German Greenhouse Gas Inventory 1990 - 2001

National Inventory Report 2003

Submission under the United Nations Framework Convention on Climate Change

Federal Environmental Agency

- Draft, last edited 26 June 2003 -

Berlin, June 2003

Contacts

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

An electronic version of this report and the related emission data in Common Reporting Format (CRF) will shortly be published on the website of the Federal Environmental Agency: http://www.umweltbundesamt.de/luft/index.htm

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0 EXECUTIVE SUMMARY

The United Nations Framework Convention on Climate Change (UN FCCC) was ratified by Germany in December 1983 and entered into force in March 1994. As a Party to the United Nations Framework on Climate Change, Germany is obliged to prepare, publish and regularly update national emission inventories of greenhouse gases.

The Kyoto Protocol on the Convention was ratified by Germany and at the same time by the European Union in May 2002. This leads to extensive obligations vis-à-vis the preparation, reporting and review of emissions inventories. *Inter alia*, the Conference of the Parties, in adopting Decision 3/CP.5, resolved that all Parties are required to prepare and submit a National Inventory Report (NIR) containing detailed and complete information on their inventories. This is intended to ensure the transparency of the inventory and support the independent review process. The Secretariat has made submission of the inventory report a pre-requisite for performance of the prescribed inventory reviews. Germany is submitting its first national inventory report together with the inventory for 2003.

National greenhouse gas emission inventories have been submitted to the Climate Secretariat for the years 1990 to 2001. This report refers to those annual emission inventories and outlines the methodology on which the calculations are based. The report and the report tables in Common Reporting Format (CRF) have been prepared in accordance with UNFCCC guidelines (*FCCC/CP/1999/7*) and as far as possible in accordance with the *IPCC Good Practice Guidance* (IPCC, 2000). The chapter structure of the report is based on that agreed at the 8^{th} Conference of the Parties (draft decision-/CP.8 in document **FCCC/SBSTA/2002/L.5/Add.1**).

Chapter 1 describes the National System of Emissions in Germany designed to aid compliance with reporting obligations with respect to atmospheric emissions and sinks as a whole. Apart from the Kyoto 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). It also outlines the Quality System of Emissions and the routes via which the emissions and sinks of the various IPCC categories have been estimated. Although in the past two years the participating institutions have made a considerable effort to successfully reduce the uncertainties and close any data gaps, there is still scope for further improvement of the inventory.

Chapter 2 provides a general outlook of trends in greenhouse gas emissions and sinks.

Chapters 3 to 9 provide detailed information on the principal source and sink categories. This year's Report aims to render the calculation of German greenhouse gas emissions and sinks more transparent. Because this is Germany's first attempt to prepare a National Inventory Report, the documentation does not meet the requirements and our own ideals in terms of scope and comprehendibility. One key focus during 2003 will be to supplement and consolidate this report in the descriptive part on data extraction for the sources consulted and the methods used. Last year, attention focussed in particular on significant improvements in completion of the reporting tables compared with prior years. For the first time, the CRF tables may be presented in detail. This means that the emissions inventories are at least verifiable from a calculatory viewpoint. Since formulation of the German emissions inventories are currently being subjected to an in-depth national review process, which also comprises methodological changes in order to implement the Good Practice Guidance, there is a fluid transition between the methodology description and the planned improvements. Against this background, out-of-date methods that are due to be replaced shortly will no longer be described; instead, NIR 2004 will outline the new techniques. For more detailed information on the individual aspects, please refer to the bibliography in **chapter 11**.

General information on uncertainties and recalculations can be found in **chapter 10.** More detailed information will only become available with the National Inventory Report 2004.

The Greenhouse Gas Inventory is compiled by the Federal Environmental Agency. 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 activity. 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 dinitrogen oxide (N_2O) by 15 %. Furthermore, a number of brand new substances such as chlorfluorocarbons (CFCs), halons, perfluorinated hydrocarbons (PFCs), hydrogenous fluorocarbons (HFCs) and sulphur hexafluoride (SF_6) have entered the atmosphere which almost never occur in nature and are generated almost exclusively by humans.

The obligation assumed by the European Community in this context to reduce greenhouse gas emissions was divided between the Member States in the form of burden sharing, whereby certain EU countries such as Spain and Portugal are still permitted substantial increases in emissions, which need to be compensated by significantly higher reductions in other countries such as Denmark and Germany. In the first obligation period (2008 to 2012), Germany was required to make a substantial contribution within the EU with a 21 % reduction in emissions compared with 1990 levels.

The effectiveness of the Kyoto Protocol vis-à-vis 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 emission data used for compliance control is reliable. As such, national reporting and the subsequent international review of emissions inventories play a key role.

0.2 Summary of national emission and removal related trends: 1990-2001 using GWP

Within the context of EU burden sharing, the Federal Government has undertaken to reduce the emissions of all six Kyoto gases by 21 % by 2010 compared with 1990 and 1995[1] levels respectively. The development to date of greenhouse gas emissions in Germany is depicted in Table 1 with a breakdown of individual greenhouse gases, whilst an overview in chart form can be found in Figure 1.

[1] For HFC, PFC and SF_6

Table 1: Greenhouse gas emissions in Germany – Reductions compared with the base year

GREENHOUSE GAS EMISSIONS	Base year(1)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
	CO_2 equivalent (Gg)												
Net CO_2 Emissions/ removals	980.750	980.750	942.080	894.392	884.300	870.103	865.358	887.471	856.197	847.984	821.341	834.274	847.067
CO_2 emissions (without LUCF)	1.014.439	1.014.439	975.769	928.081	917.989	903.792	898.758	920.871	889.597	881.384	854.741	857.968	870.762
CH_4	101.070	101.070	91.032	84.003	77.577	73.144	69.765	65.921	63.855	60.931	59.315	54.544	52.165
N_2O	87.910	87.910	83.142	84.104	80.536	77.616	78.551	80.186	75.726	62.262	59.010	59.351	60.232
HFCs	6.360	3.510	3.547	3.677	4.950	5.178	6.360	5.768	6.356	6.979	7.280	6.630	8.130
PFCs	1.759	2.696	2.356	2.138	2.012	1.627	1.759	1.723	1.377	1.481	1.247	790	723
SF_6	6.633	3.896	4.350	4.876	5.401	5.808	6.633	6.359	6.274	6.038	4.414	4.018	3.325
Total (without CO_2 from LUCF)	1.218.170	1.213.520	1.160.196	1.106.879	1.088.465	1.067.164	1.061.826	1.080.828	1.043.184	1.019.076	986.008	983.301	995.337

(1) Base year 1990 for CO_2, CH_4, N_2O; 1995 for HFC, PFC, SF_6

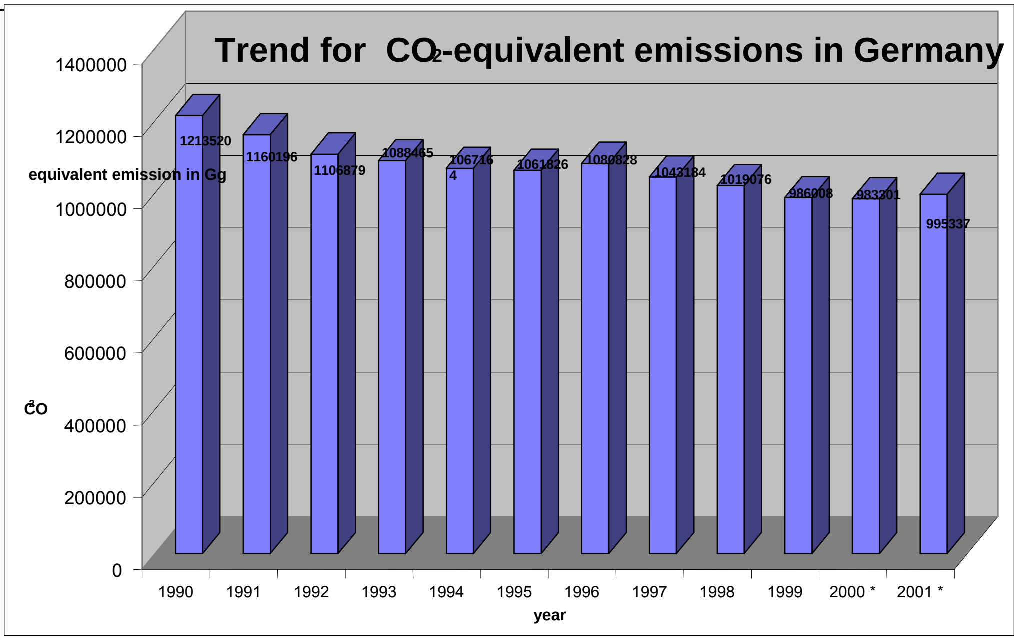


Figure 1: Overall development of greenhouse gas emissions in Germany

By the year 2001, the aforementioned obligation had already been largely met, with a reduction of more than 18 %. The individual greenhouse gases contributed to this development to varying degrees (cf. Table 1). This is hardly surprising given that the individual greenhouse gases account for varying proportions of total emissions in a given year (cf. Table 2).

Table 2 Greenhouse gas emissions in Germany – Annual share of individual greenhouse gases

GREENHOUSE GAS EMISSIONS	Base year[1]		1990		1995		2000		2001	
	Gg	%	Gg	%	Gg	%	Gg	%	Gg	%
CO_2 emissions (without LUCF) [6]	1.014.439	83,3	1.014.439	83,6	898.758	84,6	857.968	87,3	870.762	87,5
CH_4	101.070	8,3	101.070	8,3	69.765	6,6	54.544	5,5	52.165	5,2
N_2O	87.910	7,2	87.910	7,2	78.551	7,4	59.351	6,0	60.232	6,1
HFCs	6.360	0,5	3.510	0,3	6.360	0,6	6.630	0,7	8.130	0,8
PFCs	1.759	0,1	2.696	0,2	1.759	0,2	790	0,1	723	0,1
SF_6	6.633	0,5	3.896	0,3	6.633	0,6	4.018	0,4	3.325	0,3
Total (without CO_2 from LUCF) [6] [8]	**1.218.170**	100,0	**1.213.520**	100,0	**1.061.826**	100,0	**983.301**	100,0	**995.337**	100,0

The release of carbon dioxide from the processes of stationary and mobile combustion is by far the principal cause of emissions, accounting for more than 87 % of greenhouse gas emissions. In particular, due to the above-average decrease in other components, the proportion of total greenhouse gases attributable to CO2 emissions has increased from just under 84 % to over 87 % since 1990. Emissions of methane caused by animal husbandry, fuel distribution and landfill emissions account for just over 5 %. Emissions of dinitrogen oxide, caused primarily by agriculture, industrial processes and transport, account for more than 6 % of greenhouse gas releases. The remaining so-called Kyoto or F gases together account for just over 1 % of such emissions. The distribution of greenhouse gas emissions calculated here is typical of a developed industrialised country.

0.3 Overview of source and sink category emission estimates and trends

Figure 2 shows the contribution of the individual source categories to total greenhouse gas emissions. The relatively constant proportions of the individual pollutants referred to in the previous chapter are evident from this illustration, as is the complete dominance of energy-induced emissions. In fact, these have continuously decreased over time. The two slight increases in 1996 and 2001 are attributable to climatic factors in both cases. In both of these years, the average temperatures were characterised by lower temperatures in winter. This resulted in higher energy consumption on heating, which in turn led to an increase in emissions.

Emissions from the LULUCF sector are given as 5-year averages (1990 to 1994, 1995 to 1999, both very similar in terms of level). At present, the figure published since the year 2000 only represents a 2-year average. The sharp decrease in the year 2000 is attributable to wind effects caused by hurricane “Lothar”.

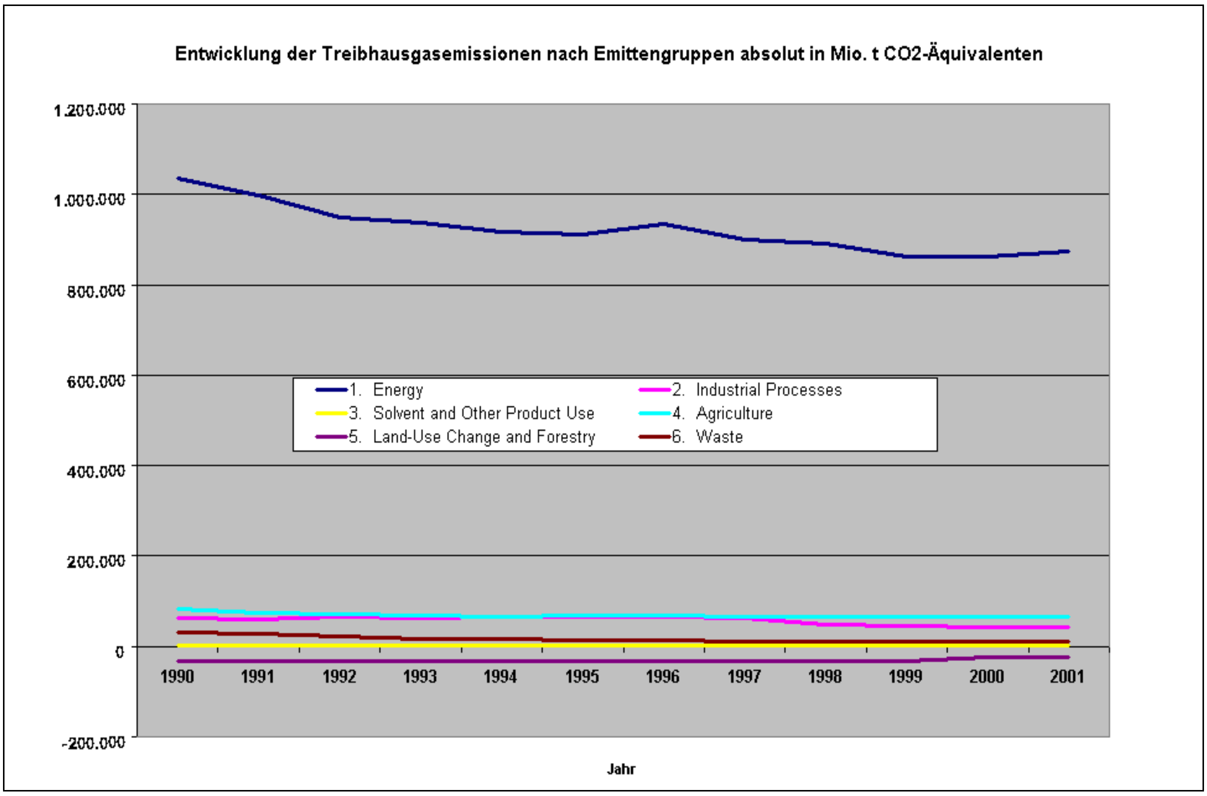


Figure 2 **Development of greenhouse gas emissions according to source categories and development of sinks in CO2 equivalents**

Figure 3 shows the relative developments of emissions from polluter categories since 1990. The most significant reduction occurred in the area of waste emissions. Despite the many methodological difficulties (cf. chapters 8.1 and 8.2), 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 produces, the emission-reducing effects 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 N2O. The development of emissions from agriculture essentially follows the development of livestock data.

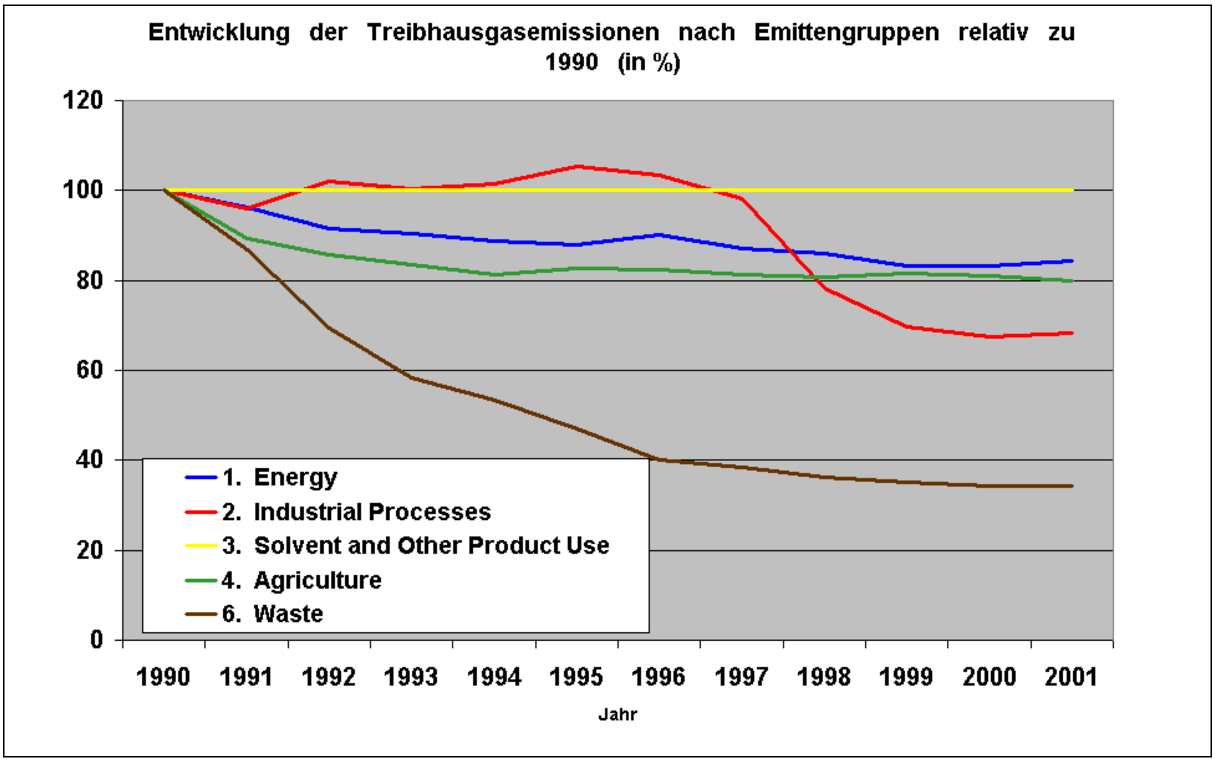


Figure 3 **Development of individual greenhouse gases since 1990, according to source categories**

1 INTRODUCTION

1.1 Background information on greenhouse gas inventories and climate change

1.1.1 The greenhouse effect

Climate change refers to a change in the average weather conditions in a certain area, or even globally, over a longer period. From research, we know that there have been fluctuations in the average global temperature in the last millions of years between 9°C and 16°C. 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 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 a so-called energetically excited state for a brief time, after which they 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 trans-regional and global changes in the substance balance of the atmosphere have been observed as a consequence of human activity. 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 dinitrogen oxide (N_2O) by 15 %. Some brand new substances such as chlorfluorocarbons (CFCs), halons, perfluorinated hydrocarbons (PFCs), hydrogenous fluorocarbons (HFCs) and sulphur hexafluoride (SF_6) have also 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 ascertained, *inter alia*, that the average global air temperature has increased by between 0.4 and 0.8°C over the past 100 years. Recent years were amongst the warmest since 1861.

1.1.3 Reduction obligations and reporting of greenhouse gases

The world's nations were quick to realise that the anticipated temperature changes posed a threat to ecosystems and human civilisation, because these changes are taking place at a fairly rapid rate and the existing systems are unable to adapt quickly enough to the new climate conditions without causing damage.

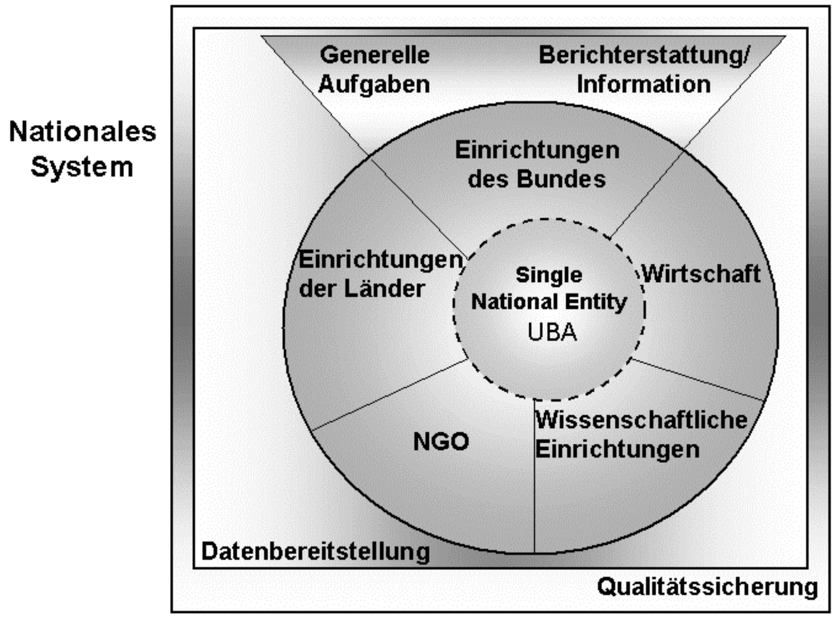
In 1992 in Rio de Janeiro the United Nations Framework Convention on Climate Change was adopted by almost all the nations of the world. At the Third Conference of the Parties in Kyoto, legally binding limitation and reduction obligations were specified for the industrialised countries for the first time. The obligation assumed by the European Community in this context to reduce greenhouse gas emissions was divided between the Member States in the form of burden sharing, whereby certain EU countries such as Spain and Portugal are still permitted substantial increases in emissions, which need to be compensated by significantly higher reductions in other countries such as Denmark and Germany. In the first obligation period (2008 to 2012), Germany was required to make a substantial contribution within the EU with a 21 % reduction in emissions compared with 1990 levels.

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

Since 1996, the nations listed in Annex I to the Framework Convention on Climate Change have been required to submit an inventory of greenhouse gases to the Secretariat of the Framework Convention on Climate Change on 15 April each year. This should include details of emissions and sinks for the base year (1990 for CO_2, N_2O, CH_4; 1995 for HFC, PFC, SF_6) and for all subsequent years up until the year preceding reporting.

1.2 Institutional arrangements and framework for inventory preparation

1.2.1 Institutional arrangements for inventory preparation



<Legende>:

National system

General tasks *Reporting/information*

Federal government institutions

Industry

Scientific institutions

NGOs

Länder institutions

Single National Entity UBA

Data provision

Quality assurance

Figure 4: Functions of the national system and the institutes to be involved

In accordance with the provisions of Article 5 (1) of the Kyoto Protocol, Germany is obliged to ensure transparent, comparable, complete, consistent and precise reporting of emissions. To this end, a *national system* must be implemented, incorporating all institutions which may make a valuable expert contribution to emissions inventories. Figure 4 provides a schematic overview of the functions that must be ensured and the institutions to be involved in implementing the national system. Further details of the functions of the national system are outlined in the IPCC Guidelines. The National System of Emissions for Germany has been under development since 2002; further details may be found in Annex 7 (chapter 19.1).

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

1. The national system is coordinated by the Federal Environmental Agency UBA (single national entity[2]). There is as yet no legally binding specification in this respect.
2. A Committee on Emissions Inventories has been set up to coordinate work within the Federal Environmental Agency. This committee meets three times a year.
3. Within the framework of committee VI *Emissions Reporting* of the Interministerial Working Group (*IMA) on CO_2 Reduction*, which was founded in 2002, in-depth inter-departmental discussions have taken place regarding the main tasks identified to date in the field of emissions inventories.

   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 national level. In this respect, interest focuses in particular on the concretisation of the objectives and requirements of the Framework Convention on Climate Change to reduce emissions of greenhouse gases. The IMA on CO_2 Reduction reports to the Federal Cabinet on the status of implementation and further development at pre-arranged dates (most recently: fifth report in 2000). The Committee on Emissions Reporting was founded in October 2000, with the adoption of the Federal Government's national reduction strategy to reduce greenhouse gases. The committee is coordinated by the BMU.
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

[2] The coordinating office (Single National Entity) should act as a 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.

agriculture dated 2 April 2001 marked the first ever inter-departmental agreement on cooperation with the calculation of emissions.

5. Data on forestry is prepared and supplied to the UBA by the BMVEL, based on the relevant surveys.

The need for further agreements is currently being ascertained within the context of a project, cf. Annex 7, chapter 19.1.

1.2.2 Framework for inventory preparation

Extensive preparatory work from the specialist departments of the UBA and other institutions is required for the purposes of inventory preparation. The National System to be developed in Germany is not only to be used for climate reporting, but also for meeting its reporting obligations towards the UN ECE (Geneva Convention on Long-Range Transboundary Air Pollution) and the EU (NEC Directive). Against this background, inventory preparation and inventory reporting should meet the following national objectives:

1. To enable the **Climate Secretariat** to commission a third party to trace the origins of the inventory in an independent review,
2. To provide the **CO_2 Monitoring Mechanism Committee of the EU** with a suitable basis for meeting the EU's obligations vis-à-vis inventory and NIR preparation (the EU is likewise a Party to the Framework Convention on Climate Change and the Kyoto Protocol, and is therefore required to report independently from the EU Member States),
3. To provide the **national coordinating office of the National System** (Single National Entity) with an overview of the areas in which further action is needed in order to achieve a system of reporting which meets the requirements (from 2003 onwards, the required actions are to be outlined in a national inventory work plan to be prepared annually, and in 2005 in a national progress report on implementation of the Kyoto Protocol.),
4. To provide those involved in the **National System of Emissions** currently under development with a description of the inventories on whose basis the required measures may be taken, so as to facilitate improved, requirement-oriented reporting in the individual source categories in future,
5. To support the **Quality System of Emissions** (QSE) currently under development in developing cooperation procedures through its cooperation with the UBA Committee on Emissions Inventories and the members of the National System which will ensure the required quality of reports and inventories.

In 2002, the Federal Environmental Agency began to develop a Quality System of Emissions (QSE) aimed at creating the framework conditions to satisfy these objectives. It is designed to meet the IPCC requirements within the framework of reporting to Articles 5, 7 and 8 of the Kyoto Protocol, and be adapted to the national situation in Germany as well as the internal structures and procedures of the reporting institution UBA. The Quality System of Emissions, currently under development, is outlined in greater detail in Annex 7 (chapter 19.2).

At present, the following framework conditions apply to inventory preparation in Germany.

1. The database of the Federal Environmental Agency's Central System of Emissions (CSE) is used for centralised data storage of all information required for the purposes of emissions calculation (methods, rates of activity, emission factors). The CSE is the principal mechanism for quality assurance at data level.

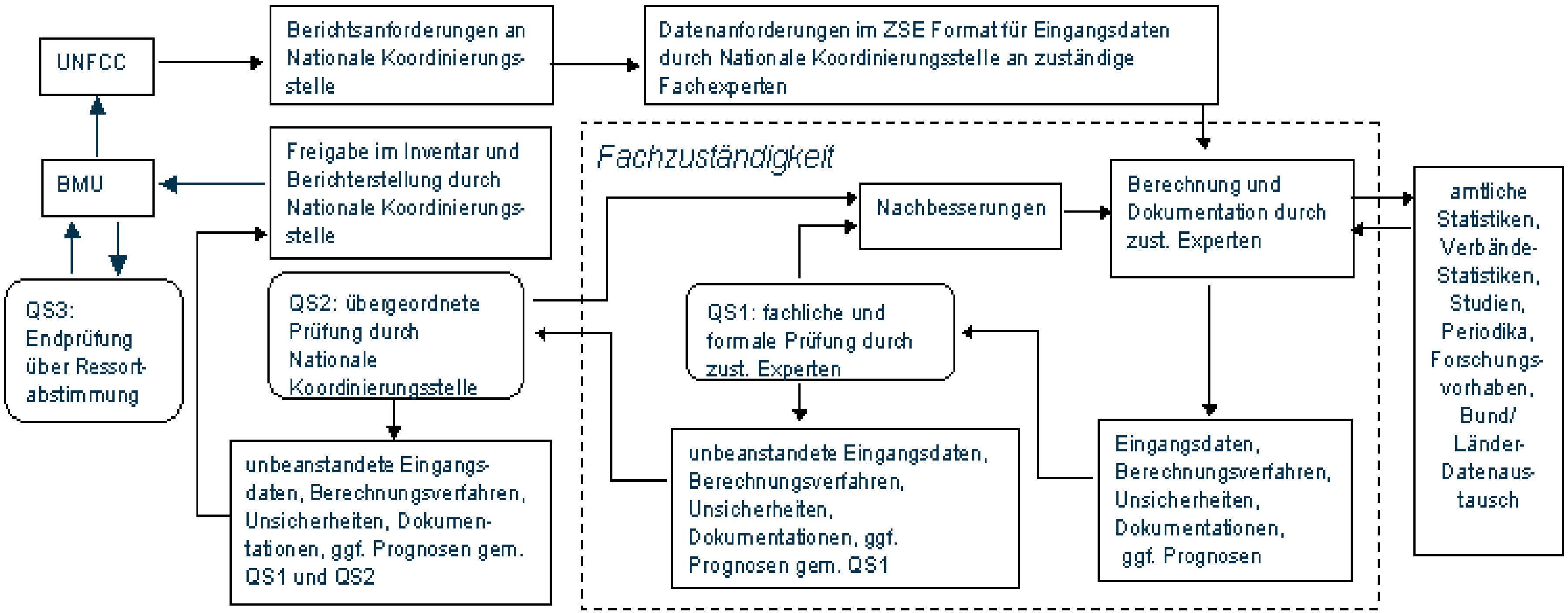
2. A binding timetable for inventory preparation has been notified to all those involved. From 2003 onwards and for all subsequent years, the following timetable shall apply to inventory data (all pollutants) and the corresponding descriptions in the national inventory report (initially greenhouse gases only):

Mid-June	Request for data and supply of the report text by the national coordinating office at the UBA
Early September	Deliveries from the UBA
Early October	Deliveries from external institutions of the NaSE
Mid-October	Validation / feedback
Mid-November	Final editing by the Single National Entity at the UBA
30/11/xx	Report to the Ministry to initiate agreement between the departments
31.12/11/xx	Report to the CO_2 Monitoring Committee
15/04/xx	Report to the Climate Secretariat

1.3 Brief description of the process of inventory preparation

Inventory preparation is managed by department II 6.3 of the UBA, which also assumes the role of Single National Entity. Since 2002, the process of inventory preparation has been closely linked to preparation of the national inventory report and the performance of quality assurance procedures. The fundamental approach is outlined in Figure 5.

Because the Quality System of Emissions is currently under development and an overall concept for quality control and quality assurance has yet to be finalised (cf. chapter 19.2.3), changes may still occur during the course of the year compared with the procedure outlined. Consequently, the procedure has not yet been fully established and implemented in every detail. Although it can be assumed that quality testing will be carried out at all the levels indicated, in particular, documentation of the quality tests conducted is still in its infancy. To date, there has only been a systematic review based on identical criteria for all source categories at the Single National Entity.



Quelle: Marion Dreher - Umweltbundesamt / Fachgebiet II 6.3 - Emissionssituation

<Legende>:

UNFCC
Reporting requirements to the Single National Entity
Data requirements in CSE format for input data by Single National Entity to the competent experts
BMU
Release in the inventory and reporting by the Single National Entity
Technical competence
Addenda
Calculation and documentation by the competent experts
Official statistics, statistics from associations, surveys, periodicals, research projects, data exchange between the Federal Government and the *Länder*
QS3: Final review via departmental coordination
QS2: Superordinate review by the Single National Entity
QS1: Technical and formal review by the competent experts
Unchallenged input data, calculation procedures, uncertainties, documentation, where applicable forecasts to QS1 and QS2
Unchallenged input data, calculation procedures, uncertainties, documentation, where applicable forecasts to QS1
Input data, calculation procedures, uncertainties, documentation, where applicable forecasts

Source: Marion Dreher – Federal Environmental Agency / department II 6.3 – Emissions situation

Figure 5: Fundamental data flow and quality assurance procedures in the National System

1.3.1 Data flow

The data requirements are sent to the source category-specific technical experts via the Single National Entity. At the same time, measures are taken to ensure that the technical experts are notified of the reporting requirements and the existing data stock on this particular source category. Data extraction and documentation takes place under the responsibility of the relevant experts. This may be achieved by evaluating official statistics or statistics from associations, studies, periodicals as well as external research projects, or by conducting their own research projects, the use of personal information, and data acquired from a data exchange between the Federal Government and the *Länder*. Often, work results obtained by other means are also reused for the purposes of emissions reporting.

1.3.1.1 Data validation

Contextual data validation occurs at expert level via technical plausibility checks (expert knowledge), the consultation of comparative figures, or expert appraisal by third parties (e.g. discussion with associations). The validated data is transmitted to the Single National Entity.

1.3.1.2 Data input

The validated individual data is imported into the CSE via a standard interface, or entered directly. To date, data input and imports into the CSE were conducted exclusively by staff of department II 6.3, because the system was only introduced at the UBA in 2002 and its use requires a comparatively high level of specialist knowledge. This means that at present, only approximately 2/3 of reporting data has been logged in the CSE, and only this data may be checked automatically with IT support.

1.3.1.3 Calculation of emissions

After carrying out all the checks and consulting the relevant parties where necessary, the emissions are calculated in the CSE by means of an automated procedure, based on the following principle:

activity rate * emissions factor = emission

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

1.3.1.4 Emissions reporting

Activity data, emissions factors and emissions are written automatically into the CRF reporting tables of the IPCC; any aggregations that may be required are likewise automated. This procedure eliminates the possibility of transfer errors with respect to concrete figures; when the CSE and CRF tables are linked for the first time, however, there is a possibility of allocation errors, and these must therefore be scrutinised with particular care. The reporting tables are forwarded to the Ministry with the NIR for inter-departmental coordination.

1.3.1.5 Archiving

The data tables coordinated between departments and the related NIR are transferred onto a CD in the version transmitted to the Climate Secretariat, and archived with clear identification information. The content of the CSE database required for calculation purposes is likewise copied and archived.

1.3.1.6 Evaluation

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. Within the context of a research project (FKZ: 202 42 266), aimed at implementing the requirements of the *Good Practice Guidance* with inventory preparation, systematic evaluation occurs jointly with the identification of uncertainties (cf. chapter 19.2.3).

In future, data evaluation will take place in the following reporting year and will be carried out by the source-specific experts. The following materials should be consulted for review purposes:

- 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 the basis for work)
- Previous year's CRF reporting tables (as a basis for work)
- Aggregation and allocation rules between the CSE and the CRF structure (as the basis for work)
- Source-specific information which has come to the attention of the Single National Entity in the interim.

1.3.1.7 Recalculation

Recalculations in accordance with the IPCC *Good Practice Guidance* have not been documented to date. Since significant changes to the inventories are anticipated in 2003, due to methodological changes, information on recalculations will not be provided prior to 2004. The effort involved in documenting unsuitable old methods that cannot be described in adequate detail would be disproportionately high; instead, these resources have been invested in a rapid inventory improvement. The 2004 inventory will provide a starting basis for subsequent recalculations to be documented. This process will also be assisted by the CSE. As the calculation procedures are stored in the CSE and the reported data stocks for archiving are "frozen", old and new calculations are easily compared with one another. In the case of the current inventory, almost all the information has changed compared with the data transmitted earlier on, due to real-time detailed emissions calculation in the database, which was introduced for the first time this year. For earlier data reports, calculations and estimates were predominantly based on the aggregate data level. Consequently, detailed and – with the exception of the LULUCF area – largely complete CRF tables have been presented for the first time in the present reporting year.

1.3.2 Peripheral technical conditions for inventory preparation

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 largely implements the diverse requirements pertaining to emissions calculation and reporting, and automates essential work stages. The CSE facilitates inventory planning (e.g. data collection) and reporting (e.g. emissions calculation, recalculation and error analysis) as well as inventory management (e.g. archiving, annual evaluation of data) and quality management. It is hoped that the CSE will meet the key requirements of the UNFCCC regarding the National System of transparency, consistency, completeness, comparability and accuracy, and also those of the UN ECE at data level.

