-0,003059	0,000902	**0,003189**	R	R
1A3a. Transport Civil Aviation	Aviation Gasoline	N_2O	18,2	63,3	**75**	200	**213,6**	0,013292	0,000039	0,000051	0,007787	0,005400	**0,009476**	D	R
1A3a. Transport Civil Aviation	Aviation Gasoline	CO_2	2897,4	4287,7	**75**	5	**75,2**	0,316745	0,001542	0,003448	0,007708	0,365689	**0,365770**	**D**	R
1A3a. Transport Civil Aviation	Aviation Gasoline	CH_4	0,8	1,1	**75**	200	**213,6**	0,000240	0,000000	0,000001	0,000076	0,000097	**0,000123**	**D**	**D**
1A3b. Transport Road Transportation	Diesel Oil	N_2O	705,3	1040,8	**20**	**75**	**77,6**	0,079394	0,000373	0,000837	0,027965	0,023670	**0,036638**	**D**	**D**
1A3b. Transport Road Transportation	Diesel Oil	CO_2	54458,1	79943,3	**20**	**7**	**21,2**	1,664822	0,028442	0,064283	0,199095	1,818190	**1,829058**	**D**	**D**
1A3b. Transport Road Transportation	Diesel Oil	CH_4	40,5	28,8	**20**	**40**	**44,7**	0,001265	-0,000004	0,000023	-0,000141	0,000655	**0,000670**	**D**	**D**
1A3b. Transport Road Transportation	Gasoline	CO_2	95794,5	79848,0	**20**	**7**	**21,2**	1,662837	0,001182	0,064206	0,008272	1,816022	**1,816041**	**D**	**D**
1A3b. Transport Road Transportation	Gasoline	N_2O	2227,0	3028,5	**20**	**75**	**77,6**	0,231028	0,000970	0,002435	0,072751	0,068878	**0,100184**	**D**	**D**
1A3b. Transport Road Transportation	Gasoline	CH_4	1276,7	199,8	**20**	**40**	**44,7**	0,008781	-0,000679	0,000161	-0,027172	0,004544	**0,027549**	**D**	**D**
1A3b. Transport Road Transportation	Liquid Gas	N_2O	0,1	0,1	**20**	**75**	**77,6**	0,000004	0,000000	0,000000	0,000000	0,000001	**0,000001**	**D**	**D**

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IPCC Greenhouse Gas Source and Sink Categories	**Fuel Type**	**Direct Greenhouse Gas**	**Base Year emissions, 1990 GWP**	**Current Year emissions, 2003 GWP**	**Uncertainty AD**	**Uncertainty EF**	**Combined uncertainty**	**Combined uncertainty as part of total nat. emissions in 2002**	**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**	**Uncertainty introduced into the trend in total nat. emissions**	**Quality Indicator EF**	**Quality Indicator AD**
			[Gg CO_2-Equivalent]		**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**		
1A3b. Transport Road Transportation	Liquid Gas	CO_2	9,0	6,5	**20**	**7**	**21,2**	0,000135	-0,000001	0,000005	-0,000005	0,000148	**0,000148**	**D**	**D**
1A3b. Transport Road Transportation	Liquid Gas	CH_4	0,0	0,0	**20**	**40**	**44,7**	0,000000	0,000000	0,000000	0,000000	0,000000	**0,000000**	**D**	**D**
1A3b. Transport Road Transportation	Petroleum	N_2O		0,6	**20**	**75**	**77,6**	0,000047	0,000001	0,000001	0,000038	0,000014	**0,000040**	**D**	**D**
1A3b. Transport Road Transportation	Petroleum	CO_2		44,4	**20**	**7**	**21,2**	0,000925	0,000036	0,000036	0,000250	0,001010	**0,001040**	**D**	**D**
1A3b. Transport Road Transportation	Petroleum	CH_4		0,0	**20**	**40**	**44,7**	0,000001	0,000000	0,000000	0,000001	0,000001	**0,000001**	**D**	**D**