In order to meet these key requirements, the CSE gives broad scope to the requirements pertaining to documentation (e.g. by the competent editors, data sources, calculation techniques). 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 as the data is provided, and all processing and transformations into reporting format only occurs in the CSE, which ensures that they remain comprehensible. In this way, the CSE is capable of administering detailed technical-specific activity data and emissions factor which are then subsequently processed into aggregate, sector-specific values for the reporting formats via calculation rules (calculation methods).

Data exchange within the framework of the national system – i.e. within the UBA and with third parties – is also organised via the CSE. As well as direct data input, aggregate figures may also be imported from existing databases via a standard interface (e.g. TREMOD[3], GAS-EM[4]).

1.3.3 Subsequent planning

Now that the principal technical requirements for compliance with the Kyoto requirements for inventories have been met with the operational launch of the CSE in 2002, the next stage is to convert the calculatory procedures for determining emissions and the organisation of data extraction completely in line with the CSE.

The aim is that inventory data should be incorporated directly into the CSE by the technical experts responsible for the content wherever possible, or at least imported via the import interface. This applies to in-house UBA employees as well as external parties involved in the national system. In order to achieve this, two fundamental preparations have been made in the past two years:

- The provision of a *standardised import format for CSE* in 2001 facilitated the direct import of data from other emissions-relevant databases.
- In September 2002, participating technical experts involved at the UBA gained direct access to the CSE via the intranet. Admittedly, the affected parties were identified by means of an interest survey, which means that comprehensive access by affected in-house technical experts is not yet available. However, write access rights for these experts are confined to the contents of the database for which they are technically responsible.
- In November 2002 a training course was held for affected UBA employees on the handling of the CSE.
- Course participants were provided with a description of the database in the form of the *CSE/Point Source User Manual*.
- It is hoped that the CSE will be linked to the Internet in 2003, thereby enabling external parties to input data and conduct searches directly in the CSE.

[3] Traffic Emission Estimation Model
[4] GASeous EMissions – A calculation program for emissions from agriculture

The Government hopes that the CSE can be incorporated into the data flow as quickly as possible, particularly in the interests of quality assurance and work efficiency. The current practice (input into the CSE at the end of the data flow) indicates that a high level of retrospective adaptation work for data supplies is linked to quality losses, particularly because of the lack of documentation of calculation methods and data sources, as well as the failure to use automated check procedures.

Other future tasks for the Central System for Emissions include comprehensive application of the database for:

- Logging of qualitative and quantitative data on data certainty and uncertainty,
- Compliance with reporting obligations under the Geneva Convention on Long-Range Transboundary Air Pollution and EU regulations (such as the NEC),
- 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 also in order to facilitate the identification of additional measures needed for target attainment.

1.4 Brief general description of methodologies and data sources used

The methods used for the individual source categories are outlined in the summary tables 3s1 and 3s2 of the CRF reporting tables. For the individual calculation methods, a distinction is made between country-specific methods (cs) and IPCC "*Tiers*", depending on the source category. *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 calculating non-CO_2 emissions from road traffic, a bottom-up Tier 2/3 approach was used as a basis with the aid of the TREMOD model. Calculation of CO_2 emissions occurs in compliance with the information from the Federal Energy Balance based on a top-down Tier 1 approach.

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

In the waste sector, too, an R&D project (FKZ: 299 42 245) has been carried out aimed at tapping into new national data sources in a targeted way for application of the IPCC methods and converting the calculation methods. Based on the available data situation, CH_4 emissions were calculated on the basis of the Tier 1 approach. For other pollutants, however, for the time being only less precise calculations may be replaced by higher-quality national methods, because the database for application of the IPCC methods is not yet available.

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

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-induced activity data, it can be assumed that Tier 1 has been used as a minimum. For other areas, too, the classification of country-specific to IPCC tiers will change, since methodological conformity will either be ascertained or created during the course of the year. It can be assumed that corresponding information in the NIR 2004 will be far more precise.

1.5 Brief description of key source categories

For the first time, the Key Sources Analysis uses both the Tier 1 procedures for determining the key sources for German greenhouse gas emissions.

As a result, a total of 20 of the 26 source categories examined here were identified as key sources. Only 8 of them were ascertained by both techniques. The source categories ascertained by the Level approach accounted for 95 % of total emissions, whilst those source categories ascertained by the Trend approach account for 57.8 % of national greenhouse gas emissions. As such, a total of 98.4 % of greenhouse gas emissions in Germany originate from key sources in accordance with Tier 1 techniques (cf. Table 3).

Table 3: Key source categories for Germany (1990-2000) according to the Tier 1 approach

IPCC	Key Source Categories	Pollu-tant	Emission 2000 (Gg CO2 Eq.)	Key Source	
				Level	Trend
1 A	Emission from Fuel Combustion	CH_4	1268		□
1 A.1, 1 A.2, 1 A.4, 1 A.5.a	Emissions from Stationary Combustion - Gas	CO_2	191145	□	□
1 A.1, 1 A.2, 1 A.4, 1 A.5.a	Emissions from Stationary Combustion - Lignite	CO_2	173040	□	□
1 A.1, 1 A.2, 1 A.4, 1 A.5.a	Emissions from Stationary Combustion - Oil	CO_2	111129	□	□
1 A.1, 1 A.2, 1 A.4, 1 A.5.a	Emissions from Stationary Combustion - Hard coal	CO_2	173535	□	
1 A.1, 1 A.2, 1 A.4, 1 A.5.a	Emission from stationary Fuel Combustion	N_2O	5527		□
1 A.3, 1 A.5b	Mobile Combustion: Road & Other	CO_2	177651	□	
1 A.3, 1 A.5b	Mobile Combustion: Road & Other	N_2O	5175		□
1 A.3	Mobile Combustion: Aviation	CO_2	4382		□
1 A.3d	Mobile Combustion: Marine	CO_2	877		□
1 B.1°	Fugitive Emissions from Coal Mining & Handling	CH_4	9968	□	□
1 B.2	Fugitive Emissions from Oil & Gas Operations	CH_4	7358		
2 A	Emissions from Mineral Production (mainly cement)	CO_2	23502	□	
2 B.2, 2 B.3	Emissions from Adipic Acid Production (incl. Nitric Acid)	N_2O	5089		□
2 E, 2 F	Total Emissions	HFCs	7700	□	□
2 E, 2 F	Total Emissions	PFCs	1709		□
4 A	Emissions from Enteric Fermentation in Domestic Livestock	CH_4	20890	□	□
4 B	Emissions from Manure Management	N_2O	13838	□	□
4 B	Emissions from Manure Management	CH_4	4425		□
4 D	Emissions from Agricultural Soils	N_2O	27351	□	
6	Emissions from Waste	CH_4	16674	□	□
2 B	Emissions from Chemical Production	CO_2	1860		
2 C	Emissions from Metal Production	CO_2	787		
3 D	Emissions from Product use	N_2O	1860		
2 E, 2 F	Total Emissions	SF_6	3442		
6 B	Emissions from Wastewater Handling	N_2O	1240		

For these, the calculation approaches applied in the German inventory system will be compared with the Tier 2 calculation methods prescribed by the *Good Practice Guidance* within the context of an R&D project (FKZ: 202 42 266).

1.6 Information on the QA/QC plan

To date, there is no central quality assurance and control plan available for the German inventory. An initial draft will be drawn up within the context of a project (FKZ: 202 42 266) and an initial version will be available in NIR 2004 (cf. chapter 19.2.3). Sector-specific plans for improvements may be given, where applicable, in the corresponding sector-specific chapters.

1.7 General uncertainty evaluation

At present, the German inventories are being adapted in line with the requirements of the Good Practice Guidance of the IPCC within the context of a project (FKZ: 202 42 266). This project will also include a systematic determination of uncertainties (cf. chapter 19.2.3). As the results in this respect are not yet available, this report only includes chapters on "*Uncertainties and time series consistency*" for the individual source categories where sector-specific data is available. There are plans to present more accurate information on sector-specific uncertainties in NIR 2004. Until these results are available, it is only possible to provide a rough qualitative evaluation of the accuracies contained in the emission calculations which can be found in CRF Table 7s1, 7s2 and 7s3.

Moreover, the following general assessment may be given:

- Emission calculations for the years after 1996 were provisionally conducted at aggregate level until the last inventory submission. The accuracy of the data was correspondingly low. With the emission inventories submitted here, the years 1995 to 2001 were calculated at a detailed level for the first time, as a result of which accuracy has become significantly more reliable, particularly with combustion-related emissions. Here, data quality is classed as high, with the exception of CH_4 and N_2O emissions and excluding the source category *readily volatile emissions from fuels* (1.B).
- Emissions from non-combustion-related activities, some of which have very complex origination processes, still entail substantial uncertainties in part. Initially, a lack of information with regard to certain emission-inducing processes is cited as a possible reason for this. The uncertainties attributable to an inadequate knowledge of the consequences of individual activities have a far more pronounced effect. This concerns both socio-economic reference data and emission factors. Higher levels of uncertainty apply in particular to CH_4 emissions.
- With the exception of CO_2, the emission factors are essentially based on measurements performed under defined conditions, whereby the number of such measurements must be considered inadequate in part. The area of non-energy-induced emissions is particularly affected by this.

1.8 General assessment of the 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, a concept was developed for the reorganisation of data records on emissions and sinks in two R&D projects (FKZ: 298 42 759 and 298 42 289). 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. This documentation has since been transferred into the CSE, and is being taken into account in the national review currently underway.

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).

All combustion-related activities (1.A) from the field of energy are recorded in full. At certain points, the Federal Energy Balance 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.

2 TRENDS IN GREENHOUSE GAS EMISSIONS

Table 4 Emissions of direct and indirect greenhouse gases and SO_2 in Germany since 1990

Emissionen der Treibhausgase und von SO2 in Deutschland 1990 - 2001 Angaben in Gg (HFC, CF4, C2F6 und SF6 in Mg)												
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000 *	2001 *
Directly acting greenhouse gases												
CO_2	1014439	975769	928081	917989	903792	898758	920871	889597	881384	854741	857968	870762
CH_4	4813	4335	4000	3694	3483	3322	3139	3041	2901	2825	2597	2484
N_2O	284	268	271	260	250	253	259	244	201	190	191	194
HFC	300	303	405	303	302	2591	2866	3276	3643	3862	4128	6179
CF_4	355	308	278	260	214	224	214	161	172	137	72	69
C_2F_6	42	38	36	35	31	32	34	32	34	31	24	18
C_3F_8	0	0	0	0	0	1	3	5	8	10	14	15
SF_6	163	182	204	226	243	278	266	262	253	185	168	139
CO_2-equivalent emission	1213520	1160196	1106879	1088465	1067164	1061826	1080828	1043184	1019076	986008	983301	995337
Indirectly acting greenhouse gases												
NOx (as NO_2)	2729	2514	2323	2208	2055	1984	1897	1784	1675	1619	1584	1592
NMVOC	3221	2796	2539	2326	2158	2020	1892	1823	1735	1663	1605	1606
CO	11213	9515	8351	7704	7065	6532	6109	5955	5424	5143	4768	4797
Aerosol precursor												
SO_2	5321	3996	3307	2945	2473	1939	1340	1039	835	738	638	650
* Preliminary data												

<Legende>:

Emissions of greenhouse gases and of SO2 in Germany

Data in Gf (HFC, CF4, C2F6 and SF6 in Mg)

Table 4 summarises the total emissions of direct and indirect greenhouse gases and emissions of the acid-forming SO_2 ascertained for this inventory. The associated annual progress over time compared with the base year of the Kyoto Protocol and 1990 is depicted in Table 5. 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, the emission of greenhouse gases calculated as CO_2 equivalent emission was down by 18.3 % compared with the base year. The associated reduction trend compared with the status of the previous year (in 2000 the reduction was almost 20 %) is attributable to the climatic conditions in the year 2001. As weather conditions were particularly cold compared with the trend since 1990, more energy was needed – with the associated emissions –in order to generate heat.

Table 5 Changes in emissions compared with the base year of the Kyoto Protocol

Development of emissions in Germany compared with the base year														
	Base year	absolute	%	1991 +/- %	1992 +/- %	1993 +/- %	1994 +/- %	1995 +/- %	1996 +/- %	1997 +/- %	1998 +/- %	1999 +/- %	2000 * +/- %	2001 * +/- %
Directly acting greenhouse gases														
CO2	1990	1014439	100.0	-3.8	-8.5	-9.5	-10.9	-11.4	-9.2	-12.3	-13.1	-15.7	-15.4	-14.2
CH4	1990	4813	100.0	-9.9	-16.9	-23.2	-27.6	-31.0	-34.8	-36.8	-39.7	-41.3	-46.0	-48.4
N2O	1990	284	100.0	-5.4	-4.3	-8.4	-11.7	-10.6	-8.8	-13.9	-29.2	-32.9	-32.5	-31.5
HFC	1995	2591	100.0					0.0	10.6	26.5	40.6	49.1	59.3	138.5
CF4	1995	224	100.0					0.0	-4.2	-27.9	-23.0	-38.9	-67.8	-69.0
C2F6	1995	32	100.0					0.0	5.0	-1.0	4.1	-3.7	-25.7	-43.4
C3F8	1995	1	100.0					0.0	131.7	310.7	547.6	774.7	1136.1	1165.1
SF6	1995	278	100.0					0.0	-4.1	-5.4	-9.0	-33.4	-39.4	-49.9
CO2-equivalent emission		1218170	100.0	-4.8	-9.1	-10.6	-12.4	-12.8	-11.3	-14.4	-16.3	-19.1	-19.3	-18.3
Indirectly acting greenhouse gases														
NOx (as NO2)		2729	100.0	-7.9	-14.9	-19.1	-24.7	-27.3	-30.5	-34.6	-38.6	-40.7	-41.9	-41.7
NMVOC		3221	100.0	-13.2	-21.2	-27.8	-33.0	-37.3	-41.3	-43.4	-46.1	-48.4	-50.2	-50.1
CO		11213	100.0	-15.1	-25.5	-31.3	-37.0	-41.7	-45.5	-46.9	-51.6	-54.1	-57.5	-57.2
Aerosol precursor														
SO2		5321	100.0	-24.9	-37.9	-44.7	-53.5	-63.6	-74.8	-80.5	-84.3	-86.1	-88.0	-87.8

* Preliminary data

Table 6 Change in emissions compared with the previous year

Development of emissions in Germany since 1990 (percentage change compared with the previous year and 2001/base year)													
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000 *	2001 *	2001 / base year
Directly acting greenhouse gases													
CO2	1014439	-3.8	-4.9	-1.1	-1.5	-0.6	2.5	-3.4	-0.9	-3.0	0.4	1.5	-14.2
CH4	5308	-9.9	-7.7	-7.7	-5.7	-4.6	-5.5	-3.1	-4.6	-2.7	-8.0	-4.4	-48.4
N2O	283	-5.4	1.2	-4.2	-3.6	1.2	2.1	-5.6	-17.8	-5.2	0.6	1.5	-31.5
HFC	200	1.1	33.5	-25.3	-0.1	756.7	10.6	14.3	11.2	6.0	6.9	49.7	138.5
CF4	355	-13.3	-9.7	-6.5	-17.7	4.5	-4.2	-24.7	6.7	-20.7	-47.3	-3.6	-69.0
C2F6	42	-8.4	-6.5	-2.8	-11.4	4.2	5.0	-5.7	5.1	-7.4	-22.9	-23.8	-43.4
C3F8	-	-	-	-	-	-	131.7	77.3	57.7	35.1	41.3	2.3	1165.1
SF6	163	11.7	12.1	10.8	7.5	14.2	-4.1	-1.3	-3.8	-26.9	-9.0	-17.2	-49.9
CO2-equivalent emission	1213500	-4.4	-4.6	-1.7	-2.0	-0.5	1.8	-3.5	-2.3	-3.2	-0.3	1.2	-18.3
Indirectly acting greenhouse gases													
NOx (as NO2)	2706	-7.9	-7.6	-5.0	-6.9	-3.4	-4.4	-6.0	-6.1	-3.4	-2.1	0.5	-41.7
NMVOC	3221	-13.2	-9.2	-8.4	-7.2	-6.4	-6.3	-3.7	-4.8	-4.2	-3.5	0.1	-50.1
CO	11213	-15.1	-12.2	-7.7	-8.3	-7.5	-6.5	-2.5	-8.9	-5.2	-7.3	0.6	-57.2
Aerosol precursor													
SO2	5321	-24.9	-17.2	-10.9	-16.0	-21.6	-30.9	-22.5	-19.7	-11.6	-13.6	1.9	-87.8

* Preliminary data

The reasons behind the outlined trend in 2001 likewise applied to the deviant development in the year 1996, when the use of fossil fuels likewise increaseddue to the prevailing weather conditions. This is also illustrated by Table 6 below.

2.1 Description and interpretation of emission trends for aggregated greenhouse gas emissions

By the year 2001, the aforementioned obligation to reduce greenhouse gas emissions within the context of EU burden sharing (Germany's share: - 21 %) had already been largely met, with a decrease of more than 18 %. The individual greenhouse gases contributed to this development to varying degrees (cf. 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.

The release of carbon dioxide from the processes of stationary and mobile combustion is by far the single largest cause of emissions, accounting for more than 87 % of greenhouse gas emissions. In particular, due to the above-average decrease in other components, the proportion of CO2 emissions amongst total greenhouse gases has increased from just under 84 % to more than 87 % since 1990. Emissions of methane caused by animal husbandry, fuel distribution and landfill emissions together account for just over 5 %. Emissions of dinitrogen oxide, caused primarily by agriculture, industrial processes and transport, account for more than 6 % of greenhouse gas releases. The remaining so-called Kyoto or F gases together account for just over 1 % of such emissions. The distribution of greenhouse gas emissions calculated here is typical of a developed industrialised country.

2.2 Description and interpretation of emission trends by gas

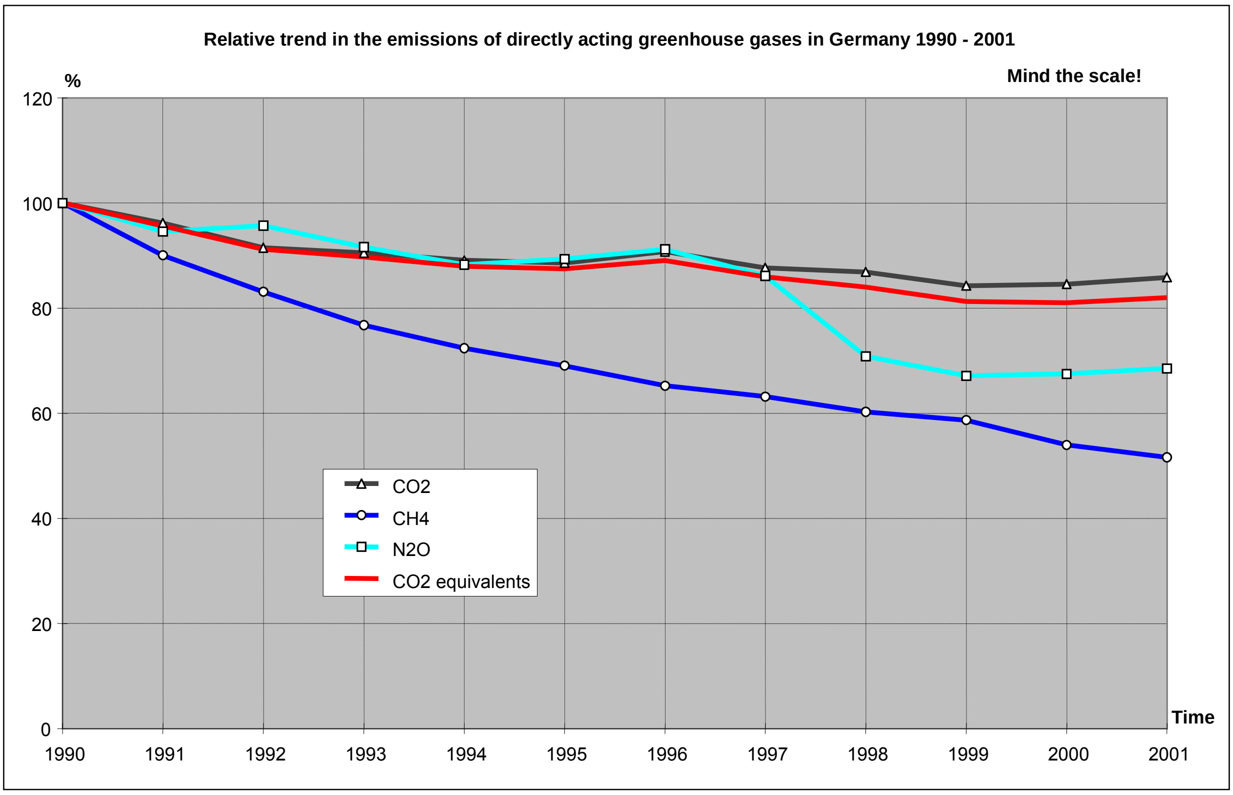
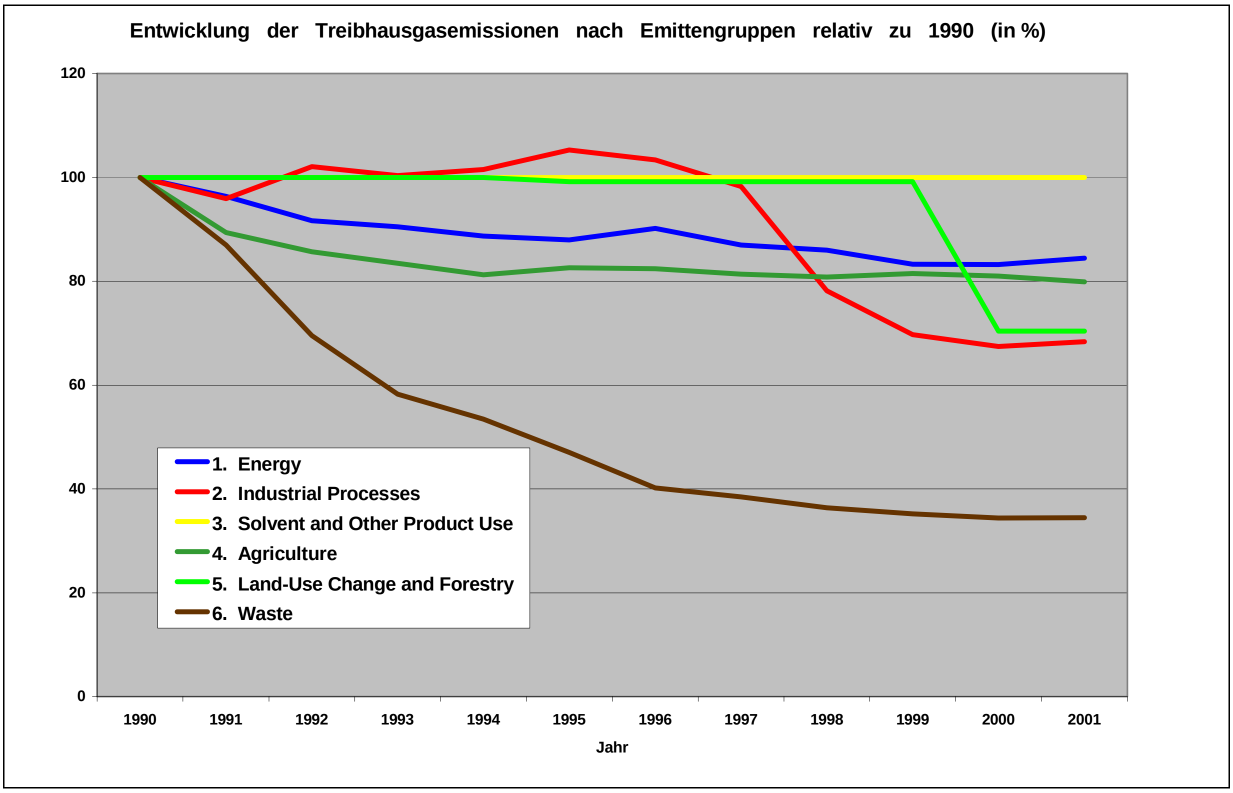


Figure 6 Relative development of greenhouse gases compared with 1990

Figure 6 shows the relative development of emissions of the individual greenhouse gases since 1990. When discussing these trends, it is important to remember that the development of each of these greenhouse gases tends to be dominated by specific development in a given source category. The reduction in CO_2 emissions is closely linked to development in the energy sector. In the area of N_2O emissions, the development of emission reductions in industry, particularly the production of adipic acid, determines the trend. In this respect, in 1997 producers in Germany completed the process of upgrading production with secondary reduction techniques. The reductions in methane emissions are closely linked to the development of agricultural livestock populations as well as the decline in landfill emissions.

2.3 Description and interpretation of emission trends by source



<Legende>: Development of greenhouse gas emissions according to emitter categories compared with 1990 (in %)

Year

Figure 7: Relative development of greenhouse gases according to emitter categories and sinks compared with 1990

In this case, the most significant reduction occurred in the area of waste emissions. Despite the many methodological difficulties (cf. chapters 8.1 and 8.2), the introduction of more widespread recycling of recyclable materials (yellow sack, Packaging Ordinance etc.) has led to a reduction in the field of landfill emissions in particular. In the area of emissions from industrial processes, emission-reducing measures in the field of adipic acid production in 1997 had a very pronounced reducing effect. Emissions from solvent and other product use are not particularly high in absolute terms; the constancy of these emissions is attributable to the updating of the figure for the narcotic use of N_2O calculated for 1990. The trend in emissions from agriculture essentially follows the development of livestock figures.

Emissions from the LULUCF sector are given as 5-year averages (1990 to 1994, 1995 to 1999, both very similar in terms of level). At present, the figure published since the year 2000 only represents a 2-year average. The sharp decrease in the year 2000 is attributable to windthrow caused by hurricane "Lothar".

2.4 Description and interpretation of emission trends for indirect greenhouse gases and SO_2

The relative trend in emissions of indirect greenhouse gases and SO_2 are illustrated in Figure 8 and are quantified in detail in Table 7 (for SO_2), Table 8 (for NO_X), Table 9 (for CO) and Table 10 (for NMVOC), each in the form of time series since 1990. 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 88 %, those of CO by 57 %, those of NMVOCs by almost 50 % and those of NO_X by 42 %.

The reasons for this development are more or less effective for all the components considered here.

- As a result of Germany's reunification in 1990, emissions from the territory of the former GDR in particular meant that the starting level was comparatively high.
- In subsequent years, outmoded and ineffective industrial plant in eastern Germany was shut down, and for the most part replaced with state-of-the-art new plant.
- 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, initially, the immission protection legislation provisions of the former Federal Republic of Germany have been applied in the east. Once provisional rulings had expired, valid law has been adapted a number of times in line with the latest state of the art.
- International legislation, particularly from the European Community, has likewise had an emission-reducing effect (e.g. the NEC Directive).

Descriptions of the emission calculations for these pollutants and further detailed parameters influencing the emission trends of the individual air pollutants may be found on the website of the Federal Environmental Agency. In future, an inventory report is to be drafted within the context of the Geneva Convention on Long-Range Transboundary Air Pollution, which regulates these pollutants amongst others, which will publish all this information in a comparative format (the first edition is scheduled for publication in 2005).

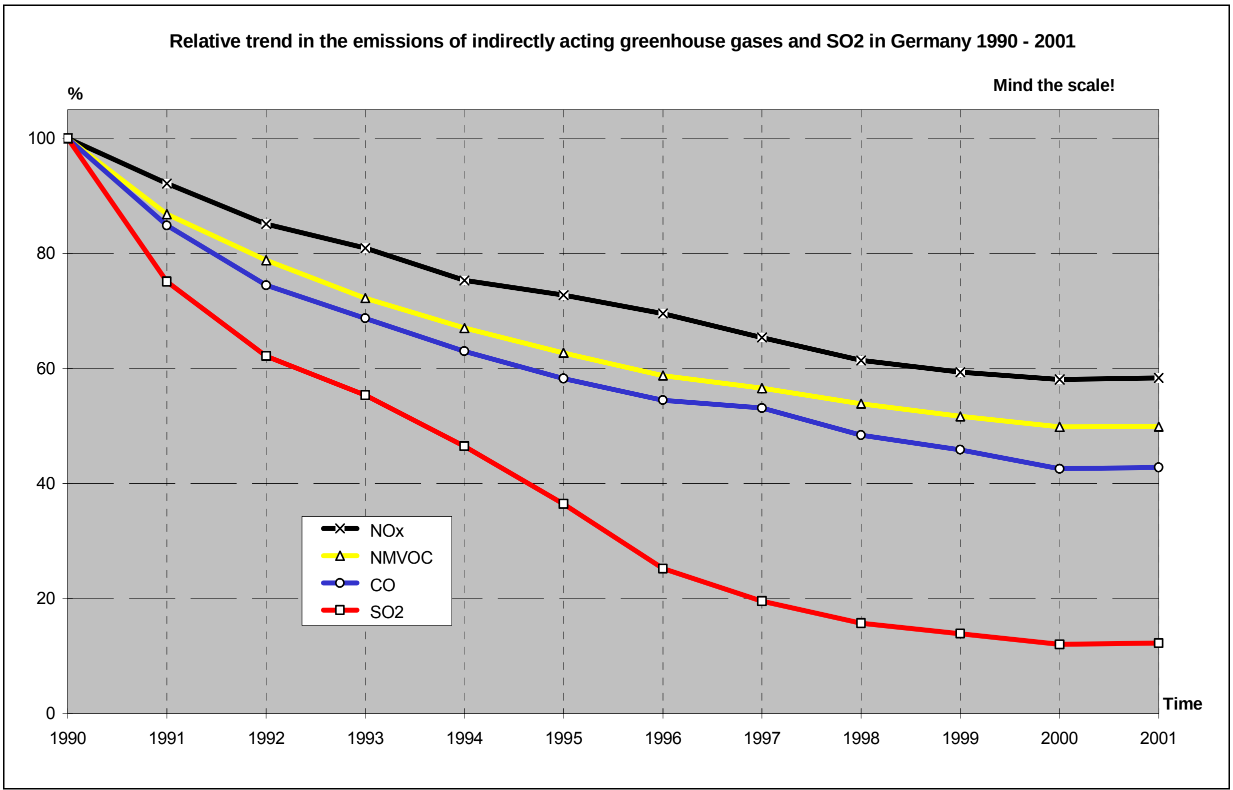


Figure 8 Relative trend in emissions of indirect greenhouse gases and of SO_2

Table 7 Development of SO_2 emissions in Germany since 1990

Germany SO_2 (Preliminary data for 1996 - 2001)

GREENHOUSE GAS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
SOURCE AND SINK CATEGORIES							(Gg)					
Total Emissions	**5321**	**3996**	**3307**	**2945**	**2473**	**1939**	**1340**	**1039**	**835**	**738**	**638**	**650**
1 Energy	**5264**	**3938**	**3251**	**2894**	**2423**	**1882**	**1286**	**983**	**778**	**681**	**582**	**594**
A Fuel Combustion (Sectoral Approach)	5095	3906	3223	2865	2396	1855	1261	959	755	660	561	573
1 Energy Industries	3078	2591	2249	2058	1767	1267	808	550	390	350	***306***	***326***
2 Manufacturing Industries and Construction	994	644	489	369	272	342	261	242	218	193	***158***	***150***
3 Transport	100	70	73	77	77	76	41	32	32	30	***21***	***21***
4 Other Sectors	852	556	383	344	272	169	150	***134***	***114***	***86***	***75***	***75***
5 Other (Military)	71	45	29	17	8	2	1	1	1	1	1	1
B Fugitive Emissions from Fuels	169	32	28	29	27	27	25	24	23	22	20	20
1 Solid Fuels	142	1	1	1	1	1	1	1	1	0	0	0
2 Oil and Natural Gas	27	30	27	28	26	27	25	24	22	21	20	20
2 Industrial Processes	**57**	**58**	**56**	**51**	**50**	**57**	**54**	**56**	**57**	**57**	**56**	**56**
A Mineral Products	11	13	13	12	13	14	14	14	14	15	15	15
B Chemical Industry	26	25	24	22	21	25	23	23	24	25	25	25
C Metal Production	18	18	17	16	16	17	17	17	18	17	16	16
3 Solvent and Other Product Use	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
4 Agriculture	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
5 Land-Use Change & Forestry	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
6 Waste	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
7 Other (please specify)	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
Memo Items *)												
International Bunkers	**130**	**111**	**91**	**115**	**106**	**103**	**97**	**105**	**102**	**106**	**106**	**106**
Aviation	4	4	4	4	4	1	1	1	1	1	1	1
Marine	126	107	87	111	102	102	96	104	101	105	105	105
Multilateral Operations	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass												

Table 8 Development of NOx emissions in Germany since 1990

Germany Nox (Preliminary data for 1996 - 2001)

GREENHOUSE GAS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
SOURCE AND SINK CATEGORIES	(Gg)											
Total Emissions	2729	2514	2323	2208	2055	1984	1897	1784	1675	1619	1584	1592
1 Energy	2675	2469	2284	2174	2024	1951	1866	1753	1644	1586	1551	1559
A Fuel Combustion (Sectoral Approach)	2675	2469	2284	2174	2024	1951	1866	1753	1644	1586	1551	1559
1 Energy Industries	603	534	458	405	351	326	315	286	274	253	265	272
2 Manufacturing Industries and Construction	355	306	270	251	242	244	232	232	215	209	163	159
3 Transport	1420	1359	1315	1272	1196	1151	1082	1022	982	968	1000	1000
4 Other Sectors	249	241	215	223	213	209	223	200	160	145	113	118
5 Other (Military)	49	29	26	23	22	22	13	13	13	11	10	10
B Fugitive Emissions from Fuels	0	0	0	0	0	0	0	0	0	0	0	0
1 Solid Fuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2 Oil and Natural Gas	0	0	0	0	0	0	0	0	0	0	0	0
2 Industrial Processes	31	24	19	15	14	15	13	13	13	13	13	13
A Mineral Products	6	7	6	5	5	6	6	6	6	6	6	6
B Chemical Industry	23	15	11	8	7	7	6	5	5	4	4	4
C Metal Production	2	2	2	2	2	2	2	2	2	2	2	2
3 Solvent and Other Product Use	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4 Agriculture	22	21	20	19	17	18	18	18	19	20	21	21
5 Land-Use Change & Forestry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
6 Waste	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
7 Other (please specify)	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Memo Items *)												
International Bunkers	206	182	165	198	191	196	200	213	210	218	222	222
Aviation	51	51	56	61	65	69	73	78	82	88	92	92
Marine	155	131	109	137	126	127	127	135	128	130	130	130
Multilateral Operations	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
CO_2 Emissions from Biomass												

Table 9 Development of CO emissions in Germany since 1990

Germany CO (Preliminary data for 1996 - 2001)

GREENHOUSE GAS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
SOURCE AND SINK CATEGORIES	(Gg)											
Total Emissions	11213	9515	8351	7704	7065	6532	6109	5955	5424	5143	4768	4797
1 Energy	10531	8876	7760	7151	6484	5925	5551	5359	4855	4593	4206	4229
A Fuel Combustion (Sectoral Approach)	10484	8836	7730	7133	6472	5914	5540	5348	4845	4584	4197	4219
1 Energy Industries	179	161	145	136	133	119	117	110	108	103	102	104
2 Manufacturing Industries and Construction	828	741	692	647	702	708	686	698	629	623	663	657
3 Transport	6767	5893	5246	4783	4184	3937	3636	3313	3039	2800	2452	2395
4 Other Sectors	2589	1964	1576	1505	1392	1094	1058	1185	1027	1025	945	1029
5 Other (Military)	122	77	72	62	60	57	43	44	42	34	36	34
B Fugitive Emissions from Fuels	47	40	30	18	12	11	11	11	10	9	9	9
1 Solid Fuels	20	17	15	12	11	11	11	11	10	9	9	9
2 Oil and Natural Gas	27	23	15	6	1	0	0	0	0	0	0	0
2 Industrial Processes	682	639	591	553	581	606	558	596	569	550	561	568
A Mineral Products	0	0	0	0	0	0	0	0	0	0	0	0
B Chemical Industry	2	2	2	1	1	1	1	1	1	1	1	1
C Metal Production	681	637	589	552	580	605	557	595	568	549	560	567
3 Solvent and Other Product Use	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4 Agriculture	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
5 Land-Use Change & Forestry	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
6 Waste	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
7 Other (please specify)	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Memo Items *)												
International Bunkers	94	87	87	98	98	102	106	111	113	119	124	124
Aviation	57	56	61	65	68	71	75	79	82	88	92	92
Marine	37	31	26	33	30	31	30	32	31	31	31	31
Multilateral Operations	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
CO_2 Emissions from Biomass												

Table 10 Development of NMVOC emissions in Germany since 1990

Germany	NMVOC					(Preliminary data for 1996 - 2001)						
GREENHOUSE GAS	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
SOURCE AND SINK CATEGORIES	(Gg)											
Total Emissions	**3221**	**2796**	**2539**	**2326**	**2158**	**2020**	**1892**	**1823**	**1735**	**1663**	**1605**	**1606**
1 Energy	**1971**	**1577**	**1363**	**1149**	**973**	**874**	**787**	**712**	**632**	**552**	**487**	**488**
A Fuel Combustion (Sectoral Approach)	1688	1328	1138	986	837	749	673	611	541	471	416	416
1 Energy Industries	8	8	7	7	7	7	7	6	6	6	*6*	*6*
2 Manufacturing Industries and Construction	12	10	9	8	9	8	8	8	8	7	*7*	*7*
3 Transport	1486	1172	1006	858	714	647	576	500	441	383	*334*	*334*
4 Other Sectors	160	128	107	105	99	79	77	*90*	*80*	*70*	*64*	*64*
5 Other (Military)	22	10	9	8	8	8	5	5	5	4	4	4
B Fugitive Emissions from Fuels	283	249	225	163	136	125	114	102	92	81	71	72
1 Solid Fuels	6	5	4	3	2	2	2	2	2	1	1	1
2 Oil and Natural Gas	277	244	221	160	134	124	112	100	90	80	70	71
2 Industrial Processes	**90**	**85**	**86**	**87**	**95**	**95**	**95**	**100**	**103**	**112**	**118**	**118**
A Mineral Products	0	0	0	0	0	0	0	0	0	0	0	0
B Chemical Industry	60	55	57	58	65	65	64	69	71	80	85	85
C Metal Production	3	3	2	2	2	2	2	2	2	2	2	2
3 Solvent and Other Product Use	**1160**	**1134**	**1090**	**1090**	**1090**	**1050**	**1010**	**1010**	**1000**	**1000**	**1000**	**1000**
4 Agriculture	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
5 Land-Use Change & Forestry	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
6 Waste	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
7 Other (please specify)	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
Memo Items *)												
International Bunkers	**25**	**22**	**21**	**23**	**23**	**24**	**24**	**25**	**25**	**26**	**27**	**27**
Aviation	9	9	10	10	11	11	12	12	12	13	14	14
Marine	15	13	11	13	12	12	12	13	13	13	13	13
Multilateral Operations	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
CO_2 Emissions from Biomass												

3 ENERGY (CRF SECTOR 1)

3.1 Overview of sector

3.1.1 Methodological issues: The Federal Energy Balance

In the Federal Republic of Germany, energy statistics are published by numerous agencies, some of which differ in terms of their representation, delimitation and aggregation. Against this background, in the early Seventies, associations of the Germany energy industry together 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 self-contained 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 meaningfulness. They therefore form the basis for the calculation of energy-induced emissions, scenarios and forecasts on the effects of energy policy and environmental policy measures.