1A3b. Transport Road Transportation	Biomass	CH_4		0,6	**20**	**40**	**44,7**	0,000028	0,000001	0,000001	0,000021	0,000015	**0,000025**	**D**	**D**
1A3b. Transport Road Transportation	Biomass	N_2O		23,3	**20**	**75**	**77,6**	0,001778	0,000019	0,000019	0,001406	0,000530	**0,001503**	**D**	**D**
1A3c. Transport Railways	Liquid Fuels	N_2O	40,5	22,2	**20**	**75**	**77,6**	0,001693	-0,000009	0,000018	-0,000662	0,000505	**0,000832**	**D**	**D**
1A3c. Transport Railways	Liquid Fuels	CO_2	2825,5	1557,7	**20**	**7**	**21,2**	0,032439	-0,000606	0,001253	-0,004245	0,035428	**0,035681**	**D**	**D**
1A3c. Transport Railways	Liquid Fuels	CH_4	4,0	2,2	**20**	**40**	**44,7**	0,000097	-0,000001	0,000002	-0,000035	0,000050	**0,000061**	**D**	**D**
1A3c. Transport Railways	Solid Fuels	N_2O	0,7	0,6	**20**	**75**	**77,6**	0,000045	0,000000	0,000000	0,000000	0,000013	**0,000013**	**D**	**D**
1A3c. Transport Railways	Solid Fuels	CO_2	53,7	53,8	**20**	**7**	**21,2**	0,001121	0,000008	0,000043	0,000056	0,001224	**0,001226**	**D**	**D**
1A3c. Transport Railways	Solid Fuels	CH_4	0,2	0,2	**20**	**40**	**44,7**	0,000007	0,000000	0,000000	0,000001	0,000004	**0,000004**	**D**	**D**
1A3d. Transport Navigation	Diesel Oil	N_2O	29,2	11,0	**20**	**75**	**77,6**	0,000836	-0,000010	0,000009	-0,000780	0,000249	**0,000819**	**D**	**D**
1A3d. Transport Navigation	Diesel Oil	CO_2	2049,8	769,3	**20**	**7**	**21,2**	0,016021	-0,000730	0,000619	-0,005110	0,017497	**0,018227**	**D**	**D**
1A3d. Transport Navigation	Diesel Oil	CH_4	1,7	0,7	**20**	**40**	**44,7**	0,000029	-0,000001	0,000001	-0,000025	0,000015	**0,000029**	**D**	**D**
1A3e. Transport Other Transportation	Gaseous Fuels	N_2O	5,3	5,5	**20**	50	**53,9**	0,000290	0,000001	0,000004	0,000046	0,000125	**0,000133**	D	R
1A3e. Transport Other Transportation	Gaseous Fuels	CO_2	637,3	811,2	**20**	**7**	**21,2**	0,016893	0,000233	0,000652	0,001631	0,018449	**0,018521**	**D**	D
1A3e. Transport Other Transportation	Gaseous Fuels	CH_4	0,1	0,6	**20**	**40**	**44,7**	0,000027	0,000000	0,000000	0,000018	0,000014	**0,000022**	**D**	D

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IPCC Greenhouse Gas Source and Sink Categories	**Fuel Type**	**Direct Greenhouse Gas**	**Base Year emissions, 1990 GWP**	**Current Year emissions, 2003 GWP**	**Uncertainty AD**	**Uncertainty EF**	**Combined uncertainty**	**Combined uncertainty as part of total nat. emissions in 2002**	**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**	**Uncertainty introduced into the trend in total nat. emissions**	**Quality Indicator EF**	**Quality Indicator AD**
			[Gg CO_2-Equivalent]		**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**		
1A3e. Transport Other Transportation	Liquid Fuels	N_2O	52,3	41,4	**20**	**75**	**77,6**	0,003159	-0,000001	0,000033	-0,000083	0,000942	**0,000945**	**D**	D
1A3e. Transport Other Transportation	Liquid Fuels	CO_2	3634,3	2887,5	**20**	**7**	**21,2**	0,060133	-0,000069	0,002322	-0,000484	0,065673	**0,065675**	**D**	D