The energy balance is prepared by the Working Group on Energy Balances (AGEB), whose members, apart from the associations of the energy industry, also include energy industry research institutes. The members of the 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. <*German Electricity Association*>, Frankfurt am Main,
- Verband der Industriellen Energie- and Kraftwirtschaft e.V. (VIK) <*Association of the Energy and Power Generation Industry*>, 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.

In 1994, the Working Group on Energy Balances (AGEB) transferred responsibility for the preparation of energy balances for Germany to the DIW. Until that date, energy balances were prepared by the General Association of the German Hard Coal Industry (GVSt) in Essen.

The principal sources are listed in Table 11. The table shows that both official (e.g. Federal Statistical Office) and semi-official (e.g. statistics from the coal industry) reporting plays a key role. However, not all components may be determined through these channels. For this reason, statistics from the associations are additionally used. In a number of cases, furthermore, personal expert opinions are used in a number of cases, e.g. to represent non-energetic consumption by the chemicals industry. In future, it is hoped that the Energy Statistics Act, which came into force in 2003, will effect an improvement in the data situation.

Overall responsibility for the preparation of energy balances lies with the German Institute for Economic Research (DIW) in Berlin starting with the balance year 1995, although the Association of the German Petroleum Industry (MMW) supplies the mineral oil data and the other associations represented in the AGEB check the data, particularly when it refers to their own particular energy carriers. Overall, with due regard for the data actually available, the energy balances provide a reliable picture of energy volume structures according to their incidence and use in the German economy.

All energy resources	**Federal Ministry of Economics and Employment (BMWA)** Electricity Industry Department – Annual statistical reports Gas Industry Department – Annual statistical reports (until 1997) **Federal Statistical Office** Annual figures for the manufacturing industry Specialist series 4 Manufacturing Industry - Series 3.1 Production in the manufacturing industry - Series 4.1.1 Employment, turnover and energy supplies of mining and manufacturing companies - Series 6.4 Power generation facilities of mining and manufacturing companies Specialist series 7 Foreign Trade - Series 2 Foreign trade by types of goods and countries Selected figures on the energy industry **Verband der Elektrizitätswirtschaft- VDEW - e.V.** *<Electricity Industry Association>* 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	**Statistics from the Kohlenwirtschaft e.V.** *<Coal Industry Association>* 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 (BAFA)** 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 **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>*

Table 11: Data sources for the energy balances (source: Ziesing et al., 2003)

3.1.1.1 Structure of the energy balances

The energy balances provide an overview of the interrelations within the energy industry in matrix format. As such, not only do they permit conclusions to be drawn regarding the consumption of energy resources in the individual sectors; what is more, they also provide information on their flow from production to use in the various generation, transformation and consumption areas (cf. Figure 9). The ***primary energy balance*** outlines

- Indigenous production
- imports
- stock depletionexports
- international marine bunkers
- stock build-up

of energy resources and summarises these into ***primary energy consumption*** (cf. Figure 9, top left). The primary energy balance forms the basis for calculations under the IPCC Reference Approach. The ***consumption balance*** (cf. Figure 9, centre to bottom left and right) is decisive for preparation of the emissions inventory. Primary energy consumption may also be determined from the consumption balance. It comprises

1. the transformation balance
2. flaring and transmission losses
3. non-energy consumption, and
4. final energy consumption.

Differences between the primary energy balance and the consumption balance are compensated via the item “statistical differences”.

The ***transformation balance***, as a component of the consumption balance, indicates which energy resources are converted into other energy resources. The transformation output indicates the result of this transformation process. The transformation of energy may be of a material nature, such as the transformation of crude oil (transformation input) into mineral oil products (transformation output), or it may be of a physical nature, e.g. via the combustion of hard coal (transformation input) in power stations to generate electrical energy (transformation output). Energy consumption in the transformation sector indicates how much energy is needed to operate the transformation plant (own consumption by the transformation sector). The transformation balance is differentiated according to 12 plant types (cf. Figure 9, centre left).

Primärenergiebilanz		Gewinnung im Inland
		Einfuhr
		Bestandsentnahmen
		Energieaufkommen im Inland
		Ausfuhr
		Hochseebunkerungen
		Bestandsaufstockungen
		Primärenergieverbrauch im Inland
Umwandlungsbilanz	Umwandlungseinsatz	Kokereien
		Stein- und Braunkohlenbrikettfabriken
		Öffentliche Wärmekraftwerke
		Industriewärmekraftwerke
		Kernkraftwerke
		Wasserkraftwerke, Wind- und Photovoltaikanlagen
		Öffentliche Heizkraftwerke
		Fernheizwerke
		Hochöfen
		Raffinerien
		Sonstige Energieerzeuger
		Umwandlungseinsatz insgesamt
	Umwandlungsausstoß	Kokereien
		Stein- und Braunkohlenbrikettfabriken
		Öffentliche Wärmekraftwerke (ohne HKW)
		Industriewärmekraftwerke
		Kernkraftwerke
		Wasserkraftwerke, Wind- und Photovoltaikanlagen
		Öffentliche Heizkraftwerke
		Fernheizwerke
		Hochöfen
		Raffinerien
		Sonstige Energieerzeuger
		Umwandlungsausstoß insgesamt
	Verbrauch in der Energiegewinnung und in den Umwandlungsbereichen	Kokereien
		Steinkohlenzechen, -brikettfabriken
		Braunkohlengruben, -brikettfabriken
		Kraftwerke
		Erdöl- und Erdgasgewinnung
		Raffinerien
		Sonstige Energieerzeuger
		E.-Verbrauch im Umwandl.-Bereich insgesamt
		Fackel- u. Leitungsverluste
		Energieangebot im Inland n.Umwandlungsbilanz
		Nichtenergetischer Verbrauch
		Statistische Differenzen

Endenergieverbrauch		**Endenergieverbrauch**
	nach Sektoren	Gewinnung von Steinen und Erden, sonst. Bergbau
		Ernährung und Tabak
		Papiergewerbe
		Grundstoffchemie
		Sonstige chemische Industrie
		Gummi- u. Kunststoffwaren
		Glas u. Keramik
		Verarbeitung v. Steine u. Erden
		Metallerzeugung
		NE-Metalle, -gießereien
		Metallbearbeitung
		Maschinenbau
		Fahrzeugbau
		Sonstige Wirtschaftszweige
		Übriger Bergbau u. Verarbeit. Gewerbe insg.
		Schienenverkehr
		Straßenverkehr
		Luftverkehr
		Küsten- und Binnenschiffahrt
		Verkehr insgesamt
		Haushalte
		Gewerbe, Handel, Dienstleistungen u.übr. Verbraucher
		Haushalte, Gewerbe, Handel und Dienstleistungen

<Legende>

Primary energy balance

- Indigenous production
- Imports
- Stock depletion
- Indigenous energy supply
- Exports
- International marine bunkers
- Stock build-up
- Indigenous primary energy consumption

Transformation balance

- Transformation input
  - Coke ovens
  - Hard coal and lignite briquette plants
  - Public thermal power plants
  - Industrial heat plants
  - Nuclear power plants
  - Hydro, wind and photovoltaic plants
  - Public heat plants

District heat plants
Blast furnaces
Refineries
Other energy producers
Total transformation input
Transformation output
Coke ovens
Hard coal and lignite briquette plants
Public thermal power plants
Industrial heat plants
Nuclear power plants
Hydro, wind and photovoltaic plants
Public heat plants
District heat plants
Blast furnaces
Refineries
Other energy producers
Total transformation output
Consumption in energy production and in transformation areas
Coke ovens
Hard coal pit and briquette plants
Lignite pit and briquette plants
Power plants
Crude oil and natural gas production
Refineries
Other energy producers
Total energy consumption in transformation areas
Flaring and distribution losses
Indigenous energy supply after transformation balance
Non-energy consumption
Statistical differences

Energy consumption

According to sectors
Final energy consumption
Quarrying, other mining
Food and tobacco
Paper industry
Basic chemicals
Other chemical industry
Rubber and plastic goods
Glass and ceramics
Processing of non-metallic minerals
Metal production
Non-ferrous metals, foundries
Metal processing
Mechanical engineering
Vehicle construction
Other sectors
Other mining and manufacturing industry, total
Rail traffic
Road traffic
Air traffic
Coastal and inland shipping
Total traffic
Households
Commerce, trade, services and other consumers
Households, commerce, trade and services

Figure 9: Line structure of energy balances from 1995 onwards (source: Ziesing et al., 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 (cf. Figure 9).

3.1.1.2 Energy resources in the Federal Energy Balance

Energieträgerstruktur in den Energiebilanzen ...

bis einschl. 1994

Steinkohlen	SK-Kohle
	SK-Koks
	SK-Briketts
	SK-Rohteer
	SK-Pech
	SK-Andere
	Rohbenzol
Braunkohlen	BK-Kohle
	BK-Briketts
	BK-Koks
	BK-Staubk.
	BK-Hartk.
Sonstige feste Brennstoffe	Brennholz
	Brenntorf
	Klär.-Müll
Mineralöle	Erdöl
	Mot.benzin
	Rohbenzin
	Flugbenz.
	Schw. Flkr.
	Diesel
	Heizöl, l.
	Heizöl, s.
	Petrolkoks
	MIN-And.
Gase	Flüssiggas
	Raffgas
	Kokereigas
	Gichtgas
	Erdgas
	Erdölgas
	Grubengas
	Klärgas
Elektr. Strom und andere Energieträger	Strom
	Wasserkr.
	Kernenergie
	Fernwärme
	Sonstige ET
Energieträger insgesamt	Primär-ET
	Sekundär-ET
	Summe

von 1995 an

Steinkohlen	SK-Kohle
	SK-Briketts
	SK-Koks
	Andere SK-Produkte
Braunkohlen	BK-Kohle
	BK-Briketts
	Andere BK-Produkte
	Hartbraunkohle
Mineralöle	Erdöl
	Ottokraftstoff
	Rohbenzin
	Flugturbinenkraftstoff
	Dieselkraftstoff
	Heizöl leicht
	Heizöl schwer
	Petrolkoks
	Flüssiggas
	Raffineriegas
	Andere Mineralölprodukte
Gase	Kokerei- u. Stadtgas
	Gichtgas u. Konvertergas
	Erdgas, Erdölgas
	Grubengas
Erneuerbare Energien	Wasserkraft
	Wind- u. Photovolatikanlagen
	Müll und sonstige Biomassen
	Sonst. Erneuerb. Energien
Elektr. Strom und andere Energieträger	Strom
	Kernenergie
	Fernwärme
Energieträger insgesamt	Primär-ET-
	Sekundär-ET
	Summe

<Legende>

Energy resource structure in the energy balances
Up to and including 1994

- Hard coal
  - Hard coal
  - Hard coal coke
  - Hard coal briquettes
  - Hard coal crude tar
  - Hard coal pitch
  - Hard coal other
  - Crude benzene
- Lignite
  - Crude lignite
  - Lignite briquettes
  - Lignite coke
  - Pulverised and dry coal
  - Hard lignite
- Other solid fuels
  - Firewood
  - Peat
  - Sewage waste
- Mineral oils
  - Petroleum
  - Motor gasoline
  - Crude benzene
  - Kerosene
  - Heavy fuel oil
  - Diesel
  - Light heating oil
  - Heavy heating oil
  - Petroleum coke
  - Other petroleum products
- Gases
  - LPG
  - Refined gas
  - Coke oven gas
  - Blast furnace gas
  - Natural gas
  - Petroleum gas
  - Firedamp
  - Sewage gas
- Electrical power and other energy resources
  - Electricity
  - Hydropower
  - Nuclear power
  - District heating
  - Other energy resources
- Total energy resources
  - Primary energy resources
  - Secondary energy resources
  - Total

from 1995 onwards

- Hard coal
  - Hard coal
  - Hard coal briquettes
  - Hard coal coke
  - Other hard coal products
- Lignite
  - Lignite coal
  - Lignite briquettes
  - Other lignite products
  - Hard lignite

Mineral oils
- Petroleum
- Gasoline
- Crude benzene
- Kerosene
- Diesel fuel
- Light heating oil
- Heavy heating oil
- Petroleum coke
- LPG
- Refinery gas
- Other mineral oil products

Gases
- Coke oven and town gas
- Blast furnace gas and converter gas
- Natural gas, petroleum gas
- Firedamp

Renewable energy resources
- Hydropower
- Wind and photovoltaic plants
- Waste and other biomass
- Other renewable energy resources

Electrical power and other energy resources
- Electricity
- Nuclear power
- District heating

Total energy resources
- Primary energy resources
- Secondary energy resources
- Total

Figure 10: Energy resource structures in the energy balances up to 1994 and from 1995 onwards (source: 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
- Mineral oil (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

(cf. Figure 10). The renewable energy resources may be further subdivided via a satellite balance.

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 the joules (J) unit using calorific value tables and conversion factors. Unlike with gas statistics or international energy balances, in the energy balance even gases are quoted in terms of calorific value.

3.1.2 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 conversions with the underlying statistics, energy industry transformation, and the altered requirements of data users. As early as the Seventies, corresponding adjustments were implemented, partly as a result of the growing liberalisation on the energy markets, but also in conjunction with the formation of a single European market, the energy statistical database was tending to deteriorate (and it was not alone) (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 segments (edition 1993, WZ 93), since 1995 only one energy balance has been submitted for Germany as a whole (in the territorial delimitation of 3 October 1990). The most recent energy balance is available for the year 1999.

3.1.2.1 The balance year 1990 and the energy balances for 1991 to 1994

The base year 1990 plays a key role for national emissions inventories, but particularly for the temporal reference of the agreed climate protection policy emission reduction targets. For Germany, admittedly, this is linked to the problem that – viewed over the entire year 1990 – there was no uniform national territorial status. The radical collapses, including the economic collapse, and the fundamental organisational/structural problems in the territory of the GDR and the new *Länder*, made the opportunities for collating energy statistics in eastern Germany substantially more difficult in 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, and later the new *Länder*, the *Institut für Energetik* (Institute of Energetics, IfE) in Leipzig undertook to prepare an energy balance for 1990 based on a system compatible with the west German balances, and to provide a detailed account of the data used for this purpose.[5] In this respect, the Institute had access to a study which had previously aimed to formulate corresponding energy balances for the GDR and for the years from 1970 to 1989 under the auspices of the DIW Berlin and others.[6]

For the new energy balances prepared within the context of a project (object number: 0108/02624272) for the year 1990 and for Germany as a whole, those of the AGEB for the old *Länder* and those of the IfE for the new *Länder* have been aggregated. The following amendments were implemented to the original balances for 1990 and for the years 1991 to 1994 in accordance with the system valid from 1995 onwards (cf. Ziesing et al., 2003):

[5] Cf. IfE Leipzig GmbH, *Energiebilanz 1990 für die neuen Bundesländer*. By Jochen Hesselbach with the assistance of Bernd Lemmnitz, Elke Lindner, Hans-Albert Müller and Ursula Zehrfeld. Study commissioned by the Federal Minister for the Economy. Leipzig, 13 November 1991

[6] Cf. Deutsches Institut für Wirtschaftsforschung <German Institute for Economic Research>, *Entwicklung des Energieverbrauchs and seiner Determinanten in der ehemaligen DDR*. By Hans-Joachim Ziesing. Study commissioned by the Federal Minister for the Economy. Sub-commissioned to: Institut für Energetik (IfE), Leipzig; Institut für Wirtschaftswissenschaften der Akademie der Wissenschaften, Berlin; Staatliche Vorratskommission für nutzbare Ressourcen der Erdkruste, Berlin. Berlin, April 1991.

In accordance with the approach adopted by international organisations (IEA, EUROSTAT, ECE), the so-called efficiency approach valid for the energy balances for Germany since 1995 was adopted instead of the substitution approach formerly used.

This approach applies to the valuation of energy resources for which there is no uniform conversion yardstick such as calorific value. This applies to foreign trade in electricity, hydropower and wind power, photovoltaics, and nuclear power.

The statistical differences shown separately in the energy balances for the old *Länder* for electrical power in the balances up to 1994 are now allocated objectively to the area of households and small consumers (new designation: trade, commerce, services).

The statistical differences in electrical power retransferred to the sector of households and small consumers refer to the following variables by which the sector's consumption is increased:

Data in GWh	1990	1991	1992	1993	1994
Allocation of the statistical differences in electrical energy to the households and small consumers sector	8658	13848	14748	16522	18682

In the absence of corresponding data, the differentiation of final energy consumption according to sectors in the manufacturing industry could not be adapted. As a result, the system changed significantly from 1995 onwards with the transition from the manufacturing industry's system (SYPRO) to the classification of industrial sectors, edition 1993 (WZ 93).

With the amendments outlined above, the energy balances for Germany and for the old and new *Länder* have been revised for all years from 1990 to 1994.

The DIW <German Institute for Economic Research> in Berlin believes that these energy balances may be viewed as the decisive energy statistical basis for determining energy-induced CO_2 emissions in Germany.

3.1.2.2 The energy balance from 1995 onwards

Primärenergiebilanz		Gewinnung im Inland
		Einfuhr
		Bestandsentnahmen
		Energieaufkommen im Inland
		Ausfuhr
		Hochseebunkerungen
		Bestandsaufstockungen
		Primärenergieverbrauch im Inland
Umwandlungsbilanz	Umwandlungseinsatz	Kokereien
		Ortsgaswerke
		Steinkohlenbrikettfabriken
		Braunkohlenbrikettfabriken
		öffentliche Wärmekraftwerke
		Zechen- und Grubenkraftwerke
		Sonstige Industriewärmekraftwerke
		Kernkraftwerke
		Wasserkraftwerke
		Heizkraftwerke, Fernheizwerke
		Hochöfen
		Raffinerien
		Sonstige Energieerzeuger
		Umwandlungseinsatz insgesamt
	Umwandlungsausstoß	Kokereien
		Ortsgaswerke
		Steinkohlenbrikettfabriken
		Braunkohlenbrikettfabriken
		öffentliche Wärmekraftwerke
		Zechen- und Grubenkraftwerke
		Sonstige Industriewärmekraftwerke
		Kernkraftwerke
		Wasserkraftwerke
		Heizkraftwerke, Fernheizwerke
		Hochöfen
		Raffinerien
		Sonstige Energieerzeuger
		Umwandlungsausstoß insgesamt
	Verbrauch in der Energiegewinnung und in den Umwandlungsbereichen	Steinkohlenzechen-, brikettfabriken
		Kokereien
		Ortsgaswerke
		Braunkohlengruben, -brikettfabriken
		Kraftwerke
		Erdöl- und Erdgasgewinnung
		Raffinerien
		Sonstige Energieerzeuger
		E.-Verbrauch im Umwandl.-Bereich insgesamt
	Fackel- u. Leitungsverluste, Bewertungsdiff.	
		Energieangebot im Inland n.Umwandlungsbilanz
		Nichtenergetischer Verbrauch
		Statistische Differenzen

Endenergieverbrauch	nach Sektoren	**Endenergieverbrauch**
		Übriger Bergbau
		Steine und Erden
		Eisenschaffende Industrie
		Eisen-, Stahl- und Tempergießereien
		Ziehereien und Kaltwalzwerke
		NE-Metallerzeug.,-halbzeugwerke,-gießereien
		Chemische Industrie
		Zellstoff-, Papier- und Pappeerzeugung
		Gummiverarbeitung
		Übriges Grundstoff- u.Produktionsgütergew.
		Grundstoff- und Produktionsgütergewerbe
		Maschinenbau
		Straßen-, Luft- und Raumfahrzeugbau
		Elektrotechnik, Feinmechanik, Optik
		Eisen-, Blech- und Metallwaren
		Übriges Investitionsgüter produz. Gewerbe
		Investitionsgüter produzierendes Gewerbe
		Glas und Feinkeramik
		Herstellung von Kunststoffwaren
		Textilgewerbe
		Übriges Verbrauchsgüter produz. Gewerbe
		Verbrauchsgüter produzierendes Gewerbe
		Zuckerindustrie
		Übriges Nahrungsmittelgewerbe
		Genußmittelgewerbe
		Nahrungs- und Genußmittelgewerbe
		Übriger Bergbau u. Verarbeit. Gewerbe insg.
		Schienenverkehr
		Straßenverkehr
		Luftverkehr
		Küsten- und Binnenschiffahrt
		Verkehr insgesamt
		Haushalte und Kleinverbraucher insgesamt
		Militärische Dienststellen

<Legende>:

Primary energy balance

Indigenous production
Imports
Stock depletion
Indigenous energy supply
Exports
International marine bunkers
Stock build-up
Indigenous primary energy consumption

Transformation balance

Transformation input

Coke ovens
Gas works
Hard coal briquette plants

- Lignite briquette plants
- Public thermal power plants
- Colliery power plants
- Other industrial CHP power plants
- Nuclear power plants
- Hydropower plants
- Heat plants, district heat plants
- Blast furnaces
- Refineries
- Other energy producers
- Total transformation input

Transformation output
- Coke ovens
- Gas works
- Hard coal briquette plants
- Lignite briquette plants
- Public thermal power plants
- Colliery power plants
- Other industrial heat plants
- Nuclear power plants
- Hydropower plants
- Public heat plants, district heat plants
- Blast furnaces
- Refineries
- Other energy producers
- Total transformation output

Consumption in energy extraction and in transformation areas
- Hard coal pit and briquette plants
- Coke ovens
- Gas works
- Lignite pit and briquette plants
- Power plants
- Crude oil and natural gas production
- Refineries
- Other energy producers
- Total energy consumption in transformation areas
- Flaring and distribution losses, assessment differences
- Indigenous energy supply acc. to transformation balance
- Non-energy consumption
- Statistical differences

Final energy consumption

According to sectors
- Final energy consumption
- Other mining
- Quarrying
- Iron-producing industry
- Iron, steel and malleable iron foundries
- Drawing plants and cold-rolling mills
- Non-ferrous metal and semi-finished production, foundries
- Chemical industry
- Paper, pulp and board
- Rubber processing
- Other basic materials and capital goods manufacturing
- Basic materials and capital goods manufacturing
- Mechanical engineering
- Road vehicle & aerospace industry
- Electrical engineering, precision mechanics, optics
- Iron, sheet-metal and metal goods
- Other capital goods manufacturing
- Capital goods manufacturing
- Glass and fine ceramics
- Manufacture of plastic goods

Textiles industry
Other consumer goods manufacturing
Consumer goods manufacturing
Sugar industry
Other food industry
Luxury goods industry
Other mining and producessing industry, total
Rail traffic
Road traffic
Air traffic
Coastal and inland shipping
Total traffic
Total households and small consumers
Military offices

Figure 11: Line structure of energy balances up to and including 1994 (source: Ziesing et al., 2003)

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 (sectors) in the energy balance matrix (cf. also chapter 3.1.2.1). 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*. A structural comparison between the energy balance pre-1994 and post-1994 can be achieved by comparing Figure 11 and Figure 9.

In the Federal Environmental Agency's (UBA) *balance of emission causes*, which further disaggregates the Federal Energy Balance, the time series from 1987 to 2001 have so far been created (for the years 1987 to 1994 for the former Federal territory and the former GDR, or the old and new *Länder*, and from 1995 onwards 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 disaggregated data for emission causes from stationary sources is currently available for Germany for this period. Data for the period 1999 to 2001 is provisional. Despite the conversion of the energy balance to the new classification of industrial sectors and the altered grouping of energy resources from the year 1995 onwards, we have so far succeeded in tracking data back to the outlined basic structure, thereby facilitating the preparation of a consistent time series.

3.1.2.3 Preparation of provisional energy balances onwards from 1999 by the UBA

At present, the final energy balances indicate a backlog of two 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 and 2001 on the basis of detailed evaluation tables by the Working Group on Energy Balances <AGEB>. The ***evaluation tables on energy balance*** are posted on the homepage of the Working Group on Energy Balances <AGEB> each summer, including data on the previous year, and are therefore generally accessible.

However, it should be noted that the data in the evaluation tables, where it has not been 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 according to sectors
- Primary energy consumption according to energy resources
- Indigenous primary energy production according to energy resources
- Total final energy consumption according to energy resources
- Final energy consumption by the rest of the mining and manufacturing industry according to energy resources
- Final energy consumption by traffic according to energy resources
- Final energy consumption by households according to energy resources
- Final energy consumption by the trade, commerce and services sector according to energy resources
- Final energy consumption by military offices according to energy resources
- Use of energy resources for the generation of power.

With figures on primary energy consumption, the use of fuel to generate electricity, non-energy consumption and final energy consumption according to sectors as the core data, the Federal Environmental Agency has supplemented the transformation balance of 1999 and to produce provisional energy balances for 2000 and 2001.

3.1.3 Methodological issues: Energy-induced 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). This is particularly true for the area of energy-induced CO_2 emissions, where the activity rates used are based almost exclusively on the sum totals of the energy balances – unlike the emissions ascertained for other air pollutants, whereby the activity rates determined from the energy balance were in part extended by activity rates from other sources; this is true, for example, of the use of firewood in the households and small consumption / trade, commerce and services sectors.

However, the energy balance data on which the inventories are based has been further differentiated or reclassified for various reasons, using a range of other data. Reasons for this include:

- Requirements derived from the various national and international reporting formats
- The need for a more differentiated determination of emissions in orderto reflect the various processes and fuels via different emission factors
- Objective allocation differences from the UBA's viewpoint.

Regarding the latter aspect, such differentiations only result from the area of energy-induced CO_2 emissions in a small minority of cases; process or fuel differentiations based on differences with regard to acidifying substances (sulphur dioxide, nitrogen oxides, ammonia) or other conventional air pollutants (dust, carbon monoxide) or non-CO_2 greenhouse gases (methane, non-methane hydrocarbons, laughing gas) are more common.

Against this background, the following comments are confined to those differentiations that are relevant in terms of non-energy-induced CO_2 emissions. This is based on a detailed analysis (Öko-Institut 2000) which takes as its source the database up until 1995. More detailed analyses have been attempted based on an interim status of the current data stocks in the UBA's Central System of Emissions (CSE), but in view of the fact that the data is only provisional, amendments are still possible once it has been validated (Ziesing et al., 2003).

Ideally, amendments or reclassifications should take place in the *UBA's balance of emission causes*. Within the context of the growing division of labour, however, some of these amendments are only implemented in the Central System of Emissions. The aim is to integrate these into the *balance of emission causes* within the context of task streamlining, so that there are no deviations between the data stocks of the two systems in future.

3.1.3.1 Supplements to the energy balance data

In the area of waste combustion, the UBA 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 up 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 up 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 up until 1994).

The UBA has supplemented this data with its own estimates on the total use of domestic waste in waste combustion plants which are based on an evaluation of operator data. The difference between the overall total calculated in this way for the use of domestic waste in 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, this supplementation process 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 12)

Table 12 Supplementation of the activity rates for the use of domestic waste in thermal power plants, public heat plants and district heat plants, old *Länder* 1990-1994 and Germany 1995-1998

	Public thermal power plants				Heat plants / district heat plants			
	Energy balance	CSE			Energy bal.	CSE		
	L. 13/11	Energy bal.	Plus	Total	L. 18/15+16	Energy bal.	Plus	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
Note: from 1990 to 1994 old *Länder*, from 1995 Germany								

Source: Working Group on Energy Balances (AGEB), UBA, calculations by the Öko-Institut

The additional consideration of this activity data produces additional CO_2 emissions in the period up to 1994 of approximately 300,000 tonnes. From 1995 onwards, the currently available database no longer includes such supplements (the corresponding time series were nevertheless created).

A similar procedure is adopted for waste combustion in industrial thermal power plants. However, in such cases, the supplementation of fuel quantities is linked to a differentiation of fuels for spent sulphite liquor, which is not emissions-relevant in relation to energy-induced CO_2 emissions. In such cases, the basis is derived from data on industrial waste combustion overall, where this is recorded by the Federal Statistical Office (FS 19, series 1.2). 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 is to 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 Federal States, 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 13 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 plants				Industrial heat producers				
	Energy bal.	CSE			Energy bal.	CSE			
	L. 15/12	Energy bal.	of which ind. waste	of which sp. sulph. liq.	L. 73/60	Energy bal.	of which ind. waste	plus ind. waste	plus spent sulphite 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	-

Notes: from 1990 to 1994 old *Länder*, from 1995 Germany. Regarding the data used by the UBA for 1993 and from 1995 onwards, there is still need for clarification

Source: Working Group on Energy Balances, UBA, calculations by the Öko-Institut

Finally, with regard to the use of waste, combustion in other plants of the transformation sector also deserves a 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 up until 1994, but from 1995 onwards there is a deviation. Here too, there is a need for clarification.

Table 14 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 (line 38 / 39)	5540	6212	11511	12969	13707	14080
Data implemented in the CSE	5540	6212	11485	10818	8387	14879
Note: Until 1994, old *Länder*, from 1995, Germany						

Source: Working Group on Energy Balances (AGEB), UBA, calculations by the Öko-Institut

There is a second supplementation of the energy balance for the use of natural gas by compressors in the natural gas network. This is calculated by means of a fixed-rate factor (0.005) which is linked to the 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 additionally included as emissions. For Germany as a whole, in the first half of the Nineties, 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).

3.1.3.2 Reclassification of energy balance data

For preparation of the inventories in the UBA, a series of reclassifications are conducted. This concern, firstly, the breakdown of energy use in combined heating and power stations where the energy balance differentiates between the use of fuel for electricity generation on the one hand, and heat generation on the other; and secondly, reclassification between various different fuels and the transfer of individual fuel inputs into other consumption areas.

Identification of the fuel input quantities of industrial CHP plants attributable to heat generation is conducted internally at UBA on the basis of a complicated procedure which has certain consequences for the allocation of emissions between industrial thermal power plants (energy balance line 15 up to 1994, and line 12 from 1995 onwards) and fuel consumption of other heat producers in the section “Other mining and manufacturing industry” (lines 51-73 up until 1994, and 46-60 from 1995 onwards).

Moreover, the following reclassifications and differentiations (relevant for energy-induced CO_2 emissions) are also implemented:

- The use of jet kerosene in the commerce, trade and services sector (energy balance line 1999) was allocated to petroleum use in small firing installations up until 1994. From 1995 onwards, the use of jet kerosene in the trade, commerce and services sector (line 74), which now also includes the military, is allocated overall to military air traffic. However, this displacement only corresponds to a maximum emissions volume of 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.

- For the area of public thermal power plants (energy balance line 13 up until 1994, and line 11 from 1995 onwards), the use of lignite is differentiated according to origin

(Rhineland, Helmstedt, Kassel, Brandenburg/Saxony, Saxony-Anhalt) whose CO_2 emission factors differ significantly from one another.

Apart from the aforementioned fuel allocation for the combined heating and power sector, further deviations in sectoral allocation as a result of reclassifications are only expected to a limited extent, and these will be cancelled out in the overall total. However, measurable deviations in the sum total may arise to a significant extent with the differentiated consideration of crude lignite input (Ziesing et al., 2003).

3.2 Fuel combustion (1.A)

The area of *fuel combustion* 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 pit and briquette plants (line 34)
- Lignite pit 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, other mining and manufacturing industry (line 60)
- Households (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 the produced electricity into the national 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 mineral oil 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 power plants in line 15 of the energy balance, only the fuel input which can be allocated to district heating 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 15, ***district heat plants*** indicates the fuel input for public district heating supply. The plants are often used to cover peak loads in district heating 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, even though this is only materially transformed. The emission-causing use of lignite is eliminated during data processing. Together with fuel inputs used to generate electricity by the power stations of hard coal pits, lignite pits and refinery power stations, the fuel inputs used to generate heat in combined heat and power generation combine to form the total fuel input in such plants. After deducting fuel inputs for heat generation in power stations from the total, this 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 for room heating. Here too, no distinction is made according to the type of heat generation. Hence part of the final energy consumption in these sectors, together with the fuel input by industrial power stations to generate electricity, constitutes the total fuel input in such plants.
7. The data on ***final energy consumption by households*** (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.

Balance of emission causes

- Sector
- Plant type
- Energy resource
- Immission protection legislation provision
- Energy balance line
- (Where necessary: regional allocation)
- Allocation to the Central System of Emissions (CSE)

Sectors include:

- Public thermal power plants
- Hard coal mining
- Lignite mining
- Deutsche Bahn AG *(German national railway)*
- Mineral oil refineries
- District heat plants
- Other transformation sector (may be further sub-classified)
- Quarrying, other mining and manufacturing industry (further sub-classification planned)
- Households
- 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).