1A3e. Transport Other Transportation	Liquid Fuels	CH_4	9,8	6,4	**20**	**40**	**44,7**	0,000281	-0,000001	0,000005	-0,000051	0,000146	**0,000154**	**D**	D
1A4a. Other Sectors Commercial/Institutional	Biomass	N_2O	3,9	6,5	**75**	50	**90,1**	0,000575	0,000003	0,000005	0,000131	0,000553	**0,000569**	**D**	R
1A4a. Other Sectors Commercial/Institutional	Biomass	CH_4	26,0	39,6	**75**	100	**125,0**	0,004859	0,000015	0,000032	0,001467	0,003373	**0,003679**	**D**	R
1A4a. Other Sectors Commercial/Institutional	Gaseous Fuels	N_2O	25,7	52,1	11	35	**36,7**	0,001878	0,000025	0,000042	0,000875	0,000652	**0,001091**	R	R
1A4a. Other Sectors Commercial/Institutional	Gaseous Fuels	CO_2	13633,4	27227,0	11	2,5	**11,3**	0,301850	0,012922	0,021893	0,032306	0,340581	**0,342110**	R	R
1A4a. Other Sectors Commercial/Institutional	Gaseous Fuels	CH_4	0,7	1,2	11	100	**100,6**	0,000119	0,000001	0,000001	0,000053	0,000015	**0,000055**	R	R
1A4a. Other Sectors Commercial/Institutional	Liquid Fuels	N_2O	63,3	47,1	10	70	**70,7**	0,003276	-0,000004	0,000038	-0,000262	0,000536	**0,000596**	R	R
1A4a. Other Sectors Commercial/Institutional	Liquid Fuels	CO_2	27280,4	20262,7	10	5	**11,2**	0,222646	-0,001654	0,016293	-0,008271	0,230422	**0,230571**	R	R
1A4a. Other Sectors Commercial/Institutional	Liquid Fuels	CH_4	0,2	0,1	10	200	**200,2**	0,000027	0,000000	0,000000	-0,000003	0,000002	**0,000004**	R	R
1A4a. Other Sectors Commercial/Institutional	Solid Fuels	N_2O	48,9	8,3	9	100	**100,4**	0,000818	-0,000025	0,000007	-0,002548	0,000085	**0,002549**	R	R
1A4a. Other Sectors Commercial/Institutional	Solid Fuels	CO_2	20901,8	1204,6	9	10	**13,5**	0,015928	-0,012781	0,000969	-0,127805	0,012329	**0,128399**	R	R
1A4a. Other Sectors Commercial/Institutional	Solid Fuels	CH_4	1057,5	23,2	9	150	**150,3**	0,003423	-0,000677	0,000019	-0,101566	0,000237	**0,101567**	R	R

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			[Gg CO_2-Equivalent]		**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**		
1A4b. Other Sectors Residential	Biomass	N_2O	43,1	90,9	**75**	50	**90,1**	0,008055	0,000045	0,000073	0,002239	0,007755	**0,008072**	D	R
1A4b. Other Sectors Residential	Biomass	CH_4	234,9	472,8	**75**	100	**125,0**	0,058080	0,000226	0,000380	0,022558	0,040322	**0,046203**	**D**	R
1A4b. Other Sectors Residential	Gaseous Fuels	N_2O	54,3	103,9	11	35	**36,7**	0,003746	0,000048	0,000084	0,001673	0,001299	**0,002118**	R	R
1A4b. Other Sectors Residential	Gaseous Fuels	CO_2	31691,8	60536,0	11	2,5	**11,3**	0,671128	0,027820	0,048677	0,069550	0,757240	**0,760427**	R	R
1A4b. Other Sectors Residential	Gaseous Fuels	CH_4	13,1	25,0	11	100	**100,6**	0,002469	0,000011	0,000020	0,001148	0,000312	**0,001189**	R	R
1A4b. Other Sectors Residential	Liquid Fuels	N_2O	144,2	150,8	9	50	**50,8**	0,007532	0,000026	0,000121	0,001322	0,001544	**0,002033**	R	R
1A4b. Other Sectors Residential	Liquid Fuels	CO_2	56162,5	58965,0	9	5	**10,3**	0,596637	0,010460	0,047414	0,052299	0,603482	**0,605744**	R	R
1A4b. Other Sectors Residential	Liquid Fuels	CH_4	1,4	3,7	9	100	**100,4**	0,000370	0,000002	0,000003	0,000207	0,000038	**0,000210**	R	R
1A4b. Other Sectors Residential	Solid Fuels	N_2O	557,7	48,6	9	100	**100,4**	0,004792	-0,000328	0,000039	-0,032784	0,000497	**0,032787**	R	R
1A4b. Other Sectors Residential	Solid Fuels	CO_2	41425,1	2941,5	9	20	**21,9**	0,063402	-0,024880	0,002365	-0,497603	0,030105	**0,498513**	R	R
1A4b. Other Sectors Residential	Solid Fuels	CH_4	950,2	76,9	9	150	**150,3**	0,011351	-0,000563	0,000062	-0,084503	0,000787	**0,084506**	R	R
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Biomass	N_2O		2,9	2	50	**50,0**	0,000144	0,000002	0,000002	0,000118	0,000007	**0,000118**	R	R
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Biomass	CH_4		17,3	2	100	**100,0**	0,001702	0,000014	0,000014	0,001392	0,000039	**0,001393**	R	R
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Gaseous Fuels	N_2O	0,9	1,6	11	35	**36,7**	0,000058	0,000001	0,000001	0,000025	0,000020	**0,000032**	R	R

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			[Gg CO_2-Equivalent]		**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**		
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Gaseous Fuels	CO_2	479,2	847,9	11	2,5	**11,3**	0,009400	0,000366	0,000682	0,000916	0,010606	**0,010645**	R	R
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Gaseous Fuels	CH_4	0,0	0,0	11	100	**100,6**	0,000004	0,000000	0,000000	0,000001	0,000000	**0,000002**	R	R
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Liquid Fuels	N_2O	82,1	61,2	20	75	**77,6**	0,004672	-0,000005	0,000049	-0,000356	0,001393	**0,001438**	R	R
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Liquid Fuels	CO_2	8088,7	5730,8	20	2,5	**20,2**	0,113521	-0,000713	0,004608	-0,001783	0,130339	**0,130351**	R	R
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Liquid Fuels	CH_4	14,1	8,9	20	200	**201,0**	0,001749	-0,000002	0,000007	-0,000429	0,000201	**0,000474**	R	R
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Solid Fuels	N_2O	12,6	1,2	7	50	**50,5**	0,000058	-0,000007	0,000001	-0,000367	0,000009	**0,000367**	R	R
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Solid Fuels	CO_2	4750,9	76,3	7	10	**12,2**	0,000915	-0,003064	0,000061	-0,030642	0,000607	**0,030648**	R	R
1A4c. Other Sectors Agriculture/Forestry/Fisheries	Solid Fuels	CH_4	260,6	0,3	7	100	**100,2**	0,000026	-0,000171	0,000000	-0,017121	0,000002	**0,017121**	R	R
1A5 Other Include Military fuel use under this category	Gaseous Fuels	N_2O	0,8	1,0	11	35	**36,7**	0,000038	0,000000	0,000001	0,000011	0,000013	**0,000017**	R	R
1A5 Other Include Military fuel use under this category	Gaseous Fuels	CO_2	509,5	653,1	11	1	**11,0**	0,007090	0,000190	0,000525	0,000190	0,008170	**0,008172**	R	R
1A5 Other Include Military fuel use under this category	Gaseous Fuels	CH_4	0,0	0,0	11	100	**100,6**	0,000000	0,000000	0,000000	0,000000	0,000000	**0,000000**	R	R
1A5 Other Include Military fuel use under this category	Liquid Fuels	N_2O	59,7	12,8	20	70	**72,8**	0,000917	-0,000029	0,000010	-0,002027	0,000292	**0,002048**	R	R