According to energy resources:

- 21 energy resources

On the basis of immission protection legislation provisions, a distinction is made between:

- Installations under the 13^{th} BImSchV
- Installations under the 17^{th} BImSchV
- Installations under the 1^{st} BImSchV
- Installations under the TA Luft

Abbreviations status for: BIMSchV =Ordinance on the Implementation of the Federal Immission Control Act; TA Luft = First General Administrative Provision on the Federal Immission Control Act, Clean Air Directive

Figure 12: UBA structure of the balance of emission causes for disaggregation of the energy balance

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)
- Indicate regional peculiarities (e.g. different qualities of crude lignite in the individual mining regions)

- Are allocated to different source categories in national and international emissions reporting
- Are specified in various energy balance lines according to their intended purpose (for electricity or heat generation) but are used in a sigle plant group (e.g. steam turbine power stations)
- These characteristics impact 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 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, is further sub-divided into 88 lines.

Figure 12 indicates the features of the BEU structure. These basic structures are analysed in greater detail in the following account of activities.

3.2.1 Public electricity and heating supply (1.a.1a)

3.2.1.1 Source category description (1.A.1a)

In the public electricity supply sector, there is an installed electrical plant output of around 75 GW operated with fossil fuels. Almost 90 % of this plant output is attributable to steam turbine power stations, approximately 6 GW to gas turbine power stations, and the remainder is attributable to motor power stations. Of the steam turbine power stations, 48 GW is operated with hard coal and lignite. In the year 1998, all plants produced some 313 TWh of electrical power, accounting for 63 % of electricity generation in the public supply.

Heat plants 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 heating. 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 heating network. 56 % of the district heating in district heat plants is produced using natural gas, 13 % with hard coal and lignite, 15 % with waste fuels, and 13 % from mineral oil products.

3.2.1.2 Methodological issues (1.A.1a)

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

Table 15 in chapter 3.2.6 indicates the structure of the fuel inputs in the Balance of Emission Causes (BEU) model. This structure allows the sector to be emulated in full.

3.2.2 Mineral oil refineries (1.A.1b)

3.2.2.1 Source category description (1.A.1b)

The crude oil distillation capacity of German mineral oil refineries totalled around 110 Mt in the year 1998. Over this period, 108 Mt of crude oil and also intermediate products were used for subsequent processing. The generation of mineral oil products totalled 117 Mt, 52

Mt of which was attributable to fuels, 33 Mt to heating oils, 10 Mt to naphtha and 22 Mt to 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 work. These plants also produce output heat for production purposes. Process heat is also produced from process furnaces with a furnace thermal output in excess of 7 GW.

3.2.2.2 Methodological issues (1.A.1b)

For the *Balance of Emission Causes (BEU)*, the fuel input of the refinery power stations was calculated from the data in the energy balance (line 12) and the fuel input for the power stations for heat generation and for process firing, both of which are reported jointly in line 38, was separated out. The plant structure in the BEU model can be found in Table 18 in chapter 3.2.6.

3.2.3 Production of solid fuels and other energy producers (1.A.1c)

3.2.3.1 Source category description (1.A.1c)

This segment includes hard coal and lignite mining as well as coke ovens and briquette plants, together with the production of crude oil and natural gas. In 1998, some 48 Mt of hard coal was mined in the German hard coal mining industry. Over the same period, coke production totalled 10 Mt. At the same time, almost 5,000 Mm^3 of coke oven gas was produced. Together, the 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 in combined heat and power generation is minimal.

In 1998, 166 Mt of crude lignite was produced in Germany. The production of lignite briquettes and other lignite products totalled 5 Mt. Particularly for the production of these products, the lignite mining industry operates power stations with an electrical output of 0.4 GW and a furnace thermal output of 2 GW. From these plants, steam for drying the crude lignite is produced for the production of lignite products.

In 1998, German production of petroleum totalled just under 3 Mt whilst production of natural gas totalled just under 20 000 Mm^3 (H_u = 31 736 kJ/m^3). The fuel input needed for operation of the plants can be found in the balance of emission causes (BEU).

3.2.3.2 Methodological issues (1.A.1c)

The data structure for hard coal and lignite mining in the balance of emission causes can be found in Table 16 in chapter 3.2.6.

The structure of petroleum production in the balance of emission causes is depicted in Table 19 in chapter 3.2.6.

3.2.4 Iron-producing industry (1.A.2a)

3.2.4.1 Methodological issues (1.A.2a)

In the blast furnace process of the iron-producing industry, energy is consumed (final energy consumption) and energy is produced in the form of blast furnace gas (transformation output) at the same time. In order to avoid duplication in the energy balance, the coke equivalent of the quantity of blast furnace gas in terms of calorific value is deducted from the coke consumption of the iron-producing industry, and reported as transformation input in the blast furnace (energy balance line 17).

The coke input in the blast furnace reduced by the coke equivalent is allocated to final energy consumption. In the balance of emission causes, this coke consumption is shown in Table 20 (chapter 3.2.6) under blast furnaces.

In terms of process procedure, the correct approach to the emission balance would be to allocate the CO_2 contained in the blast furnace gas to the blast furnace process, and the oxidation of the CO contained in the blast furnace gas to combustion of the blast furnace gas. This presupposes that the composition of the blast furnace gas is precisely known. In view of the broad bandwidth of blast furnace gas analyses, this approach has only theoretical significance. For this reason, the CO_2 emissions from blast furnace gas combustion are valued 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 CO_2 emissions potential brought into the blast furnace with the hard coal coke.

3.2.5 Other energy producers

Power stations in

- Industry (quarrying, other mining and manufacturing industry)
- Those belonging to Deutsche Bahn AG <*German national railway*>

should be classified under this category. Plants with an electrical output of 6.8 GW and a furnace thermal output of 37 GW are installed in industrial power stations. In 1998, industrial power plants generated 31 TWh of electrical energy. The bulk of the plants also produce process heat within the context of combined heat and power generation.

The fuel input used to generate electricity (sub-quantity of energy balance line 14) and the fuel input used to generate heat in the industrial power stations (sub-quantity of energy balance line 60) are outlined in Table 19 in chapter 3.2.6. A further differentiation on the basis of industry segments is currently under investigation.

The single-phase electricity generation plants of Deutsche Bahn AG have an electrical output of 1.1 GW based on fossil fuels. Their furnace thermal output is 3 GW. In 1998, 4.5 TWh of electrical energy was generated. These power stations are likewise included in Table 17 (chapter 3.2.6).

3.2.6 Tables in the "Balance of Emission Causes" on stationary combustion

The *"Balance of Emission Causes"* comprises a total of 88 tables, 66 of which apply to the emission-inducing use of fuels in stationary combustion under consideration here.

The number in the first column corresponds to the consecutive number in the table in the *balance of emission causes*. 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 "SWK" column indicates the intended purpose (see the list of abbreviations below). The "filename" in the eighth column refers to the database of the *Central System of Emissions (CSE)*.

Abbreviations used in the tables

DTKW	Steam turbine power stations
GTKW	Gas turbine power stations
GT	Gas turbines
IKW	Industrial power stations
MVA	Waste incineration plant
GFA	Large furnaces
GuD	Gas and steam turbine power plants
GMKW	Gas motor power plants
DMKW	Diesel motor power plants
FHW	District heat plants
FA	Furnaces
PF	Process furnaces
S	Electricity generation
W	Heat generation
K	Force generation (direct drive)
BImSchV	Statutory Ordinance under the Federal Immission Control Act
TA-Luft	First General Administrative Provision on the Federal Immission Control Act (Clean Air Directive)

Table 15: Public supply

Nr.	Process, fuel	EB line	Allocation to imm. prot. legislation	Plant type [1)]	Economic sector	SWK	File name	Comments, explanations
1	Electricity gen. in GFA of public thermal power plants	11	13th BImSchV	DTKW	Public supply	S	OEKW13	
2	Electricity gen. in GFA of public crude lignite power plants	11	13th BImSchV	DTKW	Public supply	S	OEKW13	
2a	Electricity gen. in GFA of public hard lignite power plants	11	13th BImSchV	DTKW	Public supply	S		
3	Electricity gen. in MVA of public thermal power plants	11	17th BImSchV	DTKW	Public supply	S	OEKW17	
4	Electricity gen. in gas turbines of public thermal power plants	11	TA Luft	GTKW	Public supply	S	OEKWGT	
4a	Electricity gen. in GuD facilities of thermal power plants (HKW)	11		GuD	Public supply	S		
5	Electricity gen. in gas engines of public thermal power plants	11	TA Luft	GMKW	Public supply	S	OEKWGM	
6	Electricity gen. in diesel engines of public thermal power plants	11	TA Luft	DMKW	Public supply	S	OEKWDM	
22	Heat generation in GFA of public thermal power plants	15	13th BImSchV	DTKW	Public supply	W	HEKW13	
22a	Heat generation in GFA of public lignite power plants (Kassel)	15	13th BImSchV	DTKW	Public supply	W	HEKW13	
23	Heat generation in MVA of public thermal power plants	15	17th BImSchV	DTKW	Public supply	W	HEKW17	
25	Heat generation in gas turbines of public thermal power plants	15	TA Luft	GTKW	Public supply	W	HEKWGT	Fuel input in gas turbines provision allocated in full to electricity generation
25a	Heat generation in GuD plants of thermal Power plants	15	13th BImSchV / TA Luft	GuD	Public supply	W		
26	Heat generation in gas machines of public thermal power plants s	15	TA Luft	GMKW	Public supply	W	HEKWGM	Fuel input in gas machines provision allocated in full to electricity generation
27	Heat generation in diesel engines of public thermal power plants	15	TA Luft	DMKW	Public supply	W	HEKWDM	
28	Heat generation in GFA of public district heat plants	16	13th BImSchV	FHW	Public supply	W	FEHW13	
29	Heat generation in MVA of public district heat plants	16	17th BImSchV	FHW	Public supply	W	FEHW17	
30	Heat generation in TA Luft facilities of public district Heat plants	16	TA Luft	FHW	Public supply	W	FEHWTA	

Table 16: Coal mining

No.	Process, fuel	EB line	Allocation to emission prot. legisl.	Plant type [1)]	Economic sector	SWK	File name	Comments, explanations
7	Electricity gen. in GFA of STEAG	12	13th BImSchV	DTKW	Coal mining/STEAG	S	STEA13	
8	Electricity gen. in GFA of other colliery power plants	12	13th BImSchV	DTKW	Other coal mining	S	ZGSK13	
8a	Electricity gen. in GFA of pit power plants	12	13th BImSchV	DTKW	Other coal mining	S	ZGBK13	
9	Electricity gen. in gas turbines of colliery and pit power plants	12	TA Luft	GTKW	Coal mining	S	ZGKWGT	
10	Electricity gen. in gas engines of colliery and pit power plants	12	TA Luft	GMKW	Coal mining	S	ZGKWGM	Assumption: Natural gas and light fuel c are used entirely in GTKW. For this reason, the file/line is left blank. Cf. also Tab. 60
11	Electricity gen. in diesel engines of colliery and pit power plants	12	TA Luft	DMKW	Coal mining	S	ZGKWDM	
32	Heat generation in GFA of STEAG	40	13th BImSchV	DTKW	Coal mining /STEAG	W	UEST13	
33	Heat generation in GFA of other colliery power plants	40	13th BImSchV	DTKW	Other coal mining	W	UEKS13	
33a	Heat generation in GFA of pit power plants	40	13th BImSchV	DTKW	Other coal mining	W	UEKB13	
38	Heat gener. in gas turbines of colliery & pit power plants	40	TA Luft	GTKW	Coal mining	W	UEKZGT	Fuel allocated in full to electricity generation
40	Heat generation in gas machines of colliery & pit power plants	40	TA Luft	GMKW	Coal mining	W	UEKZGT	
41	Direct drive by diesel motors in colliery & pit power plants	40	TA Luft	DMKW	Coal mining	K	UEKZDM	
43	Production of hard coal coke (process furnace)	40	TA Luft	PF	Coal mining	W	UEPFKO	
43a	Production of hard coal coke (17th BImSchV)	40	17th BImSchV	PF	Coal mining	W		

Table 17: Other industrial power stations

No.	Process, fuel	EB line	Allocation to immission che prot. legisl.	Plant type 1)	Economic sector	SWK	File name	Comments, explanations
12	Electricity gen. in GFA of DB p. plants	12	13th BImSchV	DTKW	Deutsche Bahn AG	S	DBKW13	
14	Electricity gen. in GFA of other ind. thermal power plants	12	13th BImSchV	DTKW	Other mining and manufacturing industry (excluding	S	UIKW13	
14a	Electricity gen. in GFA of Vereinigte Aluminium Werke (VAW), Bonn	12	13th BImSchV	DTKW	Vereinigte Aluminium Werke (VAW)	S	UIKW13	
15	Electricity generation in MVA of ind. thermal power plants	12	17th BImSchV	DTKW	Other mining and manufacturing industry	S	UIKW17	
16	Elecricity gen. in TA Luft Facilities of other ind. thermal power plants	12	TA Luft	DTKW	Other mining and manufacturing industry	S	UIKWTA	
18	Electricity gen. in gas turbines of other ind. thermal power plants	12	TA Luft	GTKW	Other mining and manufacturing industry	S	UIKWGT	
19	Electricity gen. in gas engines of other ind. thermal power plants	12	TA Luft	GMKW	Other mining and manufacturing industry	S	UIKWGM	
21	Electricity gen. in diesel engines of other ind. thermal power plants	12	TA Luft	DMK W	Other mining and manufacturing industry	S	UIKWDM	
24	Heat gen. in TA Luft facilities of other IKW (only infeed into the national grid); NBL only	15	TA Luft	DTKW	Other mining and manufacturing industry Gewerbe	W	HEKWTA	Heat gener. in thermal power plants was allocated in full to the 13th BImSchV in the old Länder
35	Heat gen. in GFA of other IKW of the transformation sector (new Fed. states only)	40	13th BImSchV		Other energy producers	W	UEKI13	
37	Heat generation in TA Luft faciltities of IKW of the transformation sector	40	TA Luft	DTKW	Other energy producers	W	UEKITA	Blank because all power stations are allocated to the 13th BImSchV
47	Heat gen. in GFA of IKW of the manufacturing industry & other mining	60	13th BImSchV	DTKW	Other mining and manufacturing industry	W	INKW13	
48	Heat gen. in MVA of IKW of the manufacturing industry & other mining	60	17th BImSchV	DTKW	Other mining and manufacturing industry	W	INKW17	
50	Heat generation in TA Lu ft facilities of IKW of manuf. industry and other mining	60	TA Luft	DTKW	Other mining and manufacturing industry	W	INKWTA	
51	Heat gen. in gas turbines of IKW of other mining and manufacturing industry	60	TA Luft	GTKW	Other mining and manufacturing s industry	W	INKWGT	Fuel input provisionally allocated in fu electricity generation
52	Heat gen. in gas engines of IKW of other mining and manufacturing industry	60	TA Luft	GMKW	Other mining and manufacturing industry	W	INKWGM	Fuel input provisionally alloca full to electricity generation
53	Heat gen. in diesel engines of IKW of other mining and manufacturing industry	60	TA Luft	DMKW	Other mining and manufacturing industry	W	INKWDM	Fuel input provisionally allocated in full to electricity generation

Table 18: Refineries

No.	Process, fuel	EB line	Allocation to imm. prot. legislation	Plant type [1)]	Economic sector	SWK	File name	Comments, explanations
13	Electricity gen. in GFA of refinery power plants	12	13th BImSchV	DTKW	Mineral oil processing	S	UIKR13	
17	Electricity gen. in gas turbines of refinery power plants	12	TA Luft	GTKW	Mineral oil processing	S	UIKRGT	
20	Electricity gen. in diesel engines of refinery power plants	12	TA Luft	DMKW	Mineral oil processing	S	UIKRDM	Blank, diesel fuel allocated in full to other mining and manufacturing industry (UIKWDM)
34	Heat gen. in GFA of refinery power plants	40	13th BImSchV		Mineral oil processing	W	UEKR13	
39	Heat gen. in gas turbines of refinery power plants	40	TA Luft	GTKW	Mineral oil processing	W	UEKRGT	Fuel allocated in full to electricity generation
42	Heat gen. in diesel engines of refinery power plants	40	TA Luft	DMKW	Mineral oil processing	W	UEKRDM	
44	Refinery process furnaces (GFA)	40	13th BImSchV	PF	Mineral oil processing	W	UEPFRG	
44a	Refinery process furnaces (TA Luft)	40	TA Luft	PF	Mineral oil processing	W	UEPFRT	

Table 19: Other energy producers

No.	Process, fuel	EB line	Allocation to imm. protection legislation	Plant type [1)]	Economic sector	SWK	File name	Comments. explanations
31	Heat generation in GFA (industrial boiler) of other transformation sector	40	13th BImSchV	FA	Other energy producers	W	UEUM13	
36	Heat generation in TA Luft plants (industrial boilers) of the transformation sector	40	TA Luft	FA	Other energy producers	W	UEUMTA	

Table 20: Iron-producing industry

No.	Process, fuel	EB line	Allocation to imm. protection legislation	Plant type [1)]	Economic sector	SWK	File name	Comments, explanations
54	Production of crude iron (process furnaces)	60	TA Luft	Blast furn.	Iron-producing industry	W	INPFHO	
55	Production of sinter (process furnaces)	60	TA Luft	Sinter plants	Iron-producing industry	W	INPFSI	

3.2.7 Road traffic (1.A.3b)

3.2.7.1 Source category description (1.A.3b)

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 commercial vehicles, heavy goods vehicles and buses. During the course of calculation, these are further differentiated according to the type of fuel used, the vehicle size and the pollutant reduction technique (so-called "*vehicle layers"*).

3.2.7.2 Methodological issues (1.A.3b)

The calculation of CO_2 emissions from motorised road traffic in Germany is based on a *top-down* approach (T*ier 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, petroleum) 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")[7]. TREMOD adopts a "*bottom-up*" (Tier 2/3) approach whereby mileage of the individual vehicle layers is multiplied by regional-specific emission factors. For passenger cars and light commercial 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 depending on the reduction technique.

For calculation with TREMOD, extensive basic data from generally accessible statistics and special surveys was used, coordinated, 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 may be found in /ifeu/.

3.2.7.2.1 Real data for the years 1990-2000

Car 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 exhaust gas testing agency in 1992 and the time series in the statistical annuals of the GDR. Between 1991 and 1993, it was necessary to estimate the figures with the aid of numerous assumptions.

Emission factors: The emissions factors for road traffic originate predominantly from the measurement programmes of TÜV Rheinland <*Rhineland Vehicle Inspectorate*> 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 goods vehicles,

[7] In order to be able to derviate and evaluate 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.

whereby emission factors were derived according to driving conduct and the traffic situation. Within the context of field monitoring, 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 the Federal Environmental Agency.

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") (published by DIW). 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 correspond to the differentiations used as a basis in emissions measurement programmes. The mileage data for the reference years cited were therefore transferred directly into TREMOD.

3.2.7.2.2 Data for the year 2001

Development of road traffic figures: The figures for 2001 are derived with the aid of a reclassification model which calculates vehicle figures differentiated on the basis of drive type, vehicle size and reduction technology, based on the real figures from the most recent available statistics (2000), the trends in estimated new registrations and new registration percentages of individual vehicle layers in recent years, together with survival probabilities.

Emission factors: The emission factors are derived from the development in the numbers of individual vehicle layers. The emission reduction achieved from the introduction of sulphur-free fuels was estimated by the Federal Environmental Agencies.

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

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

The emission data submitted was recalculated in 2002 using Version 3.0. The following changes were implemented compared with the previously reported data:

- Updating of the mileage data for passenger car and heavy commercial vehicle traffic for the years 1998 to 2001
- Updating of the motor vehicle figures and new registrations for 1999 and 2000
- Adaptation of the assumptions for the updating of the fleet composition up until 2001, particularly the mileage share of diesel passenger cars
- Consideration of the introduction and associated influence of non-sulphur fuel (10 ppm).

The time series were recalculated in full.

3.2.7.4 Source-specific QA/QC 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 4.0 % and 7.0 % were calculated in the period 1994-2001. The deviations for the consumption of diesel fuel ranged between 5.9 % and 10.3 %.

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

The TREMOD model has been created in such a way that as a general rule, if basic data changes, the entire time series must be recalculated. The most recent update occurred with Version 3.0 (cf. chapter **0**)

3.2.7.6 Source-specific planned improvements (1.A.3b)

Both activity data and emission factors are subject to a constant revision process. For the next report, new mileage data and new NOx emission factors for heavy commercial vehicles are anticipated.

3.2.8 Other transportation (1.A.3e)

3.2.8.1 Source category description (1.A.3e)

Emissions from rail traffic, coastal and inland shipping, national aviation and “other” forms of transport are reported under this category.

3.2.8.2 Methodological issues (1.A.3e)

For all the above areas, emissions are calculated as the product of the fuels consumed and regional-specific emission factors (*Tier 1 method*). The energy consumption data is taken from the *energy balance*. The emission factors are based on studies of the literature.

3.2.8.3 Source-specific planned improvements (1.A.3e)

For the area of *air traffic*, there are plans to recalculate the proportion of national air traffic based on the mileage travelled. The emission factors are to be revised on the basis of new scientific studies.

In rail traffic, train type-specific emission factors are derived. The emission calculations are being converted to a technique which links these train type-specific emission factors to the corresponding operational outputs (kilometres driven).

3.2.9 Other sectors (1.A.4)

3.2.9.1 Source category description: Households, small consumers, agriculture, forestry and fishing (1.A.4a – 1.A.4c)

Source category 1.A.4 (Other Sectors) comprises furnaces in the segments *Residential*, *Commercial and Institutional* and *Agriculture* (in D: households and small consumers sector). These sectors include all private households as well as a wide variety of small consumer groups such as trade (metal, wood, construction trade), retail and services, agriculture and horticulture, as well as public institutions, where these cannot be allocated to the area of energy transformation or industry.

The figures for furnaces in the households and small consumers segments represent a very inhomogeneous group in terms of design and size of the installations, and ranges from individual room furnaces for solid fuels with a rated thermal output of approximately 4 kW (e.g. fireplaces, ovens), to oil and gas furnaces used to generate room heating and hot water (e.g. central heating boilers), and hand-fed and automatically fed wood-burning furnaces in the commercial sector, through to licensable firing installations amongst small consumers with a rated thermal output of several megawatts, to name but a few examples. In total in 1995, more than 40 million firing installations were installed in Germany in the area of households and small consumers (source: UBA-Texte 14/00).

3.2.9.2 Methodological issues (1.A.4)

The report on the research project "Calculation of average emission factors to portray emissions development from furnaces belonging to households and small consumers" (UBA-Texte 14/00) from the year 2000 provides the data basis for the emissions factors used. Within the context of this project, device-related and sectoral emission factors for furnaces in the area of households and small consumers were calculated for all exhaust gas components with a high level of detail for the reference year 1995.

Structuring of the emission factors is based on 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 Rhenish, Lausitz and Central German regions, imported briquettes)
- Hard coal (coke, briquettes, anthracite) and
- Wood (natural wood, residual wood)

and according to the device design, age level, output category and typical mode of operation of the firing installations. In the area of small consumers, additionally, a distinction was made between installations not subject to licensing within the scope of validity of the 1st Ordinance on the Implementation of the Federal Immission Control Act (*BImSchV*) (Ordinance on Small Furnaces) and licensable installations that are subject to the requirements of the Clean Air Directive (*TA Luft*).

The description of the plant structure for installed furnaces was prepared using the statistics on residential and other buildings, the chimney-sweeping trade, and surveys by the researchers themselves in selected districts of Baden-Wuerttemberg, North-Rhine Westphalia and Saxony. The emissions behaviour of the furnaces was documented on the basis of an extensive evaluation of the literature, whereby a distinction was made between the results from test bench experiments and measurements in the field. Supplementary to this, experiments were conducted on furnaces using solid fuels, both on the test bench and via measurements in the field. 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. The method adopted in this work for preparing the emissions factors is shown in diagrammatic form in Figure 13.

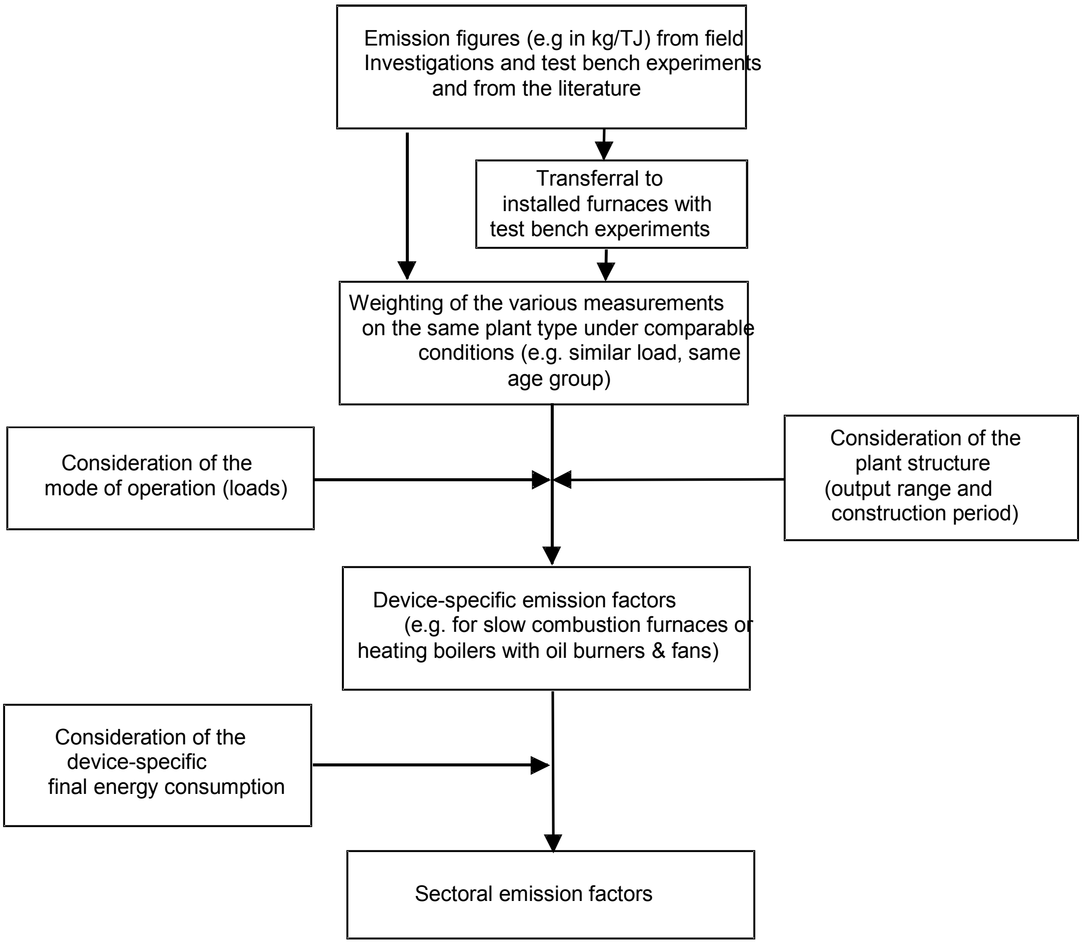


Figure 13: System for calculating device-specific and sectoral emission factors

(Source: UBA-TEXTE 14/00)

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

The calculation of reliable emission factors in this plant sector can only be achieved by means of a complex procedure. Apart from emission figures, it is also necessary to obtain other information e.g. in order to make allowance for the mode of operation (loads), the plant structure and the device-specific final energy consumption. When obtaining data during the course of the aforementioned research and development project, this approach was for the most part followed, nevertheless, given the sheer number of plants and the wide range of firing constructions and fuels used, a fairly large “basic uncertainty” of the data must be assumed.

For some plant types, moreover, when using certain fuels, only inadequate data or no data at all was available on emissions behaviour. In this respect, it is important to bear in mind that for furnaces belonging to households and small consumers, 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.

3.2.9.4 Source-specific QA/QC and verification (1.A.4)

For the purposes of quality assurance within 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. This was achieved, e.g. by means of comparisons with existing reliable data, and by means of plausibility checks. As a general principle, when describing the emissions behaviour of the firing installations, emission data was only included in the subsequent calculation if the literature contained complete, undisputed data on the fuel used, the design of the furnace, and its operating mode during measurements.

All the device-specific emissions factors calculated were furthermore subjected to an internal quality assessment within the context of the aforementioned research project to examine their underlying data basis. For example, every emission factor calculated was classified into one of four quality levels (A to D), whereby A is the highest level and D the lowest. The pre-requisite for the highest quality level was a sufficiently broad database with a high standard of quality and reliability of the emission measurements, achieved, for example, via the use of tested, assured and recognised measurement techniques and procedures whilst operating the furnaces. If the calculation was only based on a few measurements or if the measurements were not carried out using adequately tested measurement techniques, the lowest quality level was allocated to these factors. Table 1 provides a summarised overview of the evaluation of the sectoral emission factors calculated for CO_2, CH_4 and N_2O.

Table 21: Valuation of the sectoral emission factors, specifying the quality levels

Energy carrier	CO2	CH4	N2O
Heating oil EL	A	B-C	B-C
Heating oil S/SA	A	-	-[8]
Fuel gases	A	B-C	B-C
Hard coal	A	D-C	B-C
Lignite	A	D-C	B-C
Wood fuel	A	D-C	B-C

(Source: UBA-TEXTE 14/00)

<u>Quality levels</u>

A – Broad database with a reliable background

B – Medium database, background can still be considered reliable

C - Small database, emission measurements on the basis of random samples only

D – Individual measurements; estimates of the emission factors on the basis of comparable furnaces

3.2.9.5 Source-specific planned improvements (1.A.4)

In order to create a broader database for calculating certain emission factors (particularly for CH_4 when using solid fuels), further investigations are required. This is to be achieved within the context of research projects that have yet to be allocated.

[8] The database was not adquate for calculation purposes

3.2.10 Comparison with the CO_2 reference approach

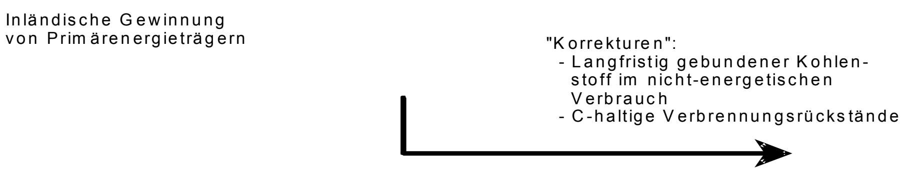
Within the context of international climate protection, reporting on combustion-induced CO_2 emissions is highly significant. To this end, industrialised countries routinely adopt a sectoral approach, which addresses the level of individual energy consumption sectors and therefore permits differentiated 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 the sectoral approach.

In order to analyse this calculation method, PROGNOS AG was commissioned to carry out a corresponding research project, which it completed in the year 2000 (PROGNOS 2000).

3.2.10.1 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 inputted and outputted with the energy resources (cf. Figure 14).

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 the indigenous production of primary energy resources. Carbon outputs are linked to exports of primary and secondary energy resources and bunkers (fuel consumption by marine shipping and international air traffic). The reference approach therefore includes the following adjustments to the carbon balance to allow for non-emissions-relevant quantities of carbon: Carbon output in combustion residues containing carbon (*fraction of carbon oxidised)* and long-term fixed carbon in downstream products from the non-energetic consumption of energy resources (*fraction of carbon stored*; e.g. use of naphtha in plastics production).



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Emissions

Carbon outputs

Exports

- Primary energy resources

- Secondary energy resources

“Corrections”:

- Fraction of carbon oxidised

- Fraction of carbon stored

Energy system

Indigenous production of primary energy resources

Imports

- Primary energy resources

- Secondary energy resources

Carbon inputs

Figure 14: Basic principle of the IPCC reference approach

(Source: Prognos, 2000)

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

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

3.2.10.1.1 Hard coal

The German energy balance does not differentiate according to different hard coal types. In the German coal statistics, however, indigenous production of hard coal is divided into bright-burning coal, bituminous coal, dry steam 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. The differentiated calculation for indigenous production based on coal types occurs separately.

The same applies to hard coal imports: Imported coal indicates different characteristic values depending on its country of origin. Based on the foreign trade statistics of the Federal Statistical Office and the statistics of the coal industry organisation *Kohlenwirtschaft e.V.,* 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.

3.2.10.1.2 Lignite

The IPCC procedure only envisages one category, "*lignite*". In order to make allowance for the particular significance of lignite in Germany, therefore, a differentiation is implemented within the context of a special calculation:

- For indigenous production, a differentiation is made according to the main mining regions of Rhineland, Lausitz, Central Germany, Helmstedt and others (Borken, Wölfersheim). The production quantities are regularly reported in mining industry statistics.
- Amongst imports, a distinction is made between lignite and hard lignite (Czech Republic) in accordance with the energy balance.
- Exports and stock changes are not further differentiated and are taken from the data in the energy balance.

3.2.10.1.3 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 indicate 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).

3.2.10.1.4 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 %.[9] These 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.

Nevertheless, when 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 mining regions and types) are not published, but may be obtained from the industry association, *Mineralöwirtschaftsverband,* 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 the carbon content (according to MARLAND 1983). The carbon content of the individual crude oil types has been estimated on the basis of this correlation and published data on specific weight ("API Gravity"[10]).

[9]) The global average is approximately 84.5 %.
[10]) Specific weights are available for all types with the exception of Russian petroleum (source: Oil&Gas Journal Data Book. 1997). Average values were used for Russian petroleum.

The purpose of the correction factors is to refine the calculation of CO_2 emission potential from the simple input/output balance of energy resources. When calculating the correction factors "*fraction of carbon stored*", in addition to the carbon actually stored in long-lived products, non-combustion-related emissions, particularly solvent and process emissions, are also included in the balance as "*carbon stored*". 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-energetic 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.

3.2.10.2 Data bases

The principal data bases 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 2001, we were unable to apply the Reference Approach here. For the main primary fuels of petroleum, natural gas, hard coal and lignite, 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 is based on the GEMIS database (Öko-Institut), together with data from the Jülich Research Centre (from the IKARUS project).

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

3.2.10.3 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 emission trend of the detailed source category-related calculations for energy-induced 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 sectoral approach. The remainder of the deviations are attributable to systematic differences between the two methods at the level of underlying energy consumption, specifically with the consideration of non-energetic consumption, waste incineration, statistical differences and losses in the transformation sector of the energy system, including energy consumption by the natural gas pipeline compressors (cf. Figure 15).