1A5 Other Include Military fuel use under this category	Liquid Fuels	CO_2	6659,1	1355,8	20	2	**20,1**	0,026782	-0,003291	0,001090	-0,006581	0,030835	**0,031530**	R	R
1A5 Other Include Military fuel use under this category	Liquid Fuels	CH_4	26,6	5,7	20	50	**53,9**	0,000302	-0,000013	0,000005	-0,000644	0,000130	**0,000657**	R	R

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			[Gg CO_2-Equivalent]		**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**		
1A5 Other Include Military fuel use under this category	Solid Fuels	N_2O	15,1	0,6	7	50	**50,5**	0,000029	-0,000009	0,000000	-0,000473	0,000005	**0,000473**	R	R
1A5 Other Include Military fuel use under this category	Solid Fuels	CO_2	4657,3	43,7	7	3	**7,6**	0,000327	-0,003029	0,000035	-0,009087	0,000348	**0,009093**	R	R
1A5 Other Include Military fuel use under this category	Solid Fuels	CH_4	210,3	0,3	7	50	**50,5**	0,000015	-0,000138	0,000000	-0,006904	0,000002	**0,006904**	R	R
1B1a. Fugitive Emissions from Fuels Coal Mining and Handling	Solid Fuels	CH_4	25644,4	6871,3	3	40	**40,1**	0,270880	-0,011344	0,005525	-0,453760	0,023441	**0,454365**	R	R
1B1b. Fugitive Emissions from Fuels Solid Fuel Transformation	Solid Fuels	CH_4	127,2	19,4	3	10	**10,4**	0,000199	-0,000068	0,000016	-0,000681	0,000066	**0,000684**	R	R
1B1c. Fugitive Emissions from Fuels Other (Abandoned Mines)	Solid Fuels	CH_4			**7**	**150**	**150,2**	0,000000	0,000000	0,000000	0,000000	0,000000	**0,000000**	**D**	**D**
1B2a. Fugitive Emissions from Fuels Oil	Oil	CH_4	226,6	137,4	1	20	**20,0**	0,002705	-0,000039	0,000111	-0,000771	0,000156	**0,000787**	R	R
1B2b. Fugitive Emissions from Fuels Natural Gas	Natural Gas	CH_4	6383,1	7214,0	18	37,5	**41,6**	0,294911	0,001601	0,005801	0,060046	0,147664	**0,159405**	R	R
1B2d. Fugitive Emissions from Fuels Other	Oil and Gas	CH_4	398,4		18	37,5	**41,6**	0,000000	-0,000262	0,000000	-0,009828	0,000000	**0,009828**	R	R
2A1. Mineral Products Cement Production		CO_2	15145,8	13373,4	1	20	**20,0**	0,263195	0,000789	0,010754	0,015781	0,015208	**0,021916**	R	R
2A2. Mineral Products Lime Production		CO_2	5890,8	5382,6	1	30	**30,0**	0,158788	0,000453	0,004328	0,013577	0,006121	**0,014893**	R	R
2A4. Soda Ash		CO_2	720,3	546,8	15	2	**15,1**	0,008132	-0,000034	0,000440	-0,000068	0,009327	**0,009327**	R	R
2A7. Glass Production		CO_2	1213,2	1455,7	5	**20**	**20,6**	0,029494	0,000372	0,001171	0,007447	0,008277	**0,011134**	R	D
2B1. Chemical Industry	Ammonia production	CO_2	1747,4	1997,7	1	5	**5,1**	0,010011	0,000457	0,001606	0,002284	0,002272	**0,003221**	R	R

A		B	C	D	E	F	G	H	I	J	K	L	M	N	O
IPCC Greenhouse Gas Source and Sink Categories	**Fuel Type**	**Direct Greenhouse Gas**	**Base Year emissions, 1990 GWP**	**Current Year emissions, 2003 GWP**	**Uncertainty AD**	**Uncertainty EF**	**Combined uncertainty**	**Combined uncertainty as part of total nat. emissions in 2002**	**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**	**Uncertainty introduced into the trend in total nat. emissions**	**Quality Indicator EF**	**Quality Indicator AD**