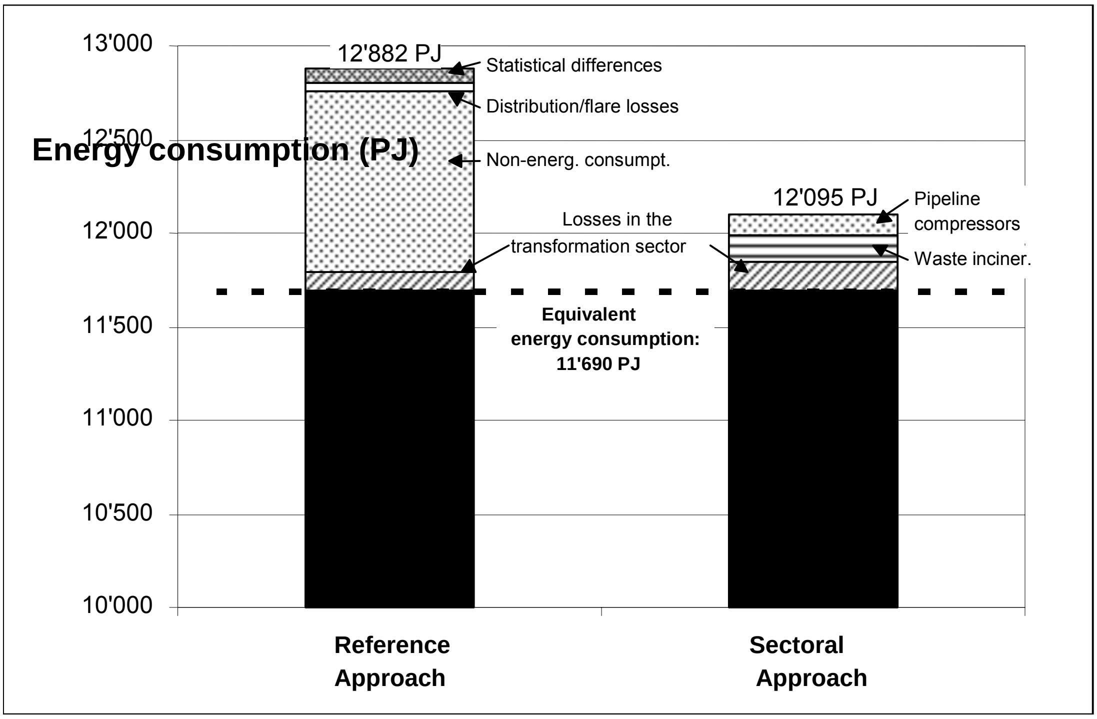


Figure 15: **Systematic differences between the reference approach and the sectoral approach (1990)**

3.2.10.4 Planned improvements

For application in Germany, as well as in most other countries where coal is highly significant as an energy resource, the calculation of country-specific "*carbon emission factors*" helps to improve precision (Germany: approximately 4 % in relation to total emissions), since the IPCC default values fail to adequately represent the different types of coal. In countries with a low consumption of coal, on the other hand, the use of the default values should produce adequate results.

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

- On the one hand, a considerable amount of data collation is needed, which is inconsistent with the objective of the Reference Approach to minimise data requirements – even in Germany, not all the necessary data is available. This is further exacerbated by delimitation problems when determining the *amount of carbon stored*, which hinders 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 the entire non-energetic 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 situation in individual countries.

3.2.11 Bunker fuels

The inventory includes emissions from the consumption of fuels for international traffic (international aviation and marine vessels).

The activity rates for international marine bunkers may be taken directly from the energy balance. The reason for this is the deviating taxation on fuel quantities sold in ports.

Unfortunately, the same sub-classification is not possible in the area of international aviation emissions. Here, total fuel consumption is recorded under domestic sales. A distinction is made in the time series via the consistent breakdown of this fuel consumption data, into 20 % for domestic aviation and 80 % for international aviation. This ratio was initially an expert estimate, but has since been confirmed as a conservative estimate within the context of a research project for the year 1996. At the time, disregarding sports and private aviation, it produced a share of almost 17 % of the total fuel volume sold in that year.

The fixed emission factors used are currently under review.

3.2.12 Feedstocks

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

3.2.13 Military

Emissions from international deployments by the Federal Armed Forces under the UN mandate are currently included in German emission inventories but not reported separately. However, this task is to be resolved within the framework of the National System.

At present, therefore, no adjustments are made to the inventories, since the fuel inputs associated with these actions are contained in the national military consumption figures.

3.2.14 Source-specific QA/QC and verification (1.A)

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

This is achieved by comparing the calculation results with the data

- from EUROSTAT
- from the IEA (sectoral approach and reference approach)
- from the CO_2 calculations performed at *Länder* level.

Table 22 compares the results of the various CO_2 calculation approaches with one another. For visualisation purposes, this is depicted in chart form on a comparative basis over time in Figure 16. It becomes clear that the relevant development trends in all calculation approaches, including the reference approach, are revealed, albeit at differing levels. In order to illustrate these level differences, the relative deviations in the data records created by the varying calculations are depicted in Figure 17.

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

Table 22: Comparison of CO_2 inventories with other independent national and international results of CO_2 emissions

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
DIW-Ergenisse (Mitteilung Ziesing)	**984,3**	**950,1**	**902,1**	**891,6**	**875,9**	**873,0**	**897,0**	**865,2**	**856,9**	**829,3**	**831,2**	**847,1**
Abweichung DIW zu UBA (in %)	-0,3	-0,1	-0,1	-0,2	-0,1	0,1	0,1	0,1	0,1	0,1	-0,1	0,1
EUROSTAT (New Cronos)	943,0	918,5	877,1	870,2	857,6	863,3	870,1	827,8	824,2	802,3	NE	NE
Abweichung EUROSTAT zu UBA (in %)	-4,6	-3,6	-2,9	-2,6	-2,3	-1,1	-3,0	-4,4	-3,8	-3,3	NE	NE
IEA Statistics Sectoral Approach (1)	964,1	941,5	892,6	884,9	871,8	870,0	908,4	879,7	861,9	830,7	833,0	NE
Abweichung IEA zu UBA (in %)	-2,4	-1,0	-1,2	-0,9	-0,6	-0,3	1,3	1,7	0,7	0,2	0,1	NE
IEA Statistics Reference Approach (1)	968,7	937,5	897,5	883,7	870,7	870,4	895,5	870,4	863,6	826,3	820,1	NE
Abweichung IEA RA zu UBA (in %)	-1,9	-1,5	-0,6	-1,1	-0,7	-0,2	-0,1	0,7	0,9	-0,3	-1,4	NE
Abweichung IEA RA zu UBA RA (in %)	-5,2	-4,7	-4,1	-4,6	-4,2	-2,9	-3,1	-2,5	-2,0	-2,5	NE	NE
Ergebnisse der Bundesländer (2)									906,5	901,8	NE	NE
Abweichung Bundesländer zu UBA (in %)									3,2	5,5	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	NE (5)	NE (5)
Abweichung RA zu UBA (in %)	3,1	3,1	3,4	3,4	3,3	2,6	2,9	3,1	2,9	2,1	NE (5)	NE (5)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
				(Gg)								
1. Energy	**986.832,48**	**951.136,86**	**902.918,70**	**893.006,09**	**877.157,72**	**872.445,95**	**896.368,31**	**864.459,40**	**855.735,84**	**828.720,23**	**831.831,57**	**846.352,02**
A. Fuel Combustion (Sectoral Approach)	986.832,48	951.136,86	902.918,70	893.006,09	877.157,72	872.445,95	896.368,31	864.459,40	855.735,84	828.720,23	831.831,57	846.352,02
1. Energy Industries	412.895,91	398.899,27	376.304,01	366.001,74	362.678,00	351.862,34	357.461,24	339.487,08	341.258,48	327.852,07	340.042,76	345.293,17
2. Manufacturing Industries and Construction	196.456,63	173.007,78	159.700,84	147.770,51	149.377,84	150.011,77	144.166,04	144.138,28	138.587,36	135.697,51	136.198,56	132.536,43
3. Transport	162.280,89	165.953,18	171.660,70	176.532,46	172.898,72	176.563,35	176.657,52	177.156,54	180.420,02	186.065,10	182.697,20	178.313,05
4. Other Sectors	203.439,18	204.882,15	188.877,21	197.590,38	187.470,08	189.986,94	214.918,37	200.628,99	192.405,23	176.485,45	170.466,93	187.892,85
5. Other	11.759,87	8.394,47	6.375,94	5.111,00	4.733,07	4.021,55	3.165,14	3.048,51	3.064,76	2.620,10	2.426,12	2.316,52
B. Fugitive Emissions from Fuels	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
1. Solid Fuels	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2. Oil and Natural Gas	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
2. Industrial Processes	**27.606,09**	**24.632,08**	**25.162,19**	**24.982,94**	**26.634,24**	**26.312,08**	**24.502,20**	**25.137,73**	**25.648,24**	**26.021,05**	**26.136,91**	**24.409,80**
A. Mineral Products	24.511,57	22.229,01	22.889,54	22.835,25	24.497,71	23.794,45	22.007,23	22.660,34	23.115,20	23.524,89	23.514,96	21.802,09
B. Chemical Industry	2.190,24	1.559,89	1.535,79	1.473,15	1.521,86	1.814,98	1.791,10	1.778,41	1.785,17	1.721,41	1.834,99	1.810,97
C. Metal Production	904,28	843,18	736,87	674,54	614,67	702,65	703,87	698,98	747,86	774,75	786,97	796,74
D. Other Production	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
G. Other	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**
4. Agriculture	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
5. Land-Use Change and Forestry (3)	**-33.688,75**	**-33.688,75**	**-33.688,75**	**-33.688,75**	**-33.688,75**	**-33.399,91**	**-33.399,91**	**-33.399,91**	**-33.399,91**	**-33.399,91**	**-23.694,82**	**-23.694,82**
6. Waste	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**
7. Other *(please specify)*	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**	**NO**
Total Emissions/Removals with LUCF (4)	**980.749,81**	**942.080,19**	**894.392,14**	**884.300,28**	**870.103,21**	**865.358,11**	**887.470,61**	**856.197,21**	**847.984,17**	**821.341,37**	**834.273,66**	**847.067,00**
Total Emissions without LUCF(4)	**1.014.438,56**	**975.768,94**	**928.080,89**	**917.989,03**	**903.791,96**	**898.758,02**	**920.870,52**	**889.597,12**	**881.384,08**	**854.741,28**	**857.968,48**	**870.761,82**
Memo Items:												
International Bunkers	**19.569,19**	**18.101,38**	**17.818,24**	**19.917,25**	**19.874,70**	**20.420,40**	**21.008,76**	**22.018,21**	**22.088,36**	**23.341,65**	**24.265,90**	**23.851,50**
Aviation	11.589,36	11.366,70	12.200,16	12.891,76	13.398,37	13.887,08	14.536,92	15.096,65	15.523,07	16.656,16	17.582,40	17.168,00
Marine	7.979,83	6.734,68	5.618,08	7.025,48	6.476,34	6.533,32	6.471,84	6.921,55	6.565,29	6.685,50	6.683,50	6.683,50
Multilateral Operations	**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**

(1) IEA OECD Statistics "CO2 Emissions from fuel combustion 1971 - 2000" Edition 2002, Paris

(2) AG Länderenergiebilanzen, UBA Analyse; beinhaltet auch Emissionen aus dem Energieverbrauch für den internationalen Verkehr

(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 signs for uptake are always (-) and for emissions (+).

(4) The information in these rows is requested to facilitate comparison of data, since Parties differ in the way they report CO_2 emissions and removals from Land-Use Change and Forestry.

(5) Das CO2-Referenzverfahren konnte im UBA wegen fehlender Detailangaben (Energiebilanz) für 2000 und 2001 nicht angewendet werden!

<Legende>

DIW results (Ziesing report)

Deviation of DIW from UBA (%)

EUROSTAT (New Cronos)

Deviation of EUROSTAT from UBA (%)

IEA Statistics Sectoral Approach (1)

Deviation of IEA from UBA (%)

IEA Statistics Reference Approach (1)

Deviation of IEA RA from UBA (%)

Deviation of IEA RA from UBA RA (%)

Results from the Federal *Länder*

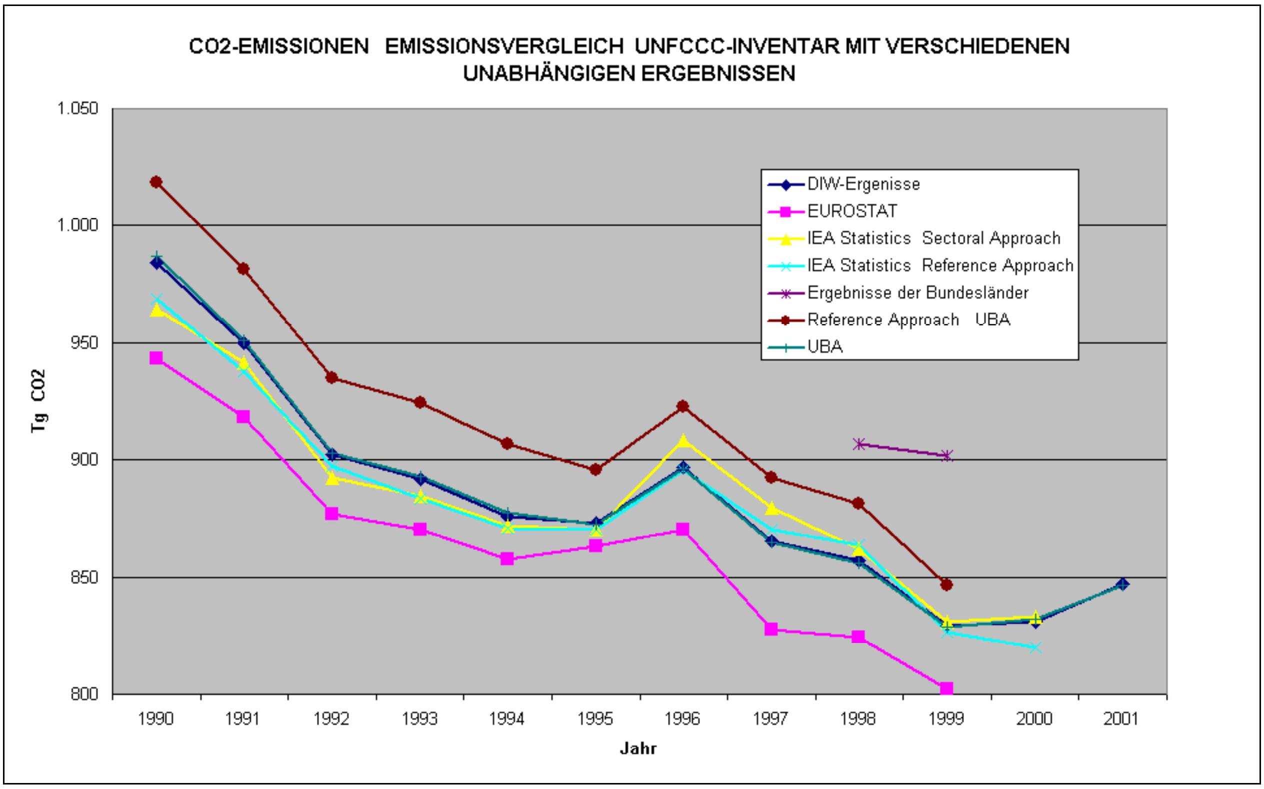
Deviation of the *Länder* from UBA (%)

Reference Approach UBA

Deviation of RA from UBA (%)

(2) Working Group on the Energy Balances of the *Länder*, UBA analysis; also includes emissions from energy consumption for international traffic

(5) The CO2 reference approach could not be used in the UBA for 2000 and 2001 due to the lack of detailed information (energy balance)



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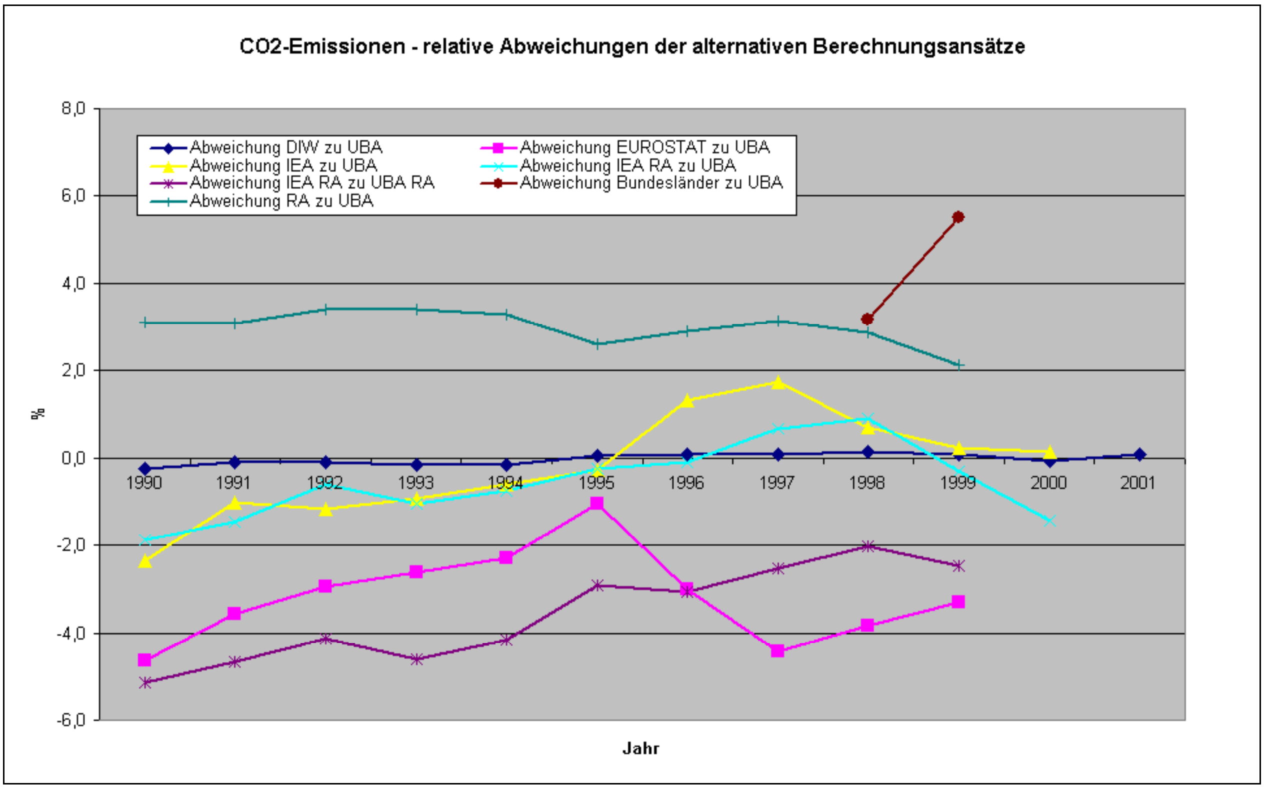
CO2 emissions – Comparison of emissions between UNFCCC inventory and various independent results
DIW results
EUROSTAT
IEA Statistics Sectoral Approach
IEA Statistics Reference Approach
Results from the Federal *Länder*
Reference Approach UBA
UBA
Year

Figure 16: **CO_2 emissions in Germany for the years 1990 to 2001 –Comparison between national and international calculation results**



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CO2 emissions – Relative deviations of the alternative calculation approaches

Deviation of DIW from UBA

Deviation of IEA from UBA

Deviation of IEA RA from UBA RA

Deviation of RA from UBA

Deviation of EUROSTAT from UBA

Deviation of IEA RA from UBA

Deviation of Federal Länder from UBA

Year

Figure 17: **CO_2 emissions in Germany for the years 1990 to 2001 – Comparison between relative deviations between national and international calculation results**

3.2.14.1 Comparison with the EUROSTAT results

The calculations performed by EUROSTAT deviate non-uniformly from the detailed national data in terms of the trend (cf. Table 23). On average, the results are 3 % below the UBA data. The fluctuation in deviations ranges from – 4.6 % (= 44 million tonnes in 1990) to – 1.1 % (= 9 million tonnes in 1995).

In order to determine the causes for these differences, in 2001 the Federal Environmental Agency commissioned a research project to the German Institute for Economic Research in

Berlin (DIW) and the Ökoinstitut, which was 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 the 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 non-energetic consumption in the preceding year. These questionnaires are sent to Member States towards the middle of the year, asking them to 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 thousand 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 Germany Petroleum Industry Association (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 million 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).
- *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 thousand 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, and the data for lignite in collaboration with the Federal Lignite Association (DEBRIV), Cologne, and the overall process coordinated with the responsible Department at the BMWi (now the Federal Ministry of Economics and Employment, BMWA).
- *Annual Questionnaire on Renewables and Wastes:* This questionnaire, which is similarly structured to the other questionnaires, records the use of renewable energy sources and wastes and differentiates individual energy sources and types of waste. Apart from charcoal and liquid biofuels, both of which are recorded in thousand 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 (auto producer) supply. Information is reported in GWh for electricity and in terajoules for heat, both for gross and net generation 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 sector and 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 BMWi compiles the required data and forwards it to EUROSTAT/IEA.

3.2.14.1.1 Reasons for discrepancies in the energy data used

The discrepancies observed vary in nature. One reason is that the questionnaires have not always been coordinated 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 registration, since there is currently a gap of two years between submission of the questionnaires and presentation of the final energy balances. For this reason, provisional figures reported to EUROSTAT/IEA can only be replaced with final data after a corresponding period of delay.

Initial consequences have been drawn from problems arising in the past (cf. also chapter 3.2.14.1.2): For example, close collaboration and cooperation 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 close collaboration with the institutions supplying the data, the Federal Statistical Office and the Working Group on Energy Balances (AGEB) in an initial provisional energy balance, 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 on primary energy consumption, non-energetic consumption and final energy consumption by sector and energy source is compiled in the early summer.

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 potential causal complexes for differences in data used for the calculation of CO_2 emissions:

So 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 – in percentage terms – the deviation is, the causes for such differences, if applicable the time of reporting, and whether and – if applicable – to what extent earlier reports have been revised, or whether these are differences of a systematic nature.

The conversion coefficients used for the 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 this is not always the case, particularly with gases, since here – for example in official statistics or price statistics – gross calorific value is often used to calculate energy quantity. 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 lignite can vary widely according to type and origin). From this point of view, the type of data and its respective sources should be examined.

Table 23: Differences between the energy balance data of EUROSTAT and the Working Group on Energy Balances (AGEB) for the balance year 1998

All figures in 1000 t	**Hard coal**			**Lignite**		**Petroleum**							
	Coal	Bri-quette	Coke	ILgnite (crude) hard lignite	Briquettes and other lignite prods.	Crude oil	Gas-oline	Naph--tha	Jet fuel	Diesel fuel incl. LHO	Heating oil, hvy	Liquid gas	Refinery gas
Indigenous production	6248	0	0	-149	0	53	0	0	0	0	0	0	0
Imports	0	0	0	-126	107	345	385	-448	104	202	-102	-23	-26
Stock depletion	818	0	3	-72	-17	0	186	41	102	564	155	76	0
Exports	0	-66	17	-140	26	0	0	0	32	-1	0	0	0
Intern. marine bunkers	0	0	0	0	0	-	-	-	-	-	0	-	-
Stock build-up	-	0	-	-	0	206	0	0	0	0	0	0	5
INDIG. PRIMARY ENERGY CON-SUMPTION	**7066**	**66**	**14**	**207**	**69**	**192**	**571**	**407**	**174**	**328**	**180**	**53**	**31**
Transformation input, total	2498	0	224	-3041	-7	193	-3995	-4884	0	-749	-2457	-381	-324
Transformation output, total	0	0	139	0	0	0	-3266	-170	39	-50	-714	-267	-225
Energy cons. in transformation area, total	2	0	0	-108	-2	0	0	0	0	46	642	77	148
Flaring & transport losses	-	-	-	-	-	-	0	0	0	-	0	0	0
NON-ENERGY CONSUMPTION	-	0	102	-1	-142	-	0	1145					
									11	-1	-581	-218	-123
Statistical differences	-360	66	405	3035	223	-1	187	106	90	67	133	79	-5
FINAL ENERGY CONSUMP.	**526**	**0**	**8**	**-92**	**-3**	**-**	**1**	**0**	**17**	**-173**	**-493**	**0**	**32**
Mining, quarrying, manufacturing industry, total	530	0	8	-59	30	-	0	0	0	330	-546	-80	32
Transport, total	0	0	0	0	-28	-	191	0	376	43	0	61	0
Households	149	0	20	73	0	-	55	0	1	0	0	-36	0
Households; Trade, Commerce and Services	-4	0	0	-106	-5	-	-190	0	-359	-546	53	19	0

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

When comparing the quantity data used in the two energy balances, there are a number of significant deviations. The following Table 23 lists these deviations for the year 1998 by way of an example.

Specifically, it is noticeable that there are substantial differences 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. As a result, the EUROSTAT figures are approximately 1,869 million tonnes higher than the figures for tonnes of gross production from *Statistik der Kohlenwirtschaft*. 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 equivalent. However, this difference diminishes considerably if values are compared in terajoules or crude oil equivalent.

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, these energy sources are included in German energy balances in the calculation of primary energy consumption, and are solely assigned to non-energetic consumption.

In the case of *lignite* (crude lignite including hard lignite) there are only minor differences with respect to production, imports and exports, which can be explained by quantities of peat that are recorded under hard lignite by the AGEB but are not recorded by EUROSTAT. The quantity of 3,014 million tonnes in the transformation sector by which the EUROSTAT figures exceed those of AGEB is roughly equivalent to the reported statistical difference amounting to 3,035 million tonnes in EUROSTAT balances, which does not exist in the AGEB energy balances.

In the case of *petroleum*, differences arise primarily in the transformation sector, and 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 the 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 equivalent – but not in terajoules – and a table of conversion coefficients. However, only a very broad range of conversion coefficients is provided in the table 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 equivalent. 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 coefficients used by EUROSTAT for crude lignite of 8 840 kJ/kg and for imports of hard lignite of 13 461 kJ/kg both lie below the coefficients used by the AGEB of 8 931 kJ/kg and 14 962 kJ/kg respectively. As a general trend, it can be asserted that the conversion coefficients used by EUROSTAT tend to be well below those used by the AGEB.

3.2.14.1.2 Analysis of the emission factors used

One reason for the deviations in data between EUROSTAT emission inventories and the national emission inventories may lie in the choice of emission factors used. To begin with, we analysed the emission factors used by EUROSTA for the area of energy-induced 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 sectors and subsectors 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 equivalent, whilst emissions were available in the unit of kilotonnes of CO_2, the emission factors were calculated (in t CO_2/TJ) from the following equation:

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

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.

<Legende>

where $EF_{i;j}$ *= emission factor for fuel i in the energy balance sector j*
$E_{i;j}$ *= CO_2 emission for fuel i in the energy balance sector j*
$Q_{i;j}$ *= energy input for fuel i in the energy balance sector j*

The numerical value is the net calorific value 41,868 kJ per kg of crude oil equivalent.

The first thing apparent from the recalculations is that EUROSTAT has not implemented any differentiations of the emission factors for the various source areas / sectors.

Table 24: Results of the recalculation of emission factors, 1991-1998

	EUROSTAT emission factors	Remarks
	t CO_2/TJ	
Hard coal	94	UBA employs values of 92 to 94 according to source category - 92 for power and district heat plants - 93 for industrial incineration plants - 94 for households and small consumers
Hard-coal coke	106	UBA employs values of 100 to 113 according to source and origin category
Hard-coal briquettes	93	UBA generally employs the value 93
Crude lignite	99	UBA employs values of 110 to 113 according to source category and origin - 110 for industry, small consumers & military - 111 for power and district heat plants & remaining transformation - 112 for other industrial power plants As far as separate energy input data exists for the new *Länder*: 113; the value for Central German crude lignite should be around 100
Hard lignite	no emission factor, included in crude lignite	UBA generally employs the value 97
BKB/Lignite briquettes	93	UBA employs values of 97 to 99 according to source category and origin - 99 for power and district heat plants - 97 for other source categories Where separate energy input data is available for the new Länder :
Lignite coke	no emission factor, classification still unknown	UBA employs values of 96 to 111 according to source category - 96 for power and district heat plants - 107 for industrial incineration plants - 111 for remaining transformation and small consumers
Pulverized & dry coal	no emission factor, classification still unknown	UBA generally employs the value 98
Peat	no emission factor, classification still unknown	UBA generally employs the value 98
Crude oil	no emission factor, classification still unknown,	UBA generally employs the value 80
Naphtha	73	UBA generally employs the value 80
Motor gasoline	69	UBA generally employs the value 72
Diesel fuel	73	UBA generally employs the value 74 from 1991
Kerosene & heavy fuel oil	71	UBA generally employs the value 74 from 1991
Light heating oill	73	UBA generally employs the value 74
Heavy heating oil	77	UBA generally employs the value 78
Liquid gas	62	UBA employs values of 64 to 65 according to source category
Refinery gas	66	UBA generally employs the value 60
Petroleum coke	no emission factor, classification still unknown	UBA generally employs the value 101
Other petroleum products	73	UBA employs values of 78 to 80 according to source category Where separate energy input data is available for the new Länder
Coke-oven & town gas	combined in EUROSTAT energy balances	UBA generally employs the value 44
Blast furnace gas		UBA generally employs the value105; to avoid double counting of blast furnace process and blast furnace gas combustion, blast furnace gas Is assessed similar to hard-coal coke
Natural gas	56	UBA employs, according to origin, values of 55 to 56 for natural gas, 58 for LPG, 55 for colliery gas. As far as separate energy input data is available for natural gas for the new *Länder*: 55
Industry waste	only organic industry waste included	UBA generally employs – with the exception of special branches – the value 20
Municipal waste	All municipal waste included, but no emission factor determinable	UBA generally employs the value 15

Sources: EUROSTAT, UBA, Öko-Institut calculations

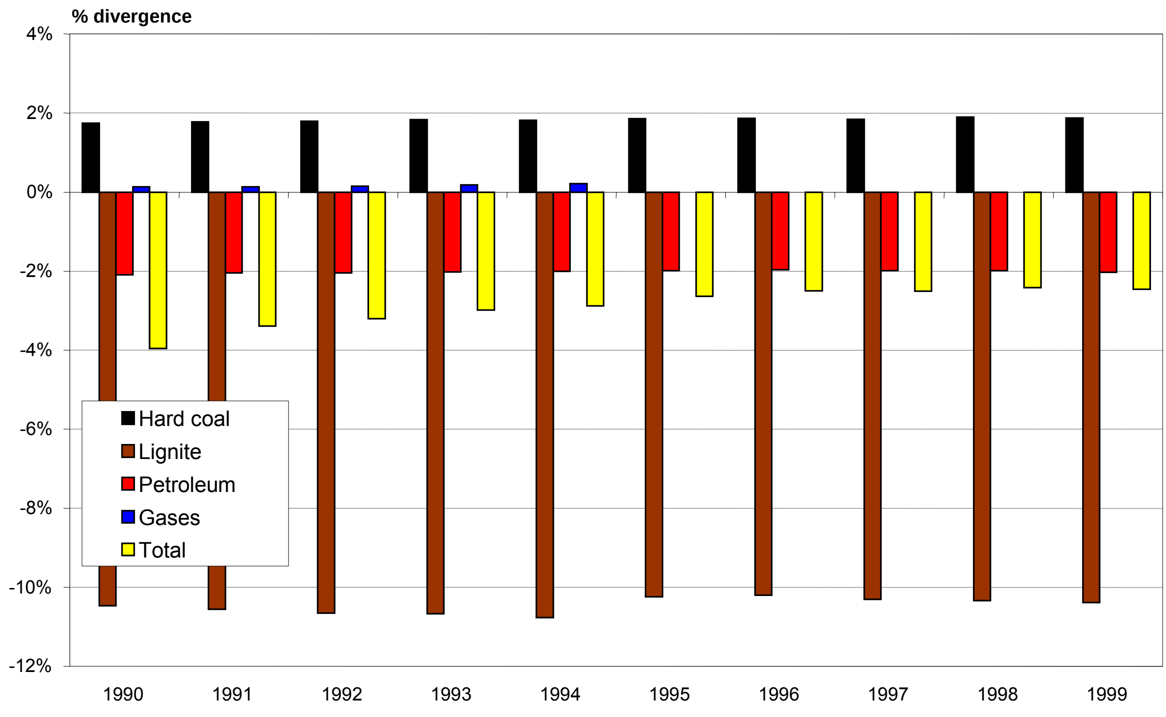
Table 24 lists the results, both in the form of an overview and also in comparison to the emission factors used in the Federal Environmental Agency's inventory system.

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 with power generation, low with small consumers) 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 are clearly underestimated, and the deviations in emission factors amount to more than 10 % in some cases. The same is true of almost all *petroleum products*; only in the case of refinery gas is 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* are very similar. Due to the predominant role of natural gas H for the current natural gas supply mix in Germany, a good level of concurrence can be ascertained.

In the area of *waste incineration*, an underestimation of emissions is to be assumed, since the non-organic components of domestic waste are likewise assigned to biomass, with an estimated neutral effect on CO_2. The extent to which such uncertainties, i.e. underestimation or overestimation of CO_2 emissions, also apply with respect to the non-organic components of industrial waste, cannot be clarified until the matter of allocation has been finalised.

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



Sources: EUROSTAT, UBA, Öko-Institut calculations

Figure 18 Divergence of UBA and EUROSTAT emission factors by fuel category, 1990-1999

Divergences arising from differing 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 are therefore underestimated by between 4.0 (1990) and 2.5 percent (1999). As illustrated by Figure 18, 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 the harmonisation of data between EUROSTAT and German institutions should not be confined solely to basic energy data, but must of necessity also be expanded to include the emission factors. There are plans for Germany to provide EUROSTAT with a complete set of emission factors representative of Germany, which will make allowance for source category-specific differentiation as well as changes over the course of time. Ideally, the emission factors should also be aggregated in line with the fuel differentiation practised by EUROSTAT.

3.2.14.1.3 Planned improvements

In making these recommendations, a distinction is to be made between those that relate to the energy statistics database, and those that focus on emissions-related issues.

With regard to the avoidance of differences in the energy statistics database, the following recommendations are of prime importance:

1. As a general principle, the energy balances published by the Working Group on Energy Balances (AGEB) should always be used as a basis when calculating CO2 emissions. This applies not only to the national emissions inventory to be drawn up by the Federal Environmental Agency, but also to international institutions such as EUROSTAT and IEA, insofar as they make their own calculations of emissions.
2. At present, finalised energy balances for Germany are only available for the years from 1990 to 1999. The AGEB, and the institute employed by it (DIW Berlin), are therefore urgently advised to substantially reduce the time lag within a reasonable period. The aim should be to present energy balances no later than 12 months after the end of the year under review.
3. The completion and submission of annual questionnaires should be better coordinated, also from the point of view of 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 by the Federal Ministry of Economics and Employment (BMWA), in close collaboration with the institutions that supply the data (the Federal Statistical Office and the AGEB) in an initial, provisional energy balance and forwarded to EUROSTAT/IEA. The “evaluation tables” prepared by the 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.
4. Corrections made by the 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:

5. When 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.

6. 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 status have not always been used. Any coordination that may be needed with EUROSTAT should be resolved as soon as possible in collaboration with the Federal Environmental Agency (and where necessary with the AGEB).

7. Within the scope of revision and verification of German inventories of atmospheric pollutants, the UBA should develop, as soon as possible, a methodology for the differentiation of bunker fuels for international aviation both within Europe and outside of Europe, 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 changes in both energy data and emission factors which in retrospect (due to new findings), turn out to be irrefutable, should be corrected retroactively. Germany, for its part, it must find a harmonisation procedure for the communication of energy data and emission factors, so that a high degree of consistency can be maintained between both sets of data. For this purpose, precise procedures must be laid down between the AGEB and the UBA on the one hand, and the BMU and the BMWA on the other.

3.2.14.2 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 2002) 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 German at present, since to this end further methodological information – particularly on the detailed data used – is needed.

However, results of the comparison confirm the data obtained from the national, detailed method (average deviation over 11 years: -0.2 %, fluctuation range from –2.4 % in 1990 to +1.7 % in 1997).

3.2.14.2.1 Planned improvements

When preparing the energy balances, the IEA also has recourse to information from EUROSTAT. As such, a deviation in emission data between both data records is worth mentioning, and will be examined more closely in time for the next inventory report. The same applies to consistency of the 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, when applying these methods to the national emission calculations there are significant deviations; in such cases, the results of the reference approach are more or less uniformly approximately 3 % above the results of the detailed, source category-specific calculation method.

3.2.14.3 Comparison with the data obtained for the individual Federal *Länder*

As a result of collaboration between the competent authorities and institutions in the Federal *Länder*, in the past ten years a Working Group of the Federal States on Energy Balance has been formed in Germany. 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*. It also includes representatives of economic institutions which prepare the energy balance in selected Federal *Länder*.

The principle task of this Working Group is to coordinate the preparation of energy balances for the individual Federal *Länder*. Since the balance year 1995, these balances have been prepared according to a uniform agreed and binding method[11].

In 1998, the Working Group of the Federal States 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*, which are likewise prepared on the basis of energy balances according to uniform 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 Federal *Länder*)” in the CO_2 balance. The reason for this parallel calculation method is the fact that up to 70 % of energy consumption in individual *Länder* is based on the import of electricity and district heating from other Federal *Länder*. Only by adopting this holistic approach is it possible to balance and evaluate the effects of prepared or implemented climate protection measures in the Federal *Länder*.

These results from the *Länder* based on the source balance are compared below with the inventories submitted here for energy-induced CO_2 emissions. This refers to data for the years 1998 and 1998, since the corresponding results for earlier or more recent years are not yet available. The comparison is made more difficult by the following restrictions in particular:

- Not all Federal *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 have prepared a CO_2 source balance as yet.
- 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 and it became necessary to use appropriate techniques to close the gaps. As a general rule, these were based on the average Federal statistical trend (percentile changes) or the average values calculated for this year.
- The energy data available at *Länder* level does not permit a precise differentiation into fuel used for national and international traffic. For this reason, with the Federal results, the CO_2 emissions from international traffic are included in the comparison for the relevant years.

[11] 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.

Table 25: Comparison of the results of the CO_2 calculations of the individual Federal *Länder* with the national inventories for the year 1998

Land	CO2-Emission Gg	Einwohner 1000	PEV PJ	CO2-Emission pro Einwohner (Mg)
Baden-Württemberg	80073	10397	1600	7,70
Bayern	91882	12066	2043	7,61
Berlin	22730	3426	316	6,63
Brandenburg	59255	2573	625	23,03
Bremen	13881	674	164	20,60
Hamburg	***18233***	1705	***416***	10,70
Hessen	***64515***	6032	1073	10,70
Mecklenburg-Vorpommern	***19336***	1808	164	10,70
Niedersachsen	81764	7845	1531	10,42
Nordrhein-Westfalen	304375	17975	4054	16,93
Rheinland Pfalz	***42974***	4018	770	10,70
Saarland	***11560***	1081	276	10,70
Sachsen	37167	4522	549	8,22
Sachsen-Anhalt	24578	2702	448	9,10
Schleswig-Holstein	21433	2757	547	7,78
Thüringen	12729	2478	227	5,14
Bund insgesamt	**906486**	**82058**	**14804**	**11,05**
zum Vergleich:				
Bundesergebnis	877683	82057,5	14521	10,70
Quelle:	UNFCCC Berichterstattung	Statistisches Bundesamt	Energiebilanz-angaben	
Abweichung von Bund insgesamt (%):	**-3,2**		**-1,9**	

<Legende>

Land

CO2 emission Gg

Inhabitants 1000

Primary energy consumption (PJ)

CO2 emission per inhabitant (Mg)

Baden-Wuerttemberg

Bavaria

Berlin

Brandenburg

Bremen

Hamburg

Hesse

Mecklenburg-Upper Pomerania

Lower Saxony

North Rhine-Westphalia

Rhineland-Palatinate

Saarland

Saxony

Saxony-Anhalt

Schleswig-Holstein

Thuringia

Federal Republic (total)

By way of comparison

Federal Government result

Source:

UNFCCC reporting

Federal Statistical Office

Energy balance data

Total deviation from Federal Republic (%)

The comparison includes two items of data – primary energy consumption, and calculated CO_2 emissions. For years in which no emissions data is available, an emission for the *Land* was calculated based on the respective number of inhabitants and the calculated nationwide per capita emission. The data used and results for the years 1998 (cf.Table 25) and 1999 (cf. Table 26) are summarised below.

Table 26: Comparison of the results of the CO_2 calculations of the individual *Länder* with the national inventories for the year 1999

Land	CO2-Emission Gg	Einwohner 1000	PEV PJ	CO2-Emission pro Einwohner (Mg)
Baden-Württemberg	80073	10476	1583	7,64
Bayern	91882	12155	2027	7,56
Berlin	22730	3387	332	6,71
Brandenburg	59255	2601	564	22,78
Bremen	13881	663	155	20,93
Hamburg	***17678***	1705	***398***	10,37
Hessen	***62761***	6052	1030	10,37
Mecklenburg-Vorpommern	***18556***	1789	168	10,37
Niedersachsen	81764	7899	***1502***	10,35
Nordrhein-Westfalen	304375	18000	3902	16,91
Rheinland Pfalz	***41801***	4031	***756***	10,37
Saarland	***11112***	1072	263	10,37
Sachsen	37167	4460	535	8,33
Sachsen-Anhalt	24578	2649	456	9,28
Schleswig-Holstein	21433	2777	***536***	7,72
Thüringen	12729	2449	228	5,20
Bund insgesamt	**901775**	**82164**	**14435**	**10,98**
zum Vergleich:				
Bundesergebnis	852066	82163,6	14324	10,37
Quelle:	UNFCCC Berichterstattung	Statistisches Bundesamt	Energiebilanz-angaben	
Abweichung von Bund insgesamt (%):	**-5,5**		**-0,8**	

<Legende>

Land

CO2 emission Gg

Inhabitants 1000

Primary energy consumption (PJ)

CO2 emission per inhabitant (Mg)

Baden-Wuerttemberg

Bavaria

Berlin

Brandenburg

Bremen

Hamburg

Hesse

Mecklenburg-Upper Pomerania

Lower Saxony

North Rhine-Westphalia

Rhineland-Palatinate

Saarland

Saxony

Saxony-Anhalt

Schleswig-Holstein

Thuringia

Federal Republic (total)

By way of comparison

Federal Government result

Source:

UNFCCC reporting

Federal Statistical Office

Energy balance data

Total deviation from Federal Republic (%)

As a result of the comparison, an acceptable level of consistency was found between the *Länder* results and the national inventory for the years 1998 and 1999. This is more favourable for the calculated primary energy consumption (deviation less than 2 %). The only selectable approach in this initial attempt to determine a nationwide overview of the CO_2 emissions of the Federal *Länder* (calculation based on number of inhabitants and national average per capita emissions) produced fairly large deviations of up to 5 % or more. Nevertheless, these comparisons confirm the CO_2 emissions calculated for Germany as a whole.

3.2.14.3.1 Planned improvements

This year, the approach chosen here was debated at length with the representatives of the Working Group of the Federal States on Energy Balances. This will lead to a methodological improvement of the comparison between the result of the *Länder* and the Federal Government result. This will be based in particular on the methods chosen here for closing the existing data gaps. Moreover, research will be undertaken to investigate the extent to which such comparisons can then be refined based on the consumption of individual energy resources or fuel categories.

3.3 Fugitive emissions from fuels (1.B)

3.3.1 Coal mining (1.B.1a)

In Germany hard coal is mined in 10 mines, and lignite in 6 coal fields, primarily using the open-cast method (14 pits).

In 2002, hard coal production totalled 26.1 million tonnes of usable production, whilst lignite production totalled 181.8 million tonnes (source: statistics from the industry association *Kohlewirtschaft e.V.*; the quantities given for lignite are provisional). As such, hard coal production has fallen by approximately 3.7 % against the previous year, whereas lignite production has increased by approximately 3.6 %.

3.3.1.1 Source category description (1.A.1c)

Methane (CH_4) is released during the production and storage of coal.

Hard coal mining is the principal source of these fugitive emissions of CH_4. Methane gas is released when mining hard coal, which is either extracted on site or dissipated via the weather.

In recent years, CH_4 emissions from hard coal mining have decreased, due to the significant decline in production and the increase in pit gas recovery, even from decommissioned shafts and mines. As well as active mines, decommissioned hard coal mines (degasing) represent another relevant source of fugitive CH_4 emissions.

3.3.1.2 Methodological issues (1.B.1a)

Emissions are calculated by multiplying the emission factors by the activity rate. Where necessary, the emission factors should be updated.

Only estimated figures are available on degassing from decommissioned mines.

3.3.1.3 Source-specific planned improvements (1.B.1a)

The emission factors used to date should be reviewed and updated. To this end, up-to-date figures must be obtained from operators, associations, and the licensing and monitoring authorities of the Federal *Länder*.

3.3.2 Oil and natural gas (1.B.2)

The distribution of natural gas constitutes the principal source of fugitive emissions of CH4. CH4 emissions from natural gas extraction and processing, as well as from transfer stations, play a subordinate role in this respect. CH4 emissions from petroleum extraction and the storage of petroleum products only accounts for approximately 3 % of emissions from natural gas.

3.3.2.1 **Source category description: Oil (1.B.2a)**

CH_4 emissions from petroleum originate primarily from diffuse emissions during extraction and from the refinery process, as well as the storage of petroleum products. Since 1991, specific emissions during petroleum extraction have declined only slightly by 10 %. On the other hand, specific fugitive CH_4 emissions from the refinery sector and in-refinery storage of petroleum products (particularly gasoline) were reduced by 60 % from 0.05 to 0.02 kg/t over the same period. Overall, CH_4 emissions were cut from 9.38 Gg in 1991 to 6.26 Gg in 2001.

3.3.2.1.2 Source category description: Natural gas (1.B.2b)

In the case of natural gas, the principal source of diffuse CH_4 emissions is the distribution of natural gas to the end consumer. Despite expanding the distribution network during the period under review by some 150,000 km to 417.497 km in 2001, a slight reduction in CH_4 emissions has been achieved, thanks to a reduction in fugitive distribution losses of around 40 %. The other fugitive emissions arising from the extraction, processing and high-pressure distribution of natural gas showed only a slight decrease during the period under review. Overall, CH_4 emissions were reduced from 367.20 Gg in 1991 to 347.18 Gg in 2001.

3.3.2.2 Methodological issues (1.B.2)

CH4 emissions for petroleum and natural gas were calculated from specific emission factors and activity rates. The activity rates originate predominantly from the National Energy Balance published annually by the Working Group on Energy Balances (AGEB). Total crude oil input in refineries is derived from the annual special publication by the petroleum industry association *Mineralölwirtschaftsverband e.V.* (MWV).

The specific emission factors were derived by the Federal Environmental Agency on the basis of research in literature and amongst companies, and have been continuously updated in line with on-going developments in the state of the art.

3.3.2.3 Source-specific planned improvements (1.B.2)

The derived emission factors are in need of evaluation, particularly in the case of natural gas. For this reason, efforts are underway to obtain up-to-date information (research and development project).

4 INDUSTRIAL PROCESSES (CRF SECTOR 2)

4.1 Mineral Products: Cement (2.A.1)

The calculation procedure for the cement industry is currently being transformed. The explanations given here are not yet included in the 2003 inventory supply, and represent the current status of the debate on methodology. Consistent calculations in the Central System of Emissions (CSE) and descriptions in the National Inventory Report (NIR) will only become available for the 2004 inventory.

4.1.1 Source category description (2.A.1)

Climate-relevant gases are emitted during the clinker combustion process, the bulk of which are CO_2. Other climate-relevant gases such as dinitrogen monoxide (N_2O) or methane (CH_4) are only emitted in minimal quantities.

CO_2 emissions are both raw material-induced and energy-induced. Raw material-induced CO_2 emissions occur during the deacidification of the limestone ($CaCO_3$) and account for around 60% of total CO_2 emissions. Energy-induced emissions arise both during the combustion of fuels as well as indirectly via the consumption of electrical energy (cf. Table 27).

Table 27: Specific CO_2 emissions from the cement industry in Germany

Year	Thermally induced[12]	Electrically induced	Raw material-induced	Total	Unit
1999	0.199	0.068	0.427	0.696	t CO_2/t cement
2000	0.195	0.068	0.431	0.694	
2001	0.179	0.067	0.415	0.661	

4.1.2 Methodological issues (2.A.1)

CO_2 emissions (raw material-induced) released due to the calcination of limestone in the cement industry ($CaCO_3$- CaO + CO_2) are calculated according to the following equation in accordance with the IPCC Good Practice Guidance:

$$CO_2 \text{ emissions} = \text{Emission Factor } (EF_{clinker}) \times \text{ Clinker Production}$$

In Germany, dust from the exhaust gas purification process is added to the clinker. The emission factor EF is calculated by analysing the lime content in the clinker and by applying the following equation:

$$EF_{clinker} = 0.785 \times \text{CaO Content (Weight Fraction) in Clinker} = 0.53 \text{ t } CO_2 / \text{ t Clinker}$$

The activity data was compiled by the German Cement Works Association, *Verein Deutscher Zementwerke e.V.* (VDZ)/Düsseldorf, by means of surveys amongst German cement factories. The following table additionally contains the raw material-induced CO_2 emissions of the German cement industry, calculated in accordance with the two equations shown above (cf. Table 28).

[12] Excluding secondary fuels

Table 28: Raw material-induced CO_2 emissions from the German cement industry

Year	Clinker production (reported) [10^6 t/a]	Cement production (from German clinker) [10^6 t/a]	CO_2 emissions from raw materials [10^6 t/a]
1987	29.399	34.171	15.6
1990	29.054	34.749	15.4
1994	29.222	35.804	15.5
1995	29.072	33.649	15.4
1996	27.668	32.858	14.7
1997	28.535	33.171	15.1
1998	29.038	34.681	15.4
1999	29.462	36.558	15.6
2000	28.494	34.685	15.1
2001	25.227	31.481	13.4

4.2 Mineral products: Lime production (2.A 2)

The calculation procedure for the lime production industry is currently being transformed. The explanations given here are not yet contained in the 2003 inventory supply, and represent the latest status in the debate on methodology. Consistent calculations in the CSE and descriptions in the NIR will only be available for the 2004 inventory.

4.2.1 Source category description (2.A.2)

The lime producing industry, in its CO_2 monitoring, refers to the Federal Environment Ministry BMU as its source for CO_2 EF (so-called Basic UN Agreement on Climate Change, 1994), which for the relevant fuels (used) is as follows:

Figures are given in t CO2/GJ: hard coal-0.093; hard coal coke-0.105; lignite coke-0.106; lignite dust-0.098; heating oil, heavy-0.078; heating oil, light-0.074; natural gas-0.056 [t CO2/ MWh]; liquid gas-0.065; other regular fuels-0.093; purchased electricity-0.67 [t CO2/ MWh]. The growing use of substitute fuels for which no records are yet available poses a problem. From the aforementioned EF and the quantities of fuel used, the CO2 emissions may be calculated (cf. Table 29).

Table 29: CO_2 emissions from the lime production industry

Fuel	Input quantity in 2001	CO_2 e. in 2001 [t]
Hard coal [t/a]	53,922	147,889
Hard coal coke [t/a]	228,319	685,670
Lignite coke [t/a]	3,676	11,664
Lignite dust [t/a]	388,891	818,091
Heavy heating oil [t/a]	44,928	142,327
Light heating oil [t/a]	10,979	34,718
Natural gas [MWh/a]	3,511,453	638,809
Liquid gas [t/a]	3,772	11,275
Other standard fuels [t/a]	795	1,582
Purchased electricity [MWh/a]	228,457	153,066
Total	-	2,645,093

During lime production, CO_2 is released during the deacidification of calcium carbonate ($CaCO_3$) to calcium oxide (CaO). The production of calcium oxide from dolomite ($CaCO_3$*MgCO3) is possible, but is of subordinate importance. Table 30 only lists the emissions from the raw material that are released during deacidification. The production and emission figures were supplied by the *Bundesverband der Deutschen Kalkindustrie* <German Lime Industry Association> and represent 90 % of production, and must therefore be extrapolated to a fictitious quantity of 100%.

Table 30: CO_2 emissions from German lime production

Year of reporting	1990	1995	1996	1997	1998	1999	2000	2001
CO_2 emissions in Gg	6.218	6.464	5.959	6.041	5.773	5.782	5.934	5.654

4.2.2 Methodological issues (2.A.2)

The estimate of CO_2 emissions follows the *IPCC Good Practice Guidance*:

$$CO_2 \text{ emission} = \text{Emission factor (EF)} * \text{lime production}$$

The decision tree in the IPCC Guideline has been followed in part. Data collation makes allowance for the quantities produced, but not the average composition of the raw materials. Current production is not classified on the basis of lime product types, and in particular, no allowance was made for its property as slaked lime with a corresponding water content. It is assumed that the precision of such a detailed calculation would not lead to a higher level of precision overall.

For CO_2 emissions from the raw material lime in the combustion process (deacidification), complete deacidification is assumed. The stoechiometry of the chemical compound calcium carbonate produces a proportion by mass of 44% CO2 and 56% calcium oxide. With complete deacidification, therefore, CO_2 is released on a ratio of 44/56, corresponding to a specific EF of **0.785 Mg CO_2 per Mg of lime product**.

With this calculation approach, it is clear that depending on the combustion process, partial deacidification may also occur. Similarly, dolomite portions in the raw material as well as the incorporation of CO_2 from the atmosphere may lead to deviating CO_2 emissions when using lime.

In view of the quality requirements placed by the industry on its products, these levels of contamination may be ignored. CO2 fixing still cannot be included in the balance of the limie-producing industry.

The activity rates for all years have been provided by the Federal Association of the German Lime Industry Association <*Bundesverband der Deutschen Kalkindustrie*> and correspond to approximately 90 % of total production, for which reason the figures have been extrapolated here to a fictitious 100%.

Table 31: Absolute lime production in Germany

Report year	1990	1995	1996	1997	1998	1999	2000	2001
Production in 106 Mg	7.92	8.23	7.59	7.70	7.35	7.37	7.56	7.20

4.3 Chemical industry (2.B)

4.3.1 Source category description: Ammonia production (2.B.1)

Ammonia is produced on the basis of hydrogen and nitrogen, using the Haber-Bosch technique. Hydrogen is obtained from synthetic gas. It is generated in a highly integrated procedure in 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 (stoechiometric H/N ratio)
- RPR - Reduced Primary Reformer Process under mild conditions in a fired primary reformer and secondary splitting with excess air (sub-stoechiometric 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-stoechiometric or stoechiometric H/N ratio).

The following procedure is also used:

- Partial oxidation – Gasification of fractions of heavy mineral oil or vacuum residues when producing synthetic gas

Most plants operate according to the principle of steam reforming with naphtha or natural gas. Only 3 % of European plants operate according to the procedure of partial oxidation.

Carbon dioxide emissions may arise with the following stages:

- Conversion of carbon monoxide to carbon dioxide,
- Absorption of carbon dioxide,
- Methanisation of residual quantities of carbon dioxide.

4.3.2 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 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 data on carbon dioxide emissions from ammonia production originates from a paper entitled “Final BAT Reference Document on Ammonia Production”, prepared in 1995/96 as a provisional MAT information sheet to serve as an initial example of the entire BREF process that has since been implemented. The data it contains are average figures from European countries.

Generally speaking the emission factor is estimated as follows:

Emission (kt) = Quantity of natural gas consumed (kt) x carbon content x 44/12

Alternatively, an estimate may also be implemented as follows:

Emission (kt) = Ammonia production quantity (kt) x emission factor (kt/kt)

4.3.3 Uncertainties and time-series inconsistency (2.B.1)

The emission factor is only an average value, and given the differing production conditions, cannot fully reflect the precise situation.

Because there are only seven ammonia producers in Germany, direct contact with a request to notify their carbon dioxide emissions could improve the data situation.

4.3.4 Source-specific planned improvements (2.B.1)

Not relevant.

4.3.5 Source category description: Nitric acid production (2.B.2)

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, nitrogen oxide and water are formed by the following unintentional 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 ammonia oxidation reactions are exothermic, and heat may be recovered to produce steam for the process and for export to other plants and/or to preheat the residual gas. The reaction water is condensed in a cooling condenser during the cooling of the reaction gases, and is then conveyed into the absorption column.

4.3.6 Methodological issues (2.B 2)

The known data for N_2O is based on measurements. The emissions depend on the technological situation and operating conditions and vary extensively from one plant to another, and even within the same plant.

4.3.7 Uncertainties and time-series consistency (2.B.2)

Given that the available database is insufficiently accurate, it would seem almost impossible to derive a uniform emission factor. In Germany, there are currently only six plants for the production of nitric acid. At present, the performance of more widespread measurements would appear to be the only option for improving the data situation.

4.3.8 Source-specific planned improvements (2.B.2)

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 ascertain more precise emission factors.

4.4 Metal production (2.C)

4.4.1 Source category description: Iron and steel production (2.C.1)

In Germany, crude steel is produced on the basis of ore in six mixed foundries. The production equipment used includes sintering plants, blast furnaces and oxygen steel plants with downstream continuous casting plants and hot-rolling lines.

Crude steel production based on scrap occurs in electrical arc furnaces in 16 electric steel works with downstream extruding plants and hot rolling lines.

The principal emission sources are as follows for:

Sinter (sinter plants)

Sinter belt exhaust fumes, room dedusting,

Pig iron (blast furnace)

Blast furnace charging, tapping and blast heating apparatus

Top-blown steel (oxygen steel works)

Primary dedusting with or without the use of converter gas, secondary dedusting (refilling of pig iron and crude steel, filling and emptying of the converter, secondary metallurgy, desulphurisation)

Electric steel (electric steel works)

Primary dedusting of the lid exhaust gases, secondary dedusting of the hall (charging, tapping, refilling of crude steel, secondary metallurgy as well as handling and storage of additives)

Hot rolled steel (hot rolled steel works)

Exhaust fumes from thermal treatment furnaces (the total production quantities shown in the statistics below for “3.16 *Hot-rolled steel products*” and “3.17 *Hot-rolled steel products from alloyed steel*” are used as a basis for the production figures).

Emissions of climate-relevant pollutants, particularly CO, CO_2, NO_x, SO_2 and MNVOC, occur at all process stages. Table 32 and Table 34 provide calculated emission factors for the year 2001. With rolled steel production, no differentiation has been made according to the steel production type (ore-based or scrap-based).

As a general principle, when measuring organic materials, individual substances and/or total carbon were ascertained. NMVOC (non-methane volatile organic compounds) measurements are not available from this sector.

4.4.1.1 Methodological issues (2.C.1)

The production figures and fuel consumption data for the year 2001 are taken from the series of documents published by the Federal Statistical Office, specialist series 4, series 8.1. The emissions factors were ascertained as follows:

The total quantity of waste gas produced per tonne of product during its production has been multiplied by an average concentration figure made up from several individual readings from different plants with a corresponding weighting. The emission factors also make allowance for diffuse emission sources. Emission measurements taken within the context of research and development and investment projects form the basis for the emission readings used.

Moreover, the emission factors were also compared with emission data in Best Available Technology (BAT) data sheets and other sources, such as emission inventories from the *Land* of North-Rhine Westphalia (NRW).

The data shown in Tables 32 and 34 refer to total emission factors.

Table 31: Emission factors for industrial furnaces in the iron and steel industry, including process-related emissions for the year 2001

Industrial furnace	CO2	CH4	N2O	NO_X	SO2	C total	CO
	kg/t	kg/t	kg/t	kg/t	kg/t	kg/t	kg/t
Sinter	179	ng	0.09	0.570	1.080	0.047	16
Pig iron	1634	ng	ng	0.038	0.063	0.008	ng
Hot-rolled steal	118	ng	ng	0.410	0.059	0.003	ng

ng: not given

The emission factors for sinter, pig iron and hot-rolled steel contain fuel-elated emission portions. In cases where no emission data was available, only the fuel-related emissions were determined. The report by the Federal Environmental Agency in Texte 14/00 entitled “Determination of average emission factors for the representation of emissions development from furnaces in the area of households and small consumers”, Table 7.21c Small Consumers (4th Ordinance on the Implementation of the Federal Immission Control Act <BImSchV>), page 261, was used as the basis for fuel-related emission factors. For blast furnace gas and coke oven gas, factors for SO_2 and NOX were derived from studies within the context of R&D projects, and applied (cf. Table 32).

Table 32: Emission factors for blast furnace gas and coke oven gas

	Unit	Blast furnace gas	Coke oven gas
SO2	kg/TJ	35	91
NOX	kg/TJ	8	38

Supplements to individual processes

Sinter

In the case of sintering plants, the above statistics only include the use of solid fuels. In addition, some 0.18 GJ/t final sinter of gaseous fuels are used for ignition. The resultant quantity of gaseous fuel is assumed as equal portions of blast furnace gas, coke oven gas and natural gas, and has been incorporated into the calculations. The computed emission factor for CO_2 was reduced by the CO_2 portion resulting from the CO share.

Top-blown steel

The CO emissions were calculated from measurements on secondary dedusting systems. Further CO emissions arising from the burning-off of primary gas containing CO were added to this. These are based on an estimate by the Environmental Agency of North-Rhine Westphalia dating from 1978.

In Germany, 68 % of top-blown steel production was produced in steel works with converter gas extraction, and 32 % in steel works without converter gas extraction. The converter gas is used as fuel gas in furnaces such as power stations. The CO_2 emissions associated with the combustion of converter gas in other furnaces was not taken into account at this process stage. The calculated CO_2 emission factors are based on a C content in pig iron of 37 kg/t of pig iron. The resultant CO_2 emission factor is 111 kg/t of crude steel. After deducting the CO_2 portion produced from a CO portion of 8 kg/t of crude steel, the emission factor for CO_2 is 86 kg/t of crude steel for steel works without converter gas extraction. With the same C content in pig iron, for steel works with converter gas extraction the above emission factor for CO_2 of 111 kg/t of crude steel was reduced by 73.5 kg/t of crude steel. This corresponds to a converter gas use of 0.7 GJ/t of crude steel. After deducting the CO_2 portion derived from a CO share of 8 kg/t of crude steel, the emission factor for CO_2 is 25 kg/t of crude steel for steel works with converter gas extraction. The CO and CO_2 data shown in Table 34 refer to total emission factors.

Table 33: Emission factors for industrial processes in the iron and steel industry excluding fuel-related emissions in the year 2001

Industrial process	CO2	NO_X	SO2	C total	CO
	kg/t	kg/t	kg/t	kg/t	kg/t
Top-blown steel	44.5	0.005	0.031	0.008	10.6
Electric steel	12.5	0.120	0.065	0.048	1.2

Electric steel production

Based on more recent data from research and development projects, emission factors were calculated for CO, CO_2 SO_2 and total carbon. These pollutants arise from the erosion of electrodes, organic adhesions to input material, and the addition of coal and natural gas. Changes in the emission factor for NOx are attributable to the use of DC electric arc furnaces.

4.4.2 Source category description: Primary aluminium production (2.C.3)

In Germany, aluminium is produced at five foundries in electrolysis furnaces with pre-burnt anodes. The principal emission sources are the waste gases from the electrolysis 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.

The largest source of PFC emissions in Germany, despite substantial reductions since 1990, remains the production of primary aluminium, where PFC is created in the production process as a side-effect of the electrolytic reduction of aluminium oxide to aluminium. Thanks to extensive modernisation measures in German aluminium foundries and the decommissioning of production capacity, absolute emissions from this sector have fallen by 76 % between 1995 and 2001.

4.4.2.1 Methodological issues (2.C.3)

The production figures for the year 2001 were taken from the monitoring report by the aluminium industry for the year 2001. The average anode consumption is 430 kg of petrol coke per tonne of aluminium. Table 3 shows the process-related emission factors. They were calculated as follows:

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 a corresponding weighting. The emission factors also make allowance for fugitive emission sources such as hall roof emissions. The emission figures used for CO and SO2 are the results of emission measurements within the context of investment projects.

The CO_2 emission factor was calculated from the specific anode consumption and reduced by the CO2 portion resulting from a CO content of 180 kg/t Al.

The emission factors shown in Table 35 were compared with the emission data in Best Available Technology (BAT) data sheets and other sources, including VDI Guideline 2286 sheet 1. These are process-related total emission factors.

Table 35: Industrial processes in primary aluminium production excluding fuel-related emissions in the year 2001

	Production	Emission factors						
		CO2	CF4	C2F6	NO_X	SO2	C total	CO
	kt	kg/t	kg/t	kg/t	kg/t	kg/t	kg/t	kg/t
Primary aluminium	652.796	1367	0.08	0.01	ng	6.00	ng	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 1998, the aluminium industry has reported annually on the development of PFC emissions from this sector. These emission figures are based on two measurement campaigns in all aluminium foundries conducted in the years 1996 and 2000. These initial figures are used together with the annually calculated operating parameters of the foundries in order to calculate emissions.

The measurements conducted in all German foundries in the year 2001 form the basis for calculation of the CF_4 emissions. In this context, specific CF_4 emission figures per anode effect were calculated, depending on the technology used. The number of anode effects was recorded and documented in the foundries. The total CF_4 emissions from a foundry was calculated by multiplying the total anode effects by the specific CF_4 emission per anode effect ascertained in 2001. The total emission factor for CF_4 is obtained by adding the CF_4 emissions of the five foundries divided by the total aluminium production of the foundries. C_2F_6 and CF_4 are produced in a fixed ratio of approximately 1:10.

Since 1998, an annual monitoring report produced by the aluminium industry organisation *Gesamtverband der Aluminiumindustrie e.V.* has provided the basis for reporting. The measurement data is not published, but is made available to the Federal Environmental Agency.

4.4.2.2 Uncertainties and time-series consistency (2.C.3)

The emission data satisfies the Tier 3a approach and is therefore rated as very precise.

4.4.2.3 Source-specific recalculations (2.C.3)

Up until 1998, emission data was based on surveys amongst the foundries with regard to production capacity and the techniques used (number and duration of anode effects) in order to determine emissions on a calculatory basis. This method (Tier 1 b) should be considered less precise than measurement. However, recalculation is not possible.

4.4.2.4 Source-specific planned improvements (2.C.3)

No further improvements are required.

4.4.3 Source category description: SF_6 in aluminium and magnesium production (2.C.4)

For the removal (degasification) of hydrogen, as well as alkaline and alkaline earth metals and solids, prior to casting in aluminium smelts, the inert gases nitrogen and/or argon are introduced to prevent porosity in the cast pieces. Generally speaking, the inert gases without additives are sufficient for rinsing secondary aluminium smelts. In a few, usually smaller, secondary aluminium foundries and in laboratories, a purification system of inert gases is used to which SF_6 is added at a concentration of 1 or 2.5 %.

When casting magnesium, SF_6 is used as a protective gas over the smelt to prevent its oxidation and ignition. SF_6 has been used in this application since the mid-Seventies, when it became a competitor to SO_2. Because SF_6 is easier to handle than the highly toxic SO_2, it became widely used in many new foundries. In Germany, protective gas is only used for the processing of magnesium that has been imported in ingot form.

4.4.3.1 Methodological issues (2.C.4)

The quantity of SF_6 used in Germany for this purpose of 500 kg is emitted completely during the course of its use (consumption = emission). The quantity is obtained directly from the only two suppliers of the gas mixture containing SF_6. The market for this is considered to be constant in the medium term.

The quantity of SF_6 used for magnesium production (consumption, activity) is equated with emissions in accordance with the revised IPCC Guidelines (1996). SF_6 consumption is best obtained by asking the foundries directly for their annual consumption, especially as the number of foundries is manageable. This input data is almost exactly consistent with the quantities sold by the gas dealers in this sector, who were likewise surveyed.

The method outlined was applied for the reporting years 1995, 1997, 1998, 2000 and 2001. The missing annual data is obtained by means of interpolation.

Table 36 contains an overview of the current status of data reporting (reporting year 2001). For the reporting years 1995 to 2000, certain other factors apply. Complete reporting is sub-classified more precisely into further sub-sectors in many areas. The factors for each sub-sector are given individually, whereas only an overview may be given here.

Table 36: Overview of data reporting and emission factors used in TABLE 2(II)s1, C. Metal Production

	Reported data 2001	Substance
Aluminium production	yes [Tier 3a]	CFC
SF_6 in aluminium production	yes [Equ. 3.12]	SF_6
SF_6 in magnesium foundries	yes [Equ. 3.12]	SF_6

4.4.3.2 Source-specific recalculations (2.C.4)

No recalculations were implemented.

4.4.3.3 Source-specific planned improvements (2.C.4)

Over the next few years, there are plans to review the market development of SF_6 in aluminium production. There are plans to conduct the future possibilities and improvements for SF_6 data collection in magnesium processing in collaboration with the magnesium processors themselves.

4.5 Production of halocarbons and SF_6 (2.E)

Apart from the conventional climate gases carbon dioxide (CO_2), methane (CH_4) and laughing gas (N_2O), the fluorinated greenhouse gases HFC, PFC and SF_6 were also included in the Kyoto Protocol. Unlike CO_2, CH_4 and N_2O, fluorinated greenhouse gases are for the most part produced deliberately and used in various applications. Because substances belonging to the substance group HFC – and in individual cases PFC – were developed as substitutes for the ozone-damaging CFCs and HCFC, their application areas are in part identical.

The most significant application areas for HFCs in Germany are cooling and air-conditioning systems, foams and technical and other aerosols, whilst those for SF_6 are its use as a filler gas in various applications, as a protective gas in magnesium processing, and as an insulating and quenching gas in electrical operating equipment. The principal application for PFC is its use as an etching gas in the semi-conductor industry.

Moreover, PFC emissions are created during the production of aluminium. Emissions of HFC-23 result from the production of HFCC-22; further HFC emissions are unavoidable during the production of these substances.

Emissions of these gases have exhibited varying development since 1990/1995; HFC emissions have increased sharply since 1990; this trend is continuing. Emissions of PFCs and SF_6, on the other hand, have actually decreased following an initial halt to rising emission levels, thanks to the efforts of industry and a successful environmental declaration. Given the considerably higher global warming potential (GWP) of PFC and SF_6 compared with HFC, total emissions in relation to CO2 equivalents have fallen to a level slightly below that of 1995, even though absolute emissions (in t) between 1995 and 2001 have almost doubled .

Current emissions of HFCs, PFCs and SF_6 in Germany were ascertained initially for the years 1995 to 1998. For the years 1998 and 1999, emissions were initially extrapolated based on the existing data. For the years 2000 and 2001, current emissions were again ascertained. Wherever possible, the Tier 2 approach was used for this purpose. The data for the years 1995 to 1999 was recalculated during the course of the new survey. Here too, the Tier 2 approach was widely used. In this way, Germany has ascertained and reported current, and in part potential, emissions for the reporting years 1995 to 2001 .

Table 37 provides an overview of the current status of data reporting (reporting year 2001). For the reporting years 1995 to 2000, other facts apply in part. In many areas, complete reporting is sub-divided into further sub-sectors. The factors for each sub-sector are also given individually, although only an overview can be given here.

Table 37: **Overview of data reporting and emission factors used** in TABLE 2(II)s1, E. (a) Production of halogenated hydrocarbons and SF_6

	Data reporting 2001	Substance
1. By-product emissions		
Production of H-CFC-22	yes [Tier 1]	HFC-23
Other	NO	
2. Manufacturing-related emissions	yes [Tier 1]	HFC, SF_6

4.5.1 Source category description: By-product emissions (2.E.1)

HFC-23 is incurred as a by-product of manufactured H-CFC-22. According to the largest manufacturer in Germany, up until 1995 this entailed approximately 1-2% of H-CFC-22 production which escaped from the production plant into the air unless it was captured for reprocessing into halons or refrigerants.

Since the CFC splitting plant in Frankfurt was commissioned in 1995, excess HFC-23 is added to the combustion process for hydrochloric acid, either directly or after delivery from the second German production plant, unless it is already collected at the production plant and marketed either as refrigerant HFC-23 or – following further distillatory purification – as an etching gas for the semi-conductor industry. Since 1995, emissions have been substantially reduced thanks to the downstream combustion process. Nevertheless, by-product emissions are still produced in the second H-CFC-22 plant, which the operator provisionally estimates at approximately 1 % of H-CFC-22 production. Precise measurements are planned for 2003.

4.5.2 Methodological issues (2.E.1)

For the reporting years 1995 to 2001, emissions have been calculated according to the production quantity of H-CFC-22, whereby for the reporting year 1995, measures for the avoidance of emissions have been used as a basis since the middle of the year for the first production plant. The production quantities were reported by the manufacturer.