			[Gg CO_2-Equivalent]		**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**		
2B2 Chemical Industry	Nitric Acid Production	N_2O	4673,4	6588,7	20	**75**	**77,6**	0,502620	0,002223	0,005298	0,166745	0,149850	**0,224185**	R	D
2B3 Chemical Industry	Adipic Acid Production	N_2O	18804,6	3778,3	20	**7**	**21,2**	0,078683	-0,009332	0,003038	-0,065324	0,085931	**0,107942**	R	**D**
2B4 Chemical Industry	Carbide Production	CO_2	443,2	15,9	20	**7**	**21,2**	0,000330	-0,000279	0,000013	-0,001952	0,000361	**0,001985**	R	**D**
2B5 Chemical Industry	other	N_2O	5,8	5,8	20	**75**	**77,6**	0,000440	0,000001	0,000005	0,000063	0,000131	**0,000146**	R	**D**
2B5 Chemical Industry	other	CH_4	331,4	405,0	20	**150**	**151,3**	0,060229	0,000108	0,000326	0,016143	0,009210	**0,018586**	R	**D**
2C1. Metal Production Iron and Steel Production	other	CH_4	3,9	2,0	1	10	**10,0**	0,000020	-0,000001	0,000002	-0,000009	0,000002	**0,000010**	R	R
2C3. Aluminium Production		CO_2	1011,6	903,6	**7**	15	**16,6**	0,014700	0,000061	0,000727	0,000916	0,007193	**0,007251**	D	R
2C3. Aluminium Production		PFC´s	2486,0	431,0	5	15	**15,8**	0,006698	-0,001289	0,000347	-0,019334	0,002451	**0,019489**	R	R
2C4. SF_6 Used in Aluminium and Magnesium Foundries		SF_6	167,3	1217,5	**75**	**75**	**106,1**	0,126910	0,000869	0,000979	0,065168	0,103835	**0,122591**	**D**	**D**
2E. Production of Halocarbons and SF_6	production of HCFC-22	HFC´s	3510,0	1211,8	**75**	**40**	**85,0**	0,101227	-0,001335	0,000974	-0,053393	0,103348	**0,116325**	**D**	**D**
2E. Production of Halocarbons and SF_6	Fugitive emissions	SF_6		239,0	**75**	**75**	**106,1**	0,024914	0,000192	0,000192	0,014414	0,020384	**0,024965**	**D**	**D**
2E. Production of Halocarbons and SF_6		PFC´s	70,0		**75**	**75**	**106,1**	0,000000	-0,000046	0,000000	-0,003454	0,000000	**0,003454**	**D**	**D**
2F. Industrial Processes	Consumption of Halocarbons and SF_6	HFC´s		7035,4	**75**	**75**	**106,1**	0,733378	0,005657	0,005657	0,424289	0,600036	**0,734891**	**D**	**D**
2F. Industrial Processes	Consumption of Halocarbons and SF_6	PFC´s	140,0	355,0	**75**	**75**	**106,1**	0,037006	0,000193	0,000285	0,014501	0,030277	**0,033571**	**D**	**D**
2F. Industrial Processes	Consumption of Halocarbons and SF_6	SF_6	3728,4	2740,6	**75**	**75**	**106,1**	0,285685	-0,000249	0,002204	-0,018688	0,233742	**0,234488**	**D**	**D**

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IPCC Greenhouse Gas Source and Sink Categories	**Fuel Type**	**Direct Greenhouse Gas**	**Base Year emissions, 1990 GWP**	**Current Year emissions, 2003 GWP**	**Uncertainty AD**	**Uncertainty EF**	**Combined uncertainty**	**Combined uncertainty as part of total nat. emissions in 2002**	**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**	**Uncertainty introduced into the trend in total nat. emissions**	**Quality Indicator EF**	**Quality Indicator AD**
			[Gg CO_2-Equivalent]		**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**		
3D.Total Solvent and Other Product Use		N_2O	1922,0	1922,0	**75**	**20**	**77,6**	0,146620	0,000281	0,001545	0,005620	0,163924	**0,164020**	**D**	**D**
4A.1. Enteric Fermentation	Dairy Cattle	CH_4	12581,5	9433,9	10	25	**26,9**	0,249646	-0,000691	0,007586	-0,017286	0,107280	**0,108664**	R	R
4A.1. Enteric Fermentation	Non-Dairy Cattle	CH_4	20011,6	14268,2	10	25	**26,9**	0,377572	-0,001692	0,011473	-0,042309	0,162254	**0,167679**	R	R
4A.3. Enteric Fermentation	Sheep	CH_4	544,2	443,2	10	25	**26,9**	0,011728	-0,000002	0,000356	-0,000042	0,005040	**0,005040**	R	R
4A.6. Enteric Fermentation	Horses	CH_4	185,6	191,4	10	**40**	**41,2**	0,007754	0,000032	0,000154	0,001271	0,002176	**0,002520**	R	D
4A.8. Enteric Fermentation	Swine	CH_4	970,8	836,5	**7**	**40**	**40,6**	0,033386	0,000034	0,000673	0,001359	0,006659	**0,006796**	**D**	**D**
4B1. Manure Management	Dairy Cattle	CH_4	8693,6	7840,3	**7**	**40**	**40,6**	0,312899	0,000585	0,006304	0,023391	0,062410	**0,066650**	**D**	**D**
4B1. Manure Management	Non-Dairy Cattle	CH_4	5915,2	3890,2	**7**	**40**	**40,6**	0,155256	-0,000763	0,003128	-0,030539	0,030967	**0,043492**	**D**	**D**
4B3. Manure Management	Sheep	CH_4	12,6	10,3	**7**	**40**	**40,6**	0,000410	0,000000	0,000008	-0,000002	0,000082	**0,000082**	**D**	**D**
4B6. Manure Management	Horses	CH_4	28,0	28,9	**7**	**40**	**40,6**	0,001154	0,000005	0,000023	0,000192	0,000230	**0,000300**	**D**	**D**
4B8. Manure Management	Swine	CH_4	12262,2	11139,2	**7**	**40**	**40,6**	0,444555	0,000890	0,008957	0,035586	0,088670	**0,095545**	**D**	**D**
4B9. Manure Management	Poultry	CH_4	186,5	199,9	**7**	**40**	**40,6**	0,007979	0,000038	0,000161	0,001522	0,001591	**0,002202**	**D**	**D**
4B13. Manure Management Other	Dairy Cows	N_2O	1626,3	767,9	**7**	**75**	**75,3**	0,056848	-0,000452	0,000617	-0,033933	0,006113	**0,034479**	**D**	**D**
4B13. Manure Management Other	Other Cattle	N_2O	1335,4	984,5	**7**	**75**	**75,3**	0,072884	-0,000087	0,000792	-0,006518	0,007837	**0,010193**	**D**	**D**
4B13. Manure Management Other	Sheep	N_2O	15,0	10,4	**7**	**75**	**75,3**	0,000771	-0,000002	0,000008	-0,000113	0,000083	**0,000140**	**D**	**D**
4B13. Manure Management Other	Horses	N_2O	250,1	257,9	**7**	**75**	**75,3**	0,019092	0,000043	0,000207	0,003212	0,002053	**0,003812**	**D**	**D**
4B13. Manure Management Other	Swine	N_2O	784,8	414,2	**7**	**75**	**75,3**	0,030661	-0,000183	0,000333	-0,013748	0,003297	**0,014138**	**D**	**D**
4B13. Manure Management Other	Poultry	N_2O	462,9	491,5	**7**	**75**	**75,3**	0,036388	0,000091	0,000395	0,006802	0,003913	**0,007847**	**D**	**D**
4D1. Agricultural Soils	Direct Soil Emissions	N_2O	27645,2	23686,3	**75**	**150**	**167,7**	3,903973	0,000858	0,019046	0,128734	2,020163	**2,024261**	**D**	**D**
4D2. Agricultural Soils	Animal Production	N_2O	2518,8	1910,2	**20**	**75**	**77,6**	0,145718	-0,000121	0,001536	-0,009088	0,043444	**0,044384**	**D**	**D**