4.5.3 Source-specific recalculations (2.E.1)

For 2003, precise calculations are planned by the operator of the second production plant, which could lead to recalculations.

4.5.4 Source-specific planned improvements (2.E.1)

At present and in future, measurements are conducted by the respective manufacturer aimed at achieving an improvement in data quality. The results will be incorporated into the next report.

4.5.5 Source category description: Production-related emissions (2.E.2)

In Germany there is only one company that produces these gases at two locations. Since 2001 (retroactively to the start of production), the company has been reporting both production and the associated losses. As the only producer of HFC in Germany, and now the only producer of SF6 in Europe, the company's confidentiality is protected. The data is reported to the Federal Environmental Agency, but then only disclosed in aggregate form.

4.5.6 Methodological issues (2.E.2)

For the reporting years 1995 to 2001, emissions were calculated according to the H-CFC-22 production quantity, whereby for the reporting year 1995, for the first production plant, measures to avoid emissions were used as a basis from the middle of the year onwards. The production quantities were reported by the manufacturer.

4.5.7 Source-specific recalculations (2.E.1)

There were no recalculations, since the measurements are only retroactive since 2001.

4.5.8 Source-specific planned improvements (2.E.1)

The data protection is considered adequate.

4.6 Consumption of halocarbons and SF_6 (2.F)

Table 38 provides an overview of the current status of data reporting (reporting year 2001): For the reporting years 1995 to 2000, other factors apply in part. In many areas, complete reporting has been subdivided more accurately into further sub-sectors. The factors for each sub-sector are also stated individually, but only an overview can be given here.

Table 38: **Overview of data reporting and emission factors used** in TABLE 2(II)s1, F. (a) Consumption of halocarbons and SF_6

1. Cooling and air-conditioning systems [Tier 2]				
Household cooling	**yes [Tier 2]**	HFC	0.0015	0.003
Commercial cooling	**yes [Tier 2]**	HFC, PFC	0.0015	0.015-0.15
Transport cooling	**yes [Tier 2]**	HFC	0.0015	0.05-0.15
Industrial cooling	**yes [Tier 2]**	HFC	0.0015	0.06
Stationary air-conditioning systems	**yes [Tier 2]**	HFC	0.0001-0.0015	0.02-0.06
Mobile air-conditioning systems				
Mobile air-conditioning, HGVs	**yes [Tier 2]**	HFC	0.0020	0.13
Mobile air-conditioning, cars	**yes [Tier 2]**	HFC	0.0025	0.10
Mobile air-conditioning, buses	**yes [Tier 2]**	HFC	0.0020	0.15
Mobile air-conditioning, ships	**yes [Tier 2]**	HFC	0.01	0.05
Mobile air-conditioning, rail vehicles	**yes [Tier 2]**	HFC	0.0020	0.05
2. Foam production [Tier 2]				
Hard foam	**yes [Tier 2]**	HFC		
Sandwich components	**yes [Tier 2]**	HFC	0.10	0.005
Integral foam	**yes [Tier 2]**	HFC	1.00	NA
PUR foam (134a)	**yes [Tier 2]**	HFC	0.03	1.00
PUR foam (152a)	**yes [Tier 2]**	HFC	NA	1.00
XPS foam (134a)	**yes Tier 2]**	HFC	0.30	0.0066
XPS foam (152a)	**yes Tier 2]**	HFC	1.00	NA
Soft foam	**NO**	HFC		
3. Fire extinguishers	**yes [national]**	HFC	0.0015	0.01
4. Aerosols/ metered dose inhalers				
Metered dose inhalers	**yes [Equ. 3.35]**	HFC	0.02	1.00
Other	**yes [Equ. 3.35]**	HFC	0.004	1.00
5. Solvents	**yes [Equ. 3.36]**	HFC		1.00
6. Semi-conductor production	**yes [Tier 2]**	HFC, PFC, SF_6		0.15-0.52

7. Electrical operating equipment					
	Data reporting 2001	**Substance**	**Production factor**	**Lifetime factor**	**Disposal factor**
Switchgear	**yes [Tier 3a]**	SF_6	0.020	0.01	0.015
Other	**yes**	SF_6	0.15	0.08	1
8. Other					
Sports shoes	**yes [Equ. 3.23]**	SF_6			1
AWACS maintenance	**yes [national]**	SF_6	0.00	0.05	
Car tyres	**yes [Equ. 3.23]**	SF_6	0.002		1
Insulated glass windows	**yes [Equ. 3.24ff]**	SF_6	0.33	0.01	1
Trace gas	**yes [Equ. 3.35]**	SF_6	1.00		

4.6.1 Source category description: Cooling and air-conditioning systems (2.F.1)

Companies have been using partially halogenated CFCs (HFC) since the early Nineties on an increasing scale, primarily as a substitute for ozone- and climate-damaging CFC and H-CFC. HFC emissions have risen sharply since 1995, and the trend is persisting.

Today, the main cause, accounting for 42 % of absolute HFC emissions (in t), lies in their use as refrigerants for stationary and mobile cooling. Almost half of these coolant emissions are attributable to car air-conditioning systems. As such, 20 % of all HFC emissions are attributable to this source alone.

4.6.1.1 Source category description – Cooling and stationary air-conditioning systems (2.F.1)

This area may be roughly divided into the sectors listed in Table 38:

Household cooling, commercial cooling, transport cooling, industrial cooling, stationary air-conditioning.

By far the most important pure HFC coolants in Germany are HFC-134a and mixtures 404A and 507, both of which consist primarily of 125 and 143a. The proportion of 134a and 404A/507 in annual new consumption together accounts for more than 90%.

4.6.1.2 Source category description: Mobile air-conditioning systems (2.F.1)

Mobile air-conditioning systems are vehicle air-conditioning systems in passenger cars, HGVs and commercial vehicles, buses, rail vehicles and ships. In terms of coolant stocks, consumption and emissions, car systems dominate, accounting for 95 % of each category.

Since late 1991, partially halogenated CFCs (HFC) have been used as ozone-neutral substitutes for CFC and HCFC. Almost 100 % of the HFC coolant used in mobile air-conditioning systems is R134a. There are two small exceptions: When converting old R12 air-conditioning systems, a drop-in coolant (mixture) was used instead of R134a in a small proportion of cases, which for its part consists of 88 % R134a. The second exception concerns new ship's air-conditioning systems, of which only one-half in Germany are filled with R134a, whilst the other half contains R404A/507.

4.6.2 Methodological issues (2.F.1)

4.6.2.1 Cooling and stationary air-conditioning systems (2.F.1)

For calculating HFC emissions from the sectors of cooling and stationary air-conditioning systems, the following key data was ascertained/estimated:

Scope of sectoral HFC stocks.

Composition of these stocks according to various HFC coolants.

Sector-specific emission factors from on-going operation.

Rate of coolant recovery during disposal.

Average plant service life (due to the timing of the first disposal emissions).

Apart from the recovery rate, which is currently assumed as the standard value proposed by the IPCC (IPCC 99) of 70 % of the original coolant filling in the absence of an empirical basis, all determining factors (key data) on which emission data are based are shown in Table 38. Because HFC has only been in use since 1991, the recovery rates have thus far been insignificant.

Regarding the breakdown of total stock into sectors, the consumption levels in the individual reporting years and for the absolute scopes and internal coolant compositions of the stocks, direct national information is obtained (enquiries about sales figures, production figures, utilisation figures); in addition, numerous recently published national and international studies were also evaluated.

The emission factors used are the result of literature evaluations and extensive expert surveys. It should also be noted that for the various reporting years, emission factors were adapted in line with technical developments. However, the methods did not change.

Caution is advised, particularly with the emission factors. The broad scatter of emission factors found in the literature for identical applications is only partly a consequence of technical changes in systems density or an expression of national differences. For the most part, it reflects real uncertainty, since there is still insufficient solid empirical research of such magnitude, which includes a study on supermarket emissions in Germany.

Given the aforementioned uncertainty with regard to emission factors, but also based on the large number of individual applications (systems), it is felt that further precision is needed with the emission data. In order to improve the reliability of data, it was compared against the sales data (material-related) of the manufacturers.

4.6.2.2 Mobile air-conditioning systems (2.F.1)

When calculating the HFC emissions from mobile air-conditioning systems, the following key data was ascertained/estimated:

- Scope of sectoral HFC stocks.
- For ships: Composition of these stocks on the basis of various HFC coolants.
- Sector-specific emission factors from on-going operation and as a result of accidents.
- Rate of coolant recovery during disposal.
- Average plant service life (due to the timing of disposal emissions).

As a general principle, the above statements on the stationary systems sector also apply here. However, the annual consumption levels of HFC may be calculated fairly precisely from the production, import and export of cars, which make up the bulk of this sector. In addition, the quota of cars equipped with air-conditioning systems and the model-specific fill quantities were also ascertained.

The emission factors used are the result of literature evaluations, measurements (cars) evaluations of workshop documentation, and extensive expert surveys. As well as regular emissions during operation, emissions also arise as a result of accidents and other external influences.

4.6.3 Uncertainties and time-series consistency (2.F.1)

The data quality is quite good and better than for stationary cooling and air-conditioning technology.

4.6.3.1 Cooling and stationary air-conditioning systems (2.F.1)

To date, Germany has only reported aggregate emissions across all sub-sectors. Within the context of the emissions survey for the years 1999 to 2001, the emissions for the reporting years 1995 to 1998 were reviewed and updated on the basis of new findings on input quantities and emission factors. This information is often only available with a considerable time delay and must therefore be estimated initially. The changes implemented are therefore not attributable to a change in the methodological approach, but merely to improved activities and technical information.

4.6.3.2 Mobile air-conditioning systems (2.F.1)

Based on the results of the expert report by the Federal Environmental Agency (UBA) and an on-going EU study on leakage rates from mobile air-conditioning systems (EU Commission 2003, ongoing), the emission factors previously assumed have been confirmed.

4.6.4 Source-specific planned improvements (2.F 1)

4.6.4.1 Cooling and stationary air-conditioning systems (2.F.2)

In future, an attempt will be made to improve data by means of prompt enquiries on consumption levels (repairs, refill quantities etc.). In view of the large number of systems (several million), however, emission data is likely to remain encumbered by uncertainties.

4.6.4.2 Mobile air-conditioning systems (2.F.2)

Further opportunities for improvement are only at the initial stages of debate.

4.6.5 Source category description: Foam production (2.F.2)

4.6.5.1 PU foam products (2.F.2)

PU foam products are comprised of soft foam, integral foam and hard foam. For soft foam, HFC is not required as a propellant. In hard foams, HCFC was used as a propellant prior to 1998, and HFC has only been used since 1998. Between 1995 and 1997, HFCs were only used in integral foam.

4.6.5.2 PUR foam (2.F.2)

Germany is the world's largest single market for polyurethane foam in can form. Can sizes of between 300 and 750 ml are sold. HFC and propane/butane are used in conjunction with dimethyl ether (DME) as a propellant. In Germany and in Central Europe in general, the industry, in a growing awareness of the climate-damaging effects of HFC, has reduced its use. Increasingly, HFC-152a – which has a lower greenhouse gas potential – is being used instead of HFC-134a.

4.6.5.3 XPS hard foam (2.F.2)

For XPS boards, no consumption or emissions of HFC occurred prior to 1999, since HCFC or CO_2 were still being used.

From the year 2000 onwards, a number of domestic producers turned to HFC solutions. Since 2001, 152a and 134a have been used as propellants, either alone or mixed together.

4.6.6 Methodological issues (2.F.2)

4.6.6.1 PU foam products (2.F.2)

The emission data are based, firstly, on the quantities produced in Germany (production-related emissions), and secondly, on the quantities used in Germany (sales in Germany). From the sales figures, it is possible to calculate the emissions in the first year, in subsequent years and at the end of the service life using the specified emission factors (Tier 2).

Apart from the recovery rate, for which sector-specific standard values proposed by the IPCC (IPCC 99) are generally used in the absence of an empirical basis, all determination factors on which the emissions data is based are shown in Table 1. Because HFC has only been in use since 1998, the recovery rates have thus far been insignificant.

For the classification of the total stock into sectors (boards ["sandwich"] and integral), the sales figures (foam containing HFC) in the individual reporting years and for the composition of the propellants, national information (enquiries relating to sales figures, production figures, utilisation figures) was obtained, and numerous international studies recently published were also evaluated.

As in the cooling/air-conditioning sector, the emission factors used are the result of evaluations of the literature and extensive expert surveys. It should also be noted that for the various reporting years, emission factors were also adapted in line with technical developments, and the propellants used have also changed.

The emissions data for prior years is considered fairly accurate, since the quantities of HFC 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.

4.6.6.2 PUR foam (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 approximately 40 % of the highly flammable gases propane, butane, and dimethyl ether (DME), and approximately 60 % HFC which is low-flammable (152a) or non-flammable (134a). The proportion of HFC used in the propellant gas has shown a declining trend since 1995; in 1995 it was 84 grams in a 660 g can, whereas by 1997 this figure had fallen to 75 g. Today, a maximum of 60 g or less than 10 % of the foam weight is HFC.

When calculating emissions, it is assumed that the doses will be used by the professional craftsman or DIY enthusiast within six months of sale at the latest. The HFC emissions for the year *n* are therefore determined as the sum total of half the sales in the year *n-1* and the year *n*. The doses consumed are not completely empty at the time of disposal, but still contain around 8 % foam including propellant. The bulk of this propellant eventually enters the atmosphere with a time delay. The same also applies to the 30 % doses that are brought to the central recovery plant for PU foam cans.

The assumptions regarding losses during production and disposal, the details on fill quantity and on the propellant ratio are based on repeated expert surveys (expert estimates), with due allowance for the development over the individual reporting years. The total quantities of cans consumed refer to sales figures in Germany.

4.6.6.3 XPS hard foam (2.F.2)

Around 3 to 3.5 kg of halogenated propellants are used per cubic metre of foam. Of this, in the case of 134a, at least 25 % is already emitted at the production plant, and in the case of 152a almost the entire propellant. Collection and recovery trials have been conducted, but to date no systems have been implemented for both technical and economic reasons.

Where 152a is used for foam production, the remaining propellant diffuses almost completely from the boards in the factory warehouse. 134a, on the other hand, remains in the product and degases almost as slowly as 142bg. The half-life for a 100 mm thick board for 134 a is 76 years, whilst for 142b it is 84 years. The annual emission factor of 0.66% for the entire product mix used here is based on a 100 mm board thickness.

The emission factors used are also the results of evaluations of the literature and extensive surveys amongst manufacturers and experts alike.

The emission data is based, firstly, on the quantities produced in Germany (production-related emissions), and secondly on the quantities used in Germany (sales in Germany). From the sales figures it is possible to calculate the emissions in the first year, in subsequent years and at the end of the service life using the emission factors given (Tier 2).

4.6.6.4 PU foam products (2.F.2)

HFC has only been in use since 1998, so that within the context of current emission surveys, only the data for the reporting years 1998 to 2000 is reviewed. Recent information on HFC consumption has been addressed, but no significant recalculations were implemented.

4.6.6.5 PUR foam (2.F.2)

On the basis of discussions with the AKPU, recalculations were carried out concerning the proportion of HFC in the individual dose and the HFC composition between 152a and 134a.

4.6.6.6 XPS hard foam (2.F.2)

No recalculations were implemented.

4.6.7 Source-specific planned improvements (2.F.2)

4.6.7.1 PU foam products (2.F.2)

HFC has only been in use since 1998, so that within the context of current emission surveys, only the data for the reporting years 1998 to 2000 was reviewed. Recent information on HFC consumption has been noted, but no significant recalculations were implemented.

4.6.7.2 PUR foam (2.F.2)

The procedure corresponds to the Tier 2 approach. The emission data is fairly accurate, because the data on domestic production, export and import is known and there are only a few filling companies. In collaboration with the manufacturers, work is underway to further improve the data situation.

4.6.7.3 XPS hard foam (2.F.2)

The option of a monitoring system is currently under discussion with the manufacturers and industry associations. The process is currently still in its infancy.

4.6.8 Source category description: Fire extinguishers (2.F.3)

Halons, which were permitted as fire extinguishers until 1991, have since been largely replaced by ecologically sound materials. In interior room sprinkler systems, primarily inert gases (nitrogen, argon) are used instead of halon 1301. Hand-held fire extinguishers for a targeted jet of extinguisher now contain powder, CO_2 or foam instead of halon 1211.

Of the proposals originating from the USA on halon substitution (HFC-23 and 236fa, HFC-227, PFC-218 and PFC-3110), HFC-227 was licensed in Germany in 1997. It is sold under the trading 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.

4.6.9 Methodological issues (2.F.2)

The emission figures are based on statistical surveys by a company on input quantities, refill quantities, accidental releases, releases in case of a fire, and trial floodings in Germany. The data is considered to be of a good quality. However, it does not cover the entire market, as there is one other supplier, who admittedly has only a very minimal market share.

4.6.10 Source-specific recalculations (2.F 2)

No recalculations were implemented.

4.6.11 Source category description: Aerosols/metered dose inhalers(2.F.4)

4.6.11.1 Source category description: Metered dose inhalers for asthma sufferers (2.F.4)

In Germany, the first metered-dose inhaler containing propellant 134a was launched on the market in April 1996, followed by two more in 1997 and 1998. There are now sufficient HFCpowered metered-dose inhalers for almost all active ingredient groups, so that the use of CFC may be dispensed with. As well as 134a, HFC-227 is also used.

4.6.11.2 Description of methodology (2.F.4)

The emission data is based on sales figures of metered-dose inhalers in Germany obtained via surveys of producers. An emission of 100 % in the year of sale is assumed.

4.6.11.3 Source-specific recalculation (2.F.4)

No recalculations were implemented.

4.6.11.4 Source-specific planned improvements (2.F.4)

No further improvements are planned at present.

4.6.11.5 Source category description (2.F.4)

In Germany, HFC is used and sold in a range of aerosol products in small quantities (units). Examples include cooling and compressed air sprays in electronics, as well as insecticide sprays.

4.6.11.6 Description of methodology (2.F.4)

The emission data is based on estimates on the sale of aerosols in Germany, obtained via surveys of producers. An emission rate of 100 % in the year of sale is assumed.

Compared with the emission data on metered-dose inhalers, this data is not considered to be very good, since the market overview is limited in view of the large number of products.

4.6.11.7 Source-specific recalculation (2.F.4)

No recalculations were implemented.

4.6.11.8 Source-specific planned improvements (2.F.4)

Improvements have been initiated in collaboration with the industry association.

4.6.11.9 Source category description: Solvents (2.F.5)

The use of HFC was banned in Germany up until the year 2001 (2nd Ordinance on the Implementation of the Federal Immission Control Act <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. No such uses are known to date.

4.6.11.10 Description of methodology (2.F.5)

The emissions result solely from the use of HFC-43-10mee from the year 2001 onwards and are the result of a manufacturer survey.

4.6.11.11 Source-specific recalculation (2.F.5)

No recalculations were implemented.

4.6.11.12 Source-specific planned improvements (2.F.5)

There are plans to conduct a survey of the applications submitted to and approved by the competent *Länder* authorities in the year 2005 at the latest.

4.6.11.13 Source category description: Semi-conductor production (2.F.6)

In the semi-conductor industry, PFC is predominantly required in the form of etching gases for structural etching and for chamber purification and is used in large quantities. In addition, HFC, SF_6 and NF_3 are also incorporated into the production process. 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, from the fact that only partial chemical conversion occurs in the plasma reactor, 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. Effective emissions depend primarily on the waste gas purification technologies used.

4.6.11.14 Description of methodology (2.F.6)

From the year 2001 onwards, on the basis of a voluntary commitment by the semi-conductor industry, good emission figures are available for this source category for all individual substances. The emission data is calculated for each production site based on the Tier 2 approach, then aggregated and reported by the industry association (German Electrical and Electronic Manufacturers' Association (ZVEI), Components Division) to the Federal Environmental Agency. The basic data for calculation is not publicly accessible but may be inspected for review purposes.

4.6.11.15 Source-specific recalculation (2.F.6)

Up until the reporting year 2000, emission figures were based on surveys of semi-conductor producers with regard to production capacities, the quantities of material used, and the technologies employed. This emission data is likewise considered to be fairly accurate. No recalculations were implemented.

4.6.11.16 Source-specific planned improvements (2.F.6)

Precise specification of data collation and emissions calculation is being sought in collaboration with the industry association.

4.6.11.17 Source category description: Electrical operating equipment (2.F.7)

Electrical operating 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 is added to new equipment and systems in the national inventory.

SF_6 is used primarily in high-voltage (110-380 kV) and medium-voltage (10-30 kV) switchgear and switching systems, where the gas is used both as an extinguisher and as an insulating material instead of air. It is not commonly used in the low-voltage segment (< 1 kV).

4.6.11.18 Description of methodology (2.F.7)

Since 1996, emissions have been determined on the basis of a highly detailed concept developed by the Federal Environmental Agency in collaboration with the manufacturers and operators. The installed quantity at the end of a given year and the emissions at the individual sources (factory losses by the manufacturers, assembly losses by the manufacturers, leakage at the operators (including maintenance), and disposal) are all ascertained.

4.6.11.19 Source-specific recalculation (2.F.7)

No recalculations were implemented.

4.6.11.20 Source-specific planned improvements (2.F.7)

In future, the CAPIEL concept applied in Europe should be used in Germany, so as to standardise the methods. Under this method, total emissions (E) are determined according to the formula E = consumed quantity – installed/existing quantity. Allowance is also made for exports and imports. The CAPIEL concept is consistent with the provisions on emissions calculation under the UNFCCC reporting instructions (Tier 3b).

4.6.12 Other (2.F.8)

4.6.12.1 Source category description: Sports shoes (2.F.8)

SF_6 is used in sports shoes to improve shock absorbency. The quantities used may be equated with emissions, whereby a time lag of three years is assumed.

4.6.12.2 Description of methodology (2.F.8)

The emission data (relevant sales of such sports shoes in Germany and hence the total quantity in Germany) is based on manufacturer information.

4.6.12.3 Source-specific recalculation (2.F.8)

No recalculations were implemented.

4.6.12.4 Source-specific planned improvements (2.F.8)

No improvements are needed.

4.6.12.5 Source category description: AWACS (airborne warning and control system) maintenance (2.F.8)

SF_6 is used as an insulating medium for radar in the AWACS surveillance aircraft. It is intended to prevent electrical crossovers in the so-called hollow conductors towards the antenna, where there are high voltages in excess of 135 kV.

4.6.12.6 Description of methodology (2.F.8)

The emission data is based on details of the consumption quantities for maintenance of the NATO AWACS fleet. Because AWACS aircraft are to be retained for the next few years, no changes to SF_6 emissions are anticipated.

4.6.12.7 Source-specific recalculation (2.F.8)

No recalculations were implemented.

4.6.12.8 Source-specific planned improvements (2.F.8)

No improvements are intended at present.

4.6.12.9 Source category description: Car tyres (2.F.8)

Another source of SF_6 in Germany concerns car tyres, which are filled with SF_6 for image-related reasons (the improved pressure constancy is not relevant in practice). Tyre manufacturers have since renounced advertising this application in view of the climate relevance of SF_6, which has led to a substantial decline. The bulk of today's emissions originate from old tyre fillings.

The peak consumption year was 1995, when over 500 of the 3,500 or so sales outlets for the German tyre trade had the option of filling tyres with SF_6 gas.

4.6.12.10 Description of methodology (2.F.8)

Emissions are ascertained on the basis of the consumption quantities, which are obtained from gas dealers and manufacturers (SF_6). Emissions follow consumption with a time lag of approximately 3 years, when the tyre is dismantled.

4.6.12.11 Source-specific recalculation (2.F.8)

No recalculations were implemented.

4.6.12.12 Source-specific planned improvements (2.F.8)

No further improvements are intended at present.

4.6.12.13 Source category description: Insulated glass windows (2.F.8)

As insulated multiple glazing gained popularity over single-glazing for windows and glass facades in the Seventies, since 1975 SF_6 has been filled into the cavity between the glazing as a form of noise insulation. At present, emissions from sound-proof windows represent the largest source of SF_6 emissions. However, the slight improvement in sound proofing obtained from using SF_6 is associated with inferior thermal insulation. The higher priority given to thermal insulation e.g. by the Thermal Insulation Ordinance, as well as the higher greenhouse gas potential of SF_6, have led to a reduction in the use of SF_6 in this application since the Nineties.

4.6.12.14 Description of methodology (2.F.8)

In order to ascertain emissions, firstly, the total consumption of SF_6 is obtained from the gas trade. Although emissions cannot be equated with this consumption, they do originate from it with a time delay. SF_6 emissions from sound insulated windows are comprised of three different categories, the quantitative significance of which changes over time: Filling losses of an average of 33 % of input are incurred in the year of production alone, and are directly proportionate to the annual consumption of SF_6. Stock emissions refer to gas losses from the filled pane totalling approximately 1 % per annum over its entire service life (an average of 25 years). Finally, disposal losses are incurred at the end of the pane's utilisation period, 25 years after the filling emissions.

Calculation is based on the above method, which is consistent with the IPCC method, and therefore, the emission data can be assumed to be of good quality.

4.6.12.15 Source-specific recalculation (2.F.8)

No recalculations were implemented.

4.6.12.16 Source-specific planned improvements (2.F.8)

No further improvements are intended at present.

4.6.12.17 Source category description: Trace gas (2.F.8)

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.

4.6.12.18 Description of methodology (2.F.8)

Emissions may be equated with the quantities used. The quantities used are determined on the basis of expert estimates and are fairly imprecise. The survey is only implemented around every five years, since according to expert opinion input quantities vary only minimally.

4.6.12.19 Source-specific recalculation (2.F.8)

No recalculations were implemented.

4.6.12.20 Source-specific planned improvements (2.F.8)

No improvements are intended at present.

4.7 Other sources (CRF sector 2)

5 SOLVENTS AND OTHER PRODUCT USE (CRF SECTOR 3)

5.1 Source category description (3)

This source group comprises emissions from the use of chemical products. At present, it contains a rough calculation of emissions from the use of N2O for narcotic purposes and data on the release of solvents from their use in industry, commerce and private households.

5.2 Methodological issues (3)

The calculation of N_2O emissions from the use of narcotics is based on an extrapolation of the statistical plant survey conducted in 1990. At the time, it was ascertained that one plant for the production of N_2O for narcotic purposes 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 suggested that there were no exports or imports of this substance, so that it was assumed that it was used entirely for domestic consumption. Regarding the per capita emission calculated from this for the former GDR, assuming the identical conditions, an N_2O emission of 6200 t for Germany was roughly estimated. Since then, this figure has been constantly updated.

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.

5.4 Source-specific recalculations (3)

A revision and recalculation of the time series is envisaged for NIR 2004.

5.5 Source-specific planned improvements (3)

This year, a research project was offered for tender which, *inter alia*, will examine emissions from the material release of N20 in its various potential applications. The various opportunities (including explosives production) will be examined, methodological specifications determined, documentation prepared, and the relevant recalculations amended in or added to the inventory.

6 AGRICULTURE (CRF SECTOR 4)

The German inventories of dinitrogen oxide and methane emissions from agricultural sources were prepared using the respective handbooks of the United Nations Economic Commission for Europe (UN/ECE, cited as EMEP/CORINAIR 2000) and the Intergovernmental Panel on Climate Change (IPCC, cited as IPCC 1996). The calculation methods and the provision of activity data are described in detail in Dämmgen et al. 2002. Livestock figures are taken from the agricultural statistics (Federal Statistical Office Specialist Series 3, Series 4), disregarding the city-states. In the absence of statistical data in other areas, it is not possible to model the emission factors for the city-states.

6.1 Enteric fermentation (4.A)

6.1.1 Source category description (4.A)

Germany reports on the emissions of methane (CH_4) from enteric fermentation in the farming of dairy cows, other cattle (cows, calves, heifers, and female and male beef cattle), pigs, sheep and horses.

6.1.2 Methodological issues (4.A)

The calculation of emissions is based on methods described as simpler methods in EMEP/CORINAIR (2000); they have been adopted by IPCC Tier 1 (1996). Essentially, the emission factors reflect Germany's situation, but the default values for Western Europe from EMEP (chapter B 1040) are used. The activity data (number of animals) was taken from the agricultural statistics (Federal Statistical Office, specialist series 3, series 4; for details cf. Dämmgen et al. 2002).

6.1.3 Uncertainties and time-series consistency (4.A)

The uncertainties regarding methane emission factors are in the region of 30 %, whilst those regarding the number of animals per category are in the region of 10 % (EMEP/CORINAIR 2000, chapter B 1040 6). For the new *Länder*, the livestock numbers and their regional distribution for the years 1990 and 1991 were calculated using the RAUMIS model, which supplies regional data for agricultural production processes and products. As the data sources do not vary with the years, the time series is considered to be consistent.

6.1.4 Source-specific QA/QC and verification (4.A)

Future QA/QC procedures pre-suppose the further development of methods and a better breakdown of activity data.

6.1.5 Source-specific recalculations (4.A)

Emissions from enteric fermentation were calculated according to the same method for the entire time series.

6.1.6 Source-specific planned improvements (4.A)

There are plans to calculate enteric fermentation according to the Tier 2 method from 2003 onwards.

6.2 Storage of commercial fertilisers (4.B)

6.2.1 Source category description (4.B)

Methane (CH_4) and dinitrogen oxide (N_2O) are produced during the storage of commercial fertilisers. Germany reports on CH_4 and N_2O emissions from dairy cows, other cattle (cows, calves, heifers, female and male beef cattle), pigs, sheep and horses.

6.2.2 Methodological issues (4.B)

The calculation of CH_4 emissions is based on the methods described in EMEP/CORINAIR (2000) as a simpler method; the method is consistent with that of the IPCC (1996). The emission factors essentially reflect Germany's situation; the default values for Western Europe from EMEP/CORINAIR (chapter B 1040 4) are used. The activity data (number of livestock) is derived from annual agricultural statistics (Federal Statistical Office specialist series 3, series 4).

The calculation procedure for N_2O emissions (simpler methods) and the corresponding standard values for storage types were taken from IPCC 2-4.33 and 4.10 ff. It is assumed that emissions of N compounds account for 20 %. The N amounts from excrement were estimated according to the simpler approach.

The activity data (livestock figures) is derived from annual agricultural statistics (Federal Statistical Office specialist series 3, series 4).

6.2.3 Uncertainties and time-series consistency (4.B)

The uncertainties are outlined in EMEP/CORINAIR (2000) and apply to Germany as well until further notice. The time series is consistent.

6.2.4 Source-specific QA/QC and verification (4.B)

Future QA/QC procedures pre-suppose the further development of methods and the better breakdown of activity data.

6.2.5 Source-specific recalculations (4.B)

None.

6.3 Agricultural soils (4.D)

6.3.1 Source category description (4.D)

The inventory contains direct N_2O emissions from nitrogen fertilisation with mineral N fertilisers, commercial fertilisers, as well as biological N fixing and plant residues in the soil. N_2O emissions from the cultivation of organic soils are likewise included as a direct emission source. Indirect N_2O emissions are calculated from the atmospheric deposition of ammonium (NH_4), elutriated N and the outflow of applied or deposited N.

6.3.2 Methodological issues (4.D)

The calculation methods and the origin of the activity data are outlined in detail in Dämmgen et al. 2002, chapter 4.1, 4.2.

6.3.3 Uncertainties and time-series consistency (4.D)

The uncertainties are outlined in EMEP/CORINAIR (2000) and apply to Germany as well until further notice. The time series is consistent.

6.3.4 Source-specific QA/QC and verification (4.D)

Future QA/QC techniques pre-suppose the further development of the methods and the improved breakdown of activity data.

6.3.5 Source-specific recalculations (4.D)

None.

6.3.6 Source-specific planned improvements (4.D)

Future calculations of indirect emissions will utilise N mass flow calculation techniques for animal husbandry and avoid the use of default values.

7 LAND USE CHANGES AND FORESTRY (CRF SECTOR 5)

Generally speaking, the calculations of greenhouse gas emissions (GHG) for land use changes and forestry (LUCF), in accordance with the general reporting framework (CRF; 5A-E), are based on linking emission factors to activity data which characterise the contribution of human activities leading to emissions or to fixations. Lacking or insufficient activity data for land use and land use changes (LULUC) are the most difficult obstacles faced by GHG reporting for agriculture. At present, methods are being drawn up to ensure that future reporting requirements can be met by compiling pre-existing data series and closing any data gaps. The following chapters (5.B-5.D) indicate the current starting situation and broadly outline the data situation for organic soil carbon and land use changes.

7.1 Changes in forest resources and other biomass stocks (5.A)

The data refers to forest as defined by the Federal Forest Inventory:

“Within the meaning of the Federal Forest Inventory (BWI), irrespective of the data in the inventory or similar directories, forest shall refer to any area of land forested with forest plants. Felled or cleared areas of ground, forest paths, forest glades, wild grazing areas, timber storage areas, riding cuts situated in the forest, other recreational facilities associated with the forest, overgrown heaths and moors, overgrown former meadows, upland pastures and woodland pastures, as well as areas of mountain pines and green alders, shall likewise be classified as forest. Heaths, moors, pastures, upland pastures and woodland pastures shall be deemed overgrown if the natural vegetation has achieved an average age of 5 years and covers at least 50 % of the area. Forested areas of less than 1000 m2 located in farmland or in developed regions, narrow thickets less than 10 m wide, and Christmas tree and decorative brushwood cultivations as well as parkland belonging to a residential area, shall not constitute forest within the meaning of the BWI. Watercourses up to 5 m wide shall not constitute an interruption to the cohesiveness of a woodland area.“ (BML 1992)

Other wooded land not conforming to the above definition of forests shall be disregarded. This report shall not include details of carbon stocks in wood products.

7.1.1 Source category description (5.A)

Depending on stock development, forests may be a net sink or a source for CO_2. The green plants absorb CO_2 from the atmosphere during photosynthesis, and fix the carbon in their biomass in the form of organic compounds. The photosynthesis of plants is therefore a CO_2 sink.

During respiration, when dead sections of plant are removed by animals, funguses and micro-organisms, and during the combustion of biomass, CO_2 is once again released; these procedures are sources of CO_2. The carbon contained in wood removed from the forest during timber harvesting is released into the atmosphere as CO_2 over long periods during the various handling and processing stages of the timber, parts of it remaining for decades or even centuries until the product reaches the end of its useful life.

In the method currently recommended by the IPCC for determining the net source or sink from forest management, a simplistic assumption is made that harvested wood is converted completely into CO_2 in the year of the wood harvest. According to this methodological approach, which is also employed in Germany, it is therefore possible to determine the source or sink effect of the forest by comparing growth with wood harvest. This method underestimates the sink effect of the forest, because part of the harvested wood is converted into long-lasting products (such as furniture) and therefore is not emitted as CO2 in the same year.

The comparison between growth and wood harvest in Germany currently produces an increase in the biomass stocks stored in the forest. In other words, more C is incorporated into the vegetation than is removed from the forest (and released) as a result of the wood harvest. The German forest is currently a net sink for CO_2.

During the course of forest management, emissions from fossil energy resources are also incurred on a modest scale, e.g. from the consumption of fuels to operate forest machinery. Allowance has been made for these emissions in the energy chapter.

The activity data required in this chapter of the greenhouse gas inventory is the **forested area**, the average annual **biomass increase** in t of dry mass per hectare, and the annual **timber harvest** in kilotonnes (Gg=10^9g) of dry mass.

7.1.1.1 Activity data – Forested area

The data on forested area originates from the Federal Forest Inventory for the old Federal *Länder* (BWI I) and the *Datenspeicher Forestfonds* (Forest Management Database) for the new Federal *Länder*, and refer to the status in 1990. Any area changes that have occurred since that date as a result of the conversion of forest into a different utilisation type and afforestation have been disregarded. Germany's forested area totals 10.74 million hectares, of which 10.4 million hectares are wooded, i.e. the portion stocked with forest plants that is used for timber production. The rest is so-called non-wooded area, including for example forest paths, forest glades, timber storage areas, riding cuts or recreational facilities located within the forest.