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IPCC Greenhouse Gas Source and Sink Categories	**Fuel Type**	**Direct Greenhouse Gas**	**Base Year emissions, 1990 GWP**	**Current Year emissions, 2003 GWP**	**Uncertainty AD**	**Uncertainty EF**	**Combined uncertainty**	**Combined uncertainty as part of total nat. emissions in 2002**	**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**	**Uncertainty introduced into the trend in total nat. emissions**	**Quality Indicator EF**	**Quality Indicator AD**
			[Gg CO_2-Equivalent]		**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**	**[%]**		
4D3. Agricultural Soils	Indirect Emissions	N_2O	13711,6	11156,3	**75**	**150**	**167,7**	1,838784	-0,000050	0,008971	-0,007505	0,951504	**0,951533**	**D**	**D**
4D4. Agricultural Soils	Other	CH_4	-672,0	-633,5	**75**	**75**	**106,1**	-0,066035	-0,000067	-0,000509	-0,005044	-0,054029	**0,054264**	**D**	**D**
6A1 Managed Waste Disposal on Land	Solid Waste Disposal on Land	CH_4	31478,9	11655,0	25	38,5	**45,9**	0,525815	-0,011335	0,009372	-0,436410	0,331344	**0,547944**	R	R
6B1. Wastewater Handling	Domestic and Commercial Wastewater	CH_4	2226,2	112,0	100	**40**	**107,7**	0,011854	-0,001375	0,000090	-0,054982	0,012736	**0,056438**	R	D
6B1. Wastewater Handling	Domestic and Commercial Wastewater	N_2O	2213,4	2275,4	100	**40**	**107,7**	0,240851	0,000373	0,001830	0,014938	0,258753	**0,259184**	R	**D**
Total CO_2 Equivalent			**1243620,4**	**1017507,1**			**Total [%]**	**5,581134**				**Total [%]**	**4,285808**		

In further determination of uncertainties pursuant to Tier 1, in keeping with Chapter 6 of GPG, plans call for treating the source categories energy, transport and agriculture separately.

The current assumptions regarding uncertainties for activity rates in the source category Energy (CRF 1) are being reviewed by experts of the Working Group on Energy Balances (AG Energiebilanzen). The uncertainties for emission factors for CO_2 are being evaluated by experts in the Federal Environmental Agency's section (FG) III 2.3.

Uncertainties for activity rates in the source category Transport (primarily CRF 1 A 3) are also being estimated by experts of the Working Group on Energy Balances. The uncertainties in the emission factors for CH_4 and N_2O are being estimated by experts in the Federal Environmental Agency's section I 3.1 and I 3.2.

Uncertainties in the source category Agriculture (CRF 4) are being estimated by experts in the Federal Ministry of Consumer Protection, Food and Agriculture (BMVEL) and in the Federal Agricultural Research Institute (FAL).

Uncertainties for other source categories are being determined successively within the framework of UBA departments' data deliveries for current emissions reporting. At the same time, guideline-supported experts' judgements are being continued especially in those source categories in which very little or no uncertainties information has been provided to date in the framework of contributions/support.