The wooded area is further sub-divided into commercial forest and "non-productive forest area". The latter refers to areas with an annual wood growth of less than 1 m3/ha, including for example mountain pine and green alder fields in the mountains, areas of bushes and other sparsely forested or less-productive forest areas. BWI I found some 180,000 ha of these types of locations in the old Federal *Länder*; such data is not available for the new Federal *Länder*.

Some 80,000 ha is attributable to glades, i.e. areas that were temporarily unforested (i.e. harvested or destroyed by acts of nature and not yet reforested) at the time of recording. The **productive forested area** therefore totalled **10.144 million hectares** (cf. Figure 19 and Table 39); the growth and timber harvesting data depicted below are based on this.

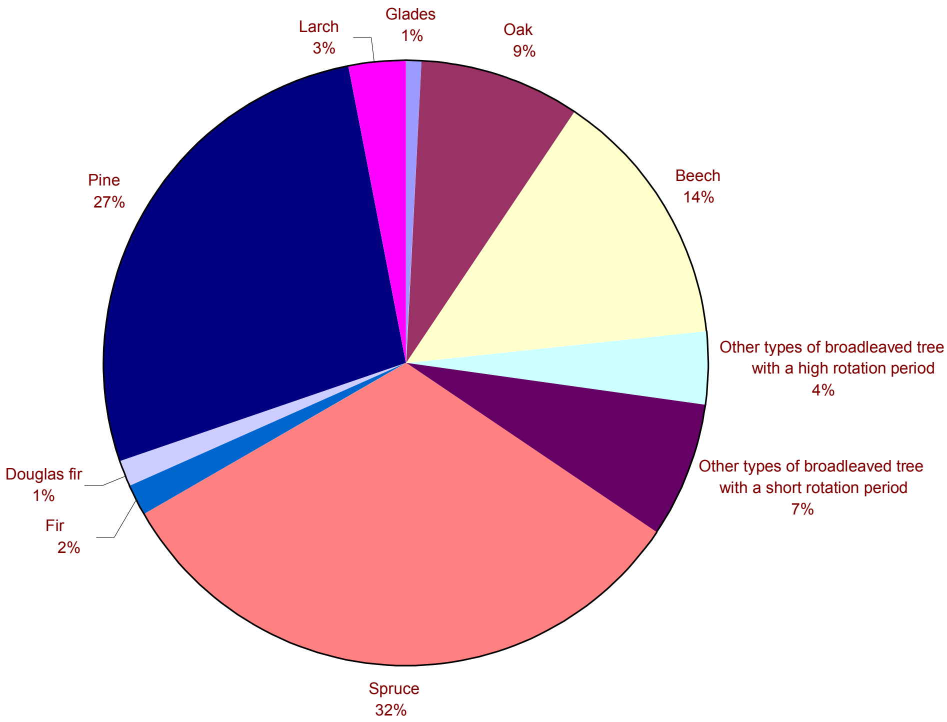


Figure 19: Productive forest area by species

Table 39: Overview of forest area 1990

Tree species	Area (ha)
Oak[13]	876,476
Beech[14]	1,424,206
Other types of broadleaved tree with a long rotation period[15]	397,860
Other types of broadleaved tree with a short rotation period[16]	744,835
Spruce[17]	3,299,281
Fir[18]	160,277
Douglas fir[19]	133,683
Pine[20]	2,807,175
Larch[21]	300,088
Total productive forested area	**10,143,881**
Glades	81,604
Total productive forest area	**10,225,485**
Non-productive forest	182,252
Non-wooded	332,908
Total forest area	**10,740,645**

[13] All species of oak including red oak
[14] Fagus sylvatica
[15] Hornbeam, ash, sycamore, Norway maple, field maple, lime, elm, cherry, robinia, sweet chestnut, wild service tree (Carpinus betulus, Fraxinus excelsior, Acer platanoides, A. pseudoplatanus, A. campestre, Tilia spec., Ulmus spec., Prunus avium, Robinia pseudacacia, Castanea sativa, Sorbus torminalis)
[16] Birch, alder, poplar, balsam poplar, willow, rowan (Betula spec., Alnus, Populus, Salix, Sorbus aucuparia) and other broadleaved trees not listed in the tree species catalogue
[17] All picea species and all other coniferous tree species not listed separately
[18] All species of fir (*Abies spec.)*
[19] Pseudotsuga menziesii
[20] All species of pine (*Pinus spec.)*
[21] All species of larch (*Larix spec.)*

The areas cited should not be interpreted as pure stocks of the tree species mentioned, but instead correspond to the sum total of land applicable to the respective tree species, whereby the tree species may occur in a variety of mixed species and combined forms. For this reason, it was not possible to separate the land into coniferous and broadleaved tree stocks as required by the Common Reporting Format. Instead, the entire forested productive area was summarised under one line, “*broadleaved and coniferous*”.

7.1.1.2 Activity data – Biomass growth

Biomass growth was estimated at **4.27 t of dry mass per ha, per annum**.

(For details of how this figure was derived, see “Methods“)

7.1.1.3 Activity data – Wood harvest

Here, timber harvest is taken to mean any quantity of wood removed, including thinning out and unregulated felling. Timber harvest data is taken from the felling statistics, from which averages were formed for 5-year periods (1990-1994, 1995-1999); from the most recent period under consideration, 2000-2004, data is currently only available for the years 2000 to 2001. The increased value for 2000 to 2001 compared with the periods 1990-94 and 1995-99 is a consequence of the severe hurricane “*Lothar*“, which swept through the South-West of Germany on 26 December 1999. Those trees that were felled and damaged by the storm were, for the most part, processed in the year 2000 and were therefore incorporated into the felling statistics for that year.

Table 40: Timber harvest in dry mass

	kt dm p. year
1990 - 1994	24 919.88
1995 - 1999	25 077.43
2000 - 2001	30 371.11

7.1.1.4 Emission factors - Summary

Carbon bound by biomass growth: **2.13 t C/ha*annum**

Carbon released by wood harvest: **0.5 t C/t dry mass**

7.1.2 Methodological issues (5.A)

Account of the calculation methods used to determine emission data – deviations from the IPCC methodology, explanatory comments and justifications for any deviations from the IPCC methodology (e.g. country-specific methods– default IPCC)

Calculations were carried out in accordance with the IPCC method based on a comparison of wood growth and timber harvest. In accordance with the IPCC default method, it was assumed that the carbon contained in the harvested timber was released completely as CO_2 in the year of harvesting.

All data refers to **overground woody biomass**. Roots and stumps were disregarded, both with regard to growth and with regard to timber harvest. Leaves, needles and ground vegetation were likewise disregarded.

Growth estimates were made using the standard yield tables used in Germany. For the required conversions from wood volume into mass units and into total biomass, species-specific expansion and conversion factors were used which had been published by various different authorities for use in Central Europe. When calculating the carbon content of the total biomass, recourse was made to the IPCC estimate of 0.5.

7.1.2.1 Derivation of growth

The "Common Reporting Format" requires that growth should be specified in tonnes of dry mass per hectare. This figure has been derived from other data via a number of conversion stages, as outlined below.

Stage 1: Determination of growth in Vfm_D (solid cubic metres)

In the forestry industry, growth is generally specified as solid cubic metres per hectare, and in Germany as solid cubic metres with bark. Solid volume refers to trunk and branch wood with a diameter of 7 cm or more. Thinner wood is referred to as branchwood.

Growth was broken down according to tree species, with due regard for the parameters measured in the Federal Forest Inventory, and the age category distribution in the relevant year 1990 was estimated with the aid of yield tables (cf. Table 41)

Table 41: Current growth (Vfm_D/ha*annum)

Tree species	Growth	Yield table	Federal *Länder*
Oak	6.1	Erteld 1961	BB, MV, SN, ST, TH
		JÜTTNER 1955	BW, BY, HE, NI, NW, RP, SL, SH
Beech	8.9	SCHOBER 1967, moderate thinning out	BW, BY, HE, NI, SW, RP, SL, SH
		DITTMAR, KNAPP, LEMBCKE 1983, average maintenance of trunk numbers	BB, MV, SN, ST, TH
Other tree species with a high rotation period	46	WIMMENAUER 1919	all
Other tree species with a low rotation period	4.0	SCHWAPPACH 1903/29	BW, BY, BB, HE, NI, NW, RP, SL, ST, SH
		MITSCHERLICH 1945	MV, SN, TH
Spruce	11.4	WENK, GEROLD, RÖMISCH 1984	BB, MV, SN, ST, TH
		WIEDEMANN 1936/42	BW, BY, HE, NI, NW, RP, SL, SH
Fir	8.3	HAUSSER 1956	all
Douglas fir	8.9	BERGEL 1985	BW, BY, HE, NI, NW, RP, SL, SH
		SCHOBER 1956	BB, MV, ST, TH
Pine	6.9	WIEDEMANN 1943	BW, BY, HE, NI, NW, RP, SL, SH
		DITTMAR, KNAPP, LEMBCKE 1975	BB, MV, SN, ST, TH
Larch	8.4	SCHOBER 1946	All

Stage 2: Extrapolation of the growth in solid volume into growth of overground wood volume (sawtimber growth)

The growth of overground wood volume (sawtimber growth) was derived from the growth in solid volume with expansion factors. It was derived from the average expansion factor of 1.45 published by BURSCHEL et al. 1993, whereby root portions of 21.2% for broadleaved trees and 31.4% for coniferous trees were deducted. Root biomass, as well as leaves and needles, were disregarded.

Table 42: Expansion factors converting solid volume into sawtimber volume

Tree species	Expansion factor (m3/VfmD)
Coniferous trees	1.14
Broadleaved trees	1.24

Stage 3: Conversion of wood volume (m³) into dry mass (t)

To this end, the **bulk density** of the principal wood species was used. The bulk density indicates the dry mass in relation to fresh volume. Because timber harvest data is only available for the four wood type groups oak, beech (including other hardwood), spruce (including fir and other softwood) and pine/larch, the other tree species had to be allocated to these wood type groups for calculation purposes, including the growth figures, for reasons of comparability.

The conversion is based on the following bulk densities:

Table 43: Bulk density (t dry mass/m^3 fresh volume)

Oak	Beech including other hardwood	Spruce including other softwood	Pine including larch
0.56	0.55	0.37	0.43

According to KNIGGE and SCHULZ, 1966

Stage 4: Conversion of dry mass into tonnes of carbon

A carbon content of 0.5 tonnes of carbon per tonne of dry mass is assumed.

Stage 5: Carbon fixing in D: Total and hectare figure:

For each tree species or species group, calculations are based on the following formula

Area (ha)*growth (VfmD (solid cubic metres)/ha)*expansion factor (m3/ VfmD (solid cubic metres)) *spatial density (tTM (dry mass)/ m3) *0.5(tC/tTM (dry mass))

The sum total across all tree species produces an annual growth of 43,295,560 t of dry mass. Divided by the productive forested area, this produces a figure of **4.27 t** dry mass per hectare, per annum.

This in turn produces a carbon absorption figure of **21,647.78 Gg C per annum** for Germany or 2.13 tC/ha*a.

This contrasts with the carbon released from timber harvests.

7.1.2.2 Timber harvest

The timber harvest data classified according to species groups was taken from the felling statistics.

Table 44: Timber harvest by timber groups

	1990 - 1994		1995 – 1999		2000 - 2001	
Species groups	m³ per annum	Biomass t dry mass	m³ per annum	Biomass t dry mass	m³ per annum	Biomass t dry mass
Oaks	1,086,200	1,139,682	1,336,200	1,401,991	1,748,000	1,834,067
Beech and other hardwoods	6,161,000	5,653,515	7,452,600	6,838,725	8,852,000	8,122,856
Spruce and other softwoods	25,930,400	13,937,702	21,048,800	11,313,821	27,037,500	14,532,773
Pine/larch	6,380,600	4,188,978	8,412,400	5,522,890	8,958,500	5,881,415
Total	**39,558,200**	**24,919,876**	**38,250,000**	**25,077,428**	**46,596,000**	**30,371,111**

Not only is branchwood left behind in the forest as logging debris; so too is unusable solid volume. In order to account for this, the harvest amount taken from the felling statistics was converted into standing stock. The other expansion and conversion factors are the same as those described for growth. The values listed under "*biomass*", which were transferred into the "*Total biomass removed in Commercial Harvest*" field in the CRF, therefore includes logging debris left behind in the forest.

7.1.3 Uncertainties and time-series consistency (5.A)

The uncertainties surrounding the volume and area information from Federal Forest Inventory I (relevant year 1987) are minimal. The random sample error for volume data of the species groups ranges between 1 and 3 %. The area error is approximately 1 %. As such, the uncertainties regarding stock estimates can be classified as negligible. No accuracy data can be given with regard to the growth estimates, since this were derived from yield table estimates, as outlined above.

For the territory of the new Federal *Länder*, no accuracy data can be given, because this information is not derived from random sample techniques. No error margins can be given for subsequent conversion stages, because there is no data available on the error of the conversion and expansion factors used.

7.1.4 Source-specific QA/QC and review (5.A)

QA/QC was applied for Federal Forest Inventory I <BWI I> (relevant year 1987). At least 5 % of the forest tract was checked by control staff (BML 1986). All calculations in the BWI were checked by the Federal *Länder* and experts. A quality assurance procedure for the subsequent calculation stages for the derivation of carbon storage has not yet been developed.

In recent years, estimates of carbon storage in German forests have been submitted by UN-ECE/FAO (2000) (TBFRA 2000) and by DIETER and ELSASSER (2002). Both estimates are considerably higher than the figures given in the greenhouse gas inventory. In the case of

TBFRA 2000, this is primarily attributable to the use of the 1995 IPCC estimate for wood density of 0.5 t/m³. In the light of the high proportion of softwood, particularly spruce, in growth and timber harvest, this figure is too high. Moreover, the root biomass was also included. In the work of DIETER and ELSASSER, additional compartments such as leaves and needles, the tree and bush sub-stratum and the root biomass are included in the estimate. For calculation purposes, somewhat higher expansion factors and higher figures for wood density were assumed.

None of the aforementioned studies is suitable for a complete independent review, since they are based on the same growth estimates derived from BWI I as the data used in the greenhouse gas inventory. A review and further development of the estimate and calculation methods is planned once the results of the 2nd Federal Forest Inventory (BWI II) become available.

7.1.5 Source-specific recalculations (5.A)

Up until the greenhouse gas inventory 2000, C was converted into CO_2 was conducted using the rounded factor of 3.67. With this year's inventory, for the first time, the non-rounded conversion factor 44/12 (=3.66666666....) was used. For the years 1990–1999 this produces a slight deviation compared with earlier inventories. The data for 2000 and 2001 corresponds to the average for 2000 to 2001.

7.1.6 Source-specific problems (5.A)

Difficulties/problems during inventory preparation

The growth was estimated from yield tables because to date, only one forest inventory has been carried out on the basis of random samples.

The **forest area** and the **species proportions** are based on the year 1990. Since then, retirements (conversion into a different form of utilisation), additions from afforestation and natural succession, as well as displacements in species composition, have been disregarded, since there are no nationwide aggregated data available on this.

The **timber harvest data** originates from heterogeneous sources and was derived using various measurement and estimate methods: Generally speaking, for high-quality rough-sawn timber, the volume is measured on the individual trunk. For industrial timber, random sample techniques (e.g. surface measurement) and incoming factory measurement on the basis of weight (oven-dry and air-seasoned). Cordwood (firewood and industrial wood in short form) is measured in cubic metres. Some of the timber harvest quantities from privately owned forests have been estimated. For statistical purposes, all figures measured or estimated in other dimensional units are converted. There is uncertainty with regard to the quantities of wood used by the owners of private forests for their own requirements.

7.1.7 Source-specific planned improvements (5.A)

It is anticipated that the currently ongoing Second Federal Forest Inventory (BWI II) (relevant year 2002) will bring about a major improvement in the database. The results are expected in 2004. Up-to-date, reliable data on forests will then be available for the whole of Germany.

For the *old* Federal *Länder*, the following data will be available on the basis of measurements conducted in a systematic network of random samples: changes in forest area and stock changes between 1987 and 2002, growth and timber harvest data. For the *new* Federal *Länder* which joined the Federal Republic of Germany in 1990, BWI II represents the first inventory based on this technique. In those *Länder*, until the next inventory, growth and stock changes can only be estimated on the basis of the forest structure determined by BWI II. However, BWI II is expected to produce key findings to effect an improvement in the estimate.

7.2 Forest and grassland conversion (5.B)

7.2.1 Source category description (5.B)

This category actually comprises the conversion of existing forest and natural grassland into other forms of land use. CO_2, CH_4, CO, N_2O, NO_X and NMVOCs are emitted during the combustion and decomposition of biomass. As there are no natural grasslands in Germany, this section must consider the conversion of forest land into agriculturally used land, i.e. into managed pastures or arable land, as well as conversions in the opposite direction. Burning-off is an uncommon conversion method and is banned by federal law. The conversion of forest and agriculturally used land into human settlements, infrastructure and other forms of utilisation must likewise be considered.

7.2.2 Methodological issues (5.B)

The principal problem is to compile suitable activity data which fulfils the quality requirements for this task. At present, no valid estimates are available for this category.

7.2.2.1 Activity data on land use and land use changes (5.B)

In the past, land use and land use changes in Germany, depending on their intended purpose, were recorded with a variety of different methods and not with a view to logging climate-relevant parameters. The data thereby obtained from various studies invariably varies and is only comparable to a limited extent.

The most comprehensive survey of land use is the land register survey (land survey), i.e. the compilation of land use entries in the land registers (cf. Table 45). However, use is not verified locally by the officials, so the actual use may deviate from the registered use of a piece of land. Moreover, the land registers are not always entirely up-to-date but instead lag behind actual land changes to a certain extent. As a general principle, the survey is conducted every four years. The data is only suitable under certain conditions for use within the context of IPCC reporting.

Table 45: Land area by actual use type (areas in 1000 ha)

Year	Buildings and open spaces	Recre-ational area	Transport area	Agri-cultural area	Forest area	Water area	Other	Total land area
1993	2066	231	1633	19543	10433	780	1012	35697
1997	2194	237	1678	19314	10491	794	994	35703
2001	2308	266	1712	19103	10531	808	975	35703

7.2.2.2 Activity data for arable land and grassland

Data on agricultural land may be found in the main survey of land use, which records agriculturally used land, differentiated on an annual basis according to utilisation and cultivation types. The survey is conducted every four years on a general basis, and on a representative basis in the intervening years. It covers all agricultural operations with 2 ha or more of land, as well as operations with less than 2 ha of land which meet or exceed certain minimum limits of special cultivations or livestock levels. These statistics have a very high level of accuracy. The extent of land that falls beneath the detection level is comparatively insignificant and should be disregarded when observing land changes. Because a company's land holdings are allocated to its registered domicile, there may be a lack of clarity with respect to spatial distribution with detailed regional classification (local authorities, districts).

The results of the main land use survey form the basis for the on-going production statistics, and have so far been used primarily to assess the supply situation and the generation of income in agriculture, to meet reporting obligations to the EU, and for advisory and forecasting purposes in the agricultural sector.

7.2.2.3 Forest activity data

The information on forest area originates from the Federal Forest Inventory and its East German counterpart, the *Datenspeicher Waldfond,* and has already been outlined in chapter 5A (cf. 7.1 for details).

Comprehensive data on the conversion of forest into other land use types is not available. In Germany, forest area is increasing, i.e. conversions from forest into another form of use is being overcompensated in area terms. Land use changes from forest into forms of use only concern around 0.02-0.03% of the total forest area each year. Timber incurred from such land is likely to be incorporated into the timber harvest statistics, at least in part, and should therefore already be included in CRF 5 A (cf. Chapter 7.1).

When calculating C emissions from land use changes, it is important to avoid duplicate counts as a result of this.

7.3 Abandonments of managed lands (5.C)

7.3.1 Source category description (5.C)

This group comprises the fixation of CO_2 via the conversion of formerly managed land (i.e. fields or pastures) into abandoned land. The groups 5C1-5C5 cited in the CRF are distinguished according to the type of biomass that subsequently grows on the abandoned land. In Germany, only group 5C2 "*Temperate Forests*" is applicable, since this is the type of vegetation which naturally occurs under the given climatic conditions.

7.3.2 Methodological issues (5.C)

The principal problem concerns the compilation of activity data which meets the quality requirements for this task. At present, no valid estimates are available for this source category.

7.4 CO2 emissions and removals from soil (5.D)

Emissions and removals of CO_2 from soil, linked to land use and management, include CO_2 emissions from the liming of agricultural soils.

7.4.1 Source category description (5.D)

Soils are the end product of a very lengthy physical, chemical and biological development process in the transitional area from the lithosphere to the atmosphere. Soils are characterised by the fact that they contain organic material (substances containing C and N that are formed and modified by biological processes). The release or removal of CO_2 in soils is essentially determined by changes to this organic carbon (C_{org}) stored in the soil. A release of CO_2 may also occur from inorganic sources, such as naturally occurring carbonates or added lime (liming). According to CRF, only emissions from liming should be reported. Changes in the C supply of the soils tend to occur primarily in the uppermost soil strata (cultivation horizon, root penetration space). They are the result of a discontinuation in a flux equilibrium between the addition of organic carbon via photosynthesis in the plants, and biological degradation processes in the soil. The smallest agricultural unit for which uniform management can be assumed is the plot.

However, it cannot be assumed that a plot comprises only one uniform type of soil. The determining factors for the C content are the so-called management factors, such as the type of plants cultivated, the type of soil cultivation, the quantity and nature of nutrients added to the plants (fertilisation), and the climate. In Germany, this information is not recorded throughout all regions, differentiated according to soil types. According to CRF, the net carbon flows should be determined on the basis of a sliding 20-year difference. This data is not available classified according to soil type.

The liming of soils is a measure carried out in order to avoid soil acidification from plant activity and atmospheric discharges. Data on liming is available from the fertilisation statistics via domestic sales of mineral fertilisers containing lime and other nutrients. These are given in tonnes of nutrients or in tonnes of oxides (e.g. CaO) with the following distinctions:

- Fertiliser type
- For lime: Use for agriculture or forestry
- Federal States.

The data is recorded every quarter and per financial year (July/June) as an official statistic with compulsory disclosure. Annual data may differ from the summated quarterly data, because concluding reports from the companies subject to compulsory reporting are taken into account when processing data for the financial year which may deviate from the quarterly figures already reported.

7.4.2 Methodological issues (5.D)

In order to report on emissions and removals of CO_2 in soils as a result of LULUCF, it is necessary to calculate changes in the C content in forest as well as in agricultural soils. Because insufficient direct CO_2 flow measurements are available, the C balance approach is currently the only sensible choice. Activity data for this purpose must be further sub-divided into soil categories or types and must be further categorised on the basis of management types. In order to describe a change in the stock, two series of activity data at different times are needed. In the past, the extent of carbon stock changes in Germany's soils was only a subject of scientific interest in that it provided an insight into the procedure of global substance cycles, or issues relating to the structuring of agricultural management. To this end, permanent soil experiments were created which would supply findings by observing changes in the soil at the respective location, and then be transferred by way of example to other soils. The concept of a C inventory in agricultural soils, changes in which are to be reported in full, correctly, verifiably, regularly and annually, is very recent. Because carbon supplies in soil were of no significance for agricultural and economic policy in the past, they were not included in the official Federal statistics. The 1996 soil status survey in the forest includes carbon supplies in soil, but not changes thereto.

7.4.3 Data used for provisional C supply estimates

The task of collating data on the spatial distribution and availability of soils and minerals, and making this information available to the general public, falls to the Federal Institute for Geosciences and Natural Resources (BGR). The spatial distribution of soil associations in Germany is provided in the form of a digital soil map on a scale of 1: 1 000 000 (BUEK 1000). The soil maps are based on the proportionate allocation of discrete profile information (obtained at individual points in the landscape) on land units (polygons) on the map. The profiles provide quantitative information on a range of key factors measured. These include information on C content, soil density and skeleton proportions, classified according to depth. However, as soils are considered static elements within the context of soil maps, soil maps also contain information which was never intended to be allocated to a given monitoring period. Consequently, the information is comprised of profile investigations which may originate from widely divergent periods.

In the interests of requisite reporting, therefore, soil maps are an indispensable aid, but do not provide the required information *per se*.

7.4.4 Uncertainties and time-series consistency (5.D)

At present, there are no qualified calculations available on CO_2 emissions and removals from soils during the period in question, 1990-2001, according to CRF. Provisional C supply estimates for agriculture are based on the soil maps with a scale of 1: 1 000 000 (BUEK 1000). The data for forestry in Table 46 to Table 49 originates from the same data source and is only included for the sake of completeness. The percentages of arable land, pasture land and forest land were taken from the database "CORINE Landcover"; they deviate slightly from the land use data in Table 45. More precise data for the provisional C supply estimate for forestry is based on the soil status survey in the forest (1987-1993). A synthesis will be drawn up in future.

7.4.4.1 Agriculture

One approach for estimating the current C supply in German soils on the basis of the soil map on a scale of 1:1,000,000 (BUEK 1000) is presented below. BUEK 1000, which was prepared by the Federal Institute for Geosciences and Natural Resources (BGR), represents Germany's classification into 71 legend units (leading soil associations). Although the scale of the map is not sufficiently detailed, a rough estimate of C supply may be made on the basis of this map combined with a large number of assumptions. The meta-database belonging to BÜK 1000 lists reference soil profiles for all relevant legend units, in part classified according to utilisation types. The soil profile data comprises all horizons occurring in a depth of up to 2 m, as well as their vertical expansion. For all horizons, according to the mapping instructions, 4 (KA 4) items of classified data are available on skeleton content, dry raw density and humus content. For each legend unit, the area (polygon area total) is given in km^2, together with the percentages of arable land, grassland and forest land, derived from the CORINE Land Cover model in accordance with the BGR classification.

The C content was calculated on the basis of this data and the assumption that the reference soil profile is representative of the entire legend unit. For certain types of usage (arable land/grassland), missing soil profile data (humus content) was added, assuming a ratio of 1:1.5 between arable land and grassland. In accordance with K4, the humus content ranges were specified at the respective class averages, for contents of more than 300 to 350 mg g^{-1}. These figures were converted with the ratio humus content x 0.58 = organic carbon (C_{org}). The dry raw density classes 1-7 in accordance with K4 were transformed into the densities 1.0-1.6 kg dm^{-3}. Data on skeleton content was disregarded. The results of these calculations are outlined in Table and Table .

Table 46: C supplies in Germany's soils up to a depth of 2 m (in Pg C)

	Arable	Grassland	Forest	Total
Min. soils	1.33	0.33	0.58	**2.25**
Org. soils	1.44	3.24	0.02	**4.69**
Total	**2.77**	**3.57**	**0.60**	**6.94**

Table 47: Average C contents in Germany's soils (0-2 m; in t ha^{-1})

	Arable	Grassland	Forest	Weighted average
Min. Soils	83	110	57	**77**
Org. Soils	2460	3683	92	**2854**
Weighted average	**166**	**910**	**58**	**224**

For the sols of Germany's land used for agricultural and forestry purposes, this produces a total content of 6.9 Pg C. IPC 2000 specifies the global soil carbon supply at ~2000 Pg. Taking into account Germany's share of the earth's total land mass (area D ~ $0.357 * 10^6$ km^2 ; land area of the world ~ $130 * 10^6$ km^2), then the figure of 6.9 Pg exceeds the calculatory global share of 5.5 Pg. This is plausible, since soil supplies are higher at higher latitudes and more moderate climates than in other regions.

According to the CRF, only the carbon supplies in the top 30 cm of the profile should be considered. This is also feasible with the data basis of BÜK 1000. In this case, profile sections which exceed the depth of 30 cm are only considered on a proportionate linear basis. The relevant data is shown in Table 48 and Table 49

Table 48: C supplies in Germany's soils up to a depth of 30 cm (in Pg C)

	Arable	Grassland	Forest	Total
Min. soils	0.99	0.24	0.52	**1.76**
Org. soils	0.24	0.54	0.01	**0.79**
Total	**1.23**	**0.78**	**0.54**	**2.55**

Table 49: Average C contents in Germany's soils (0-30cm; in t C ha^{-1})

	Arable	Grassland	Forest	Weighted average
Min. soils	62	80	51	**60**
Org. soils	406	609	80	**479**
Weighted average	**74**	**198**	**58**	**82**

This shows that 78 % of the C supply in mineral soils is present in the top 30 cm, whereas only 17 % is found in organic soils. Because organic soils may be more than 2 m thick, it is to be assumed that the C supplies in these soils were not fully covered by this evaluation.

For mineral arable soils, according to BÜK 1000, the average C content is 62 t ha^{-1}. The Revised Guidelines (IPCC 1996) specify a "default" procedure for estimating C supplies in soil. For soils with a high and low level of activity in moderate, cool, damp climates, like those existing in Germany, this procedure assumes a C content of 80 t ha^{-1} under natural vegetation. By using the "default" factors of 0.7 for long-term cultivation, 1.0 for full soil working and 1.2 for a high discharge, this produces an anticipated C content for arable soils of 57 t ha^{-1}, whereas the same procedure calculates an anticipated C content for grassland of 88 t ha^{-1}. With due regard for the existing uncertainties in both calculations (in BUEK 1000 and IPCC 1996), a surprisingly good level of correlation with the figures shown in **Fehler! Verweisquelle konnte nicht gefunden werden.** is ascertained.

However, it remains clear that BUEK 1000 is incapable of identifying a supply change (ΔC), nor is it suitable for confirming data on land use distribution from the land use survey.

7.4.4.2 Forest

The available C_{org} supply data for forest soils originate from the first soil status survey in the forest (sampling period 1987-1993). The total C supply up to a depth of 30 cm, including the humus layer, is 0.858 Pg. The average content per ha up to a depth of 30 cm including the humus layer is 80.2 t C. Both figures are higher than those calculated according to BUEK 1000. Some of these deviations may be explained by the fact that BUEK 1000 does not make allowance for the profile data of any top humus. For example, the profiles in BUEK 1000 typically contain lower C_{org} contents under forest than profiles of the same soil type under arable land or pasture land. This is inconsistent with the general realization that forest soils contain higher stocks of C_{org} than arable land. This indicates that when using soil maps as a source for calculating the soil carbon supply, it is important to proceed with extreme caution.

7.4.4.3 Liming

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.

It must be noted that the data describes deliveries by producers and importers to wholesalers and end users. They do not provide direct information on the annual use of fertilizers in agriculture and forestry.

- Differences are possible due to changes in warehouse stocks
- The use of fertiliser outside of agriculture and forestry, e.g. on private land, gardens, sports facilities

Up 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, data from the BMVEL based on GDR statistics was converted into the same categories as the fertiliser statistics in the Federal Republic of Germany to facilitate comparison. For the years 1990-1992, the data on GDR fertiliser consumption was updated on a linear basis in the absence of relevant surveys. From 1993/94 onwards, the results are surveyed and published for a unified Germany.

7.4.5 Source-specific QA/QC and review

At the present time, no source-specific QA/QC and reviews for C_{org} stocks are available. For liming it can be said that this data is based on the official fertilizer statistics under the Federal Statistics Act with the usual high-quality specification. General principles include neutrality, objectivity and scientific independence. The companies are required by law to provide truthful, comprehensive information.

7.4.6 Source-specific planned improvements

After considering the situation and the need for compliance with the reporting requirements following ratification of the Kyoto Protocol, activities were introduced to obtain the required information on agricultural soils (2001; 53.5 % of the total area). However, the difficulties of retrospectively estimating the C supply for prior years, particularly for the base year 1990, remain unresolved.

7.4.6.1 Agriculture

The current unsatisfactory data situation in the area of agricultural land use needs urgent improvement with a view to reporting within the context of the Framework Convention on Climate Change.

A number of steps have been initiated aimed at effecting a lasting improvement. These will address the following techniques for obtaining data:

- **Inventories** (direct measurements of the soil carbon on a random sample conducted repeatedly at regular intervals) and the performance of repeat inventories at the Federal Forest Inventory and the forest soil status survey
- **Statistical surveys** (information collated regularly on land management affecting the whole of Germany and with due regard for the geographical distribution of soil types),
- **Mathematical modelling** (for each financial year, mathematical calculations on the anticipated changes in soil carbon prepared using the information from the statistical surveys and climate events),
- **Long-term soil experiments** (continuation of the experiments, regular annual measurements on them and the merging of the information acquired in order to derive national C factors).

By 2006, the pre-requisites should be in place for qualified reporting in the area of carbon supply changes in agricultural soils.

7.4.6.2 Forests

At present, the second soil status survey is under preparation, and is scheduled for the period 2006 to 2008. It is anticipated that once evaluations of the first and second forest soil status survey are available, it will be possible to calculate the changes in the C_{org} supply in forest soils.

7.4.6.3 Liming

Data on liming will be provided in the next report to CRF5 D.

8 WASTE AND WASTE WATER (CRF SECTOR 6)

8.1 Solid waste disposal on land (6.A)

8.1.1 Source category description (6.A)

In the calculation, a distinction is made between:

- Controlled landfills (CRF: 6 A 1)
- Unsanctioned landfills (CRF: 6 A 2)
- Other landfills (CRF: 6 A 3)

Only controlled landfilling is of relevance for German emissions reporting. It concerns the:

- Landfilling of waste from human settlements
- Landfilling of sewage sludge

Special waste landfills, construction rubble landfills, ash and slag landfills are also operational. However, with reference to the existing reporting obligations, relevant emissions are only anticipated from landfills for waste from human settlements and sewage sludge landfills. Unsanctioned landfilling is prohibited by law in Germany.

8.1.2 Methodological issues (6.A)

8.1.2.1 Landfilling of municipal waste

According to [IPCC 2000, 5.1.1], methane is the relevant greenhouse gas from the landfilling of waste. It only specifies calculation methods for the determination of methane. The default methods are distinguished according to Tier 1 and Tier 2 method. Tier 2 describes an equation of the first order and, theoretically, emulates the development of landfill gas formation over time more precisely. For this purpose, however, historical data (dating back to the Sixties) on waste volumes and waste composition is needed. As this historical data cannot be reconstructed with the required degree of accuracy – not least in view of Germany's special history and the large number of sites – and the other specifications required in both default methods entail a high level of uncertainty, methane emissions from the landfilling of waste are calculated here using the Tier 1 method.

a) Default method - Tier 1 [IPCC 2000, 5.1.1.2]

$$CH4\ (Mg/yr) = [(MSWT * MSWF * L0) - R] * (1 - OX)$$

The terms "MSWT" and "MSWF" refer to the portion of MSW (municipal solid waste) that is landfilled. During the subsequent consideration of methodology, this is referred to as "MSW".

The term L0 refers to the methane generation potential of the landfilled waste and in [IPCC 2000] this is determined via a further calculation formula:

$$L0 = MCF * DOC * DOCF * F * 16/12\ (Mg\ CH4/Mg\ waste)$$

The term R refers to the quantity (Mg/yr) of methane recovered annually via collection systems. For the purposes of implementation in the calculation method, it is expedient to define the term R as recovered landfill gas as a proportion of total landfill gas arising. At IPCC, the term MCF is used for controlled landfills with a default value of 1. This value may be used consistently for Germany, with due regard for the IPCC criteria [IPCC 2000, chap. 5.1.1.2, Table 5.1] and is therefore not considered in any further depth in the calculation formula.

As such, this produces the following:

$$CH4\ (Mg/yr) = (MSW * DOC * DOCF * F * 16/12) * (1-R) * (1 - OX)$$

Parameter	Description		Default
MSW:	Amount of MSW landfilled (Mg wet)	Quantity of municipal solid waste that is landfilled (Mg/year)	
MCF:	Methane correction factor	Factor for incorporating the quality of landfill management	1
DOC:	Degradable organic carbon	Proportion of degradable organic carbon in the waste (%)	*)
DOCF:	Fraction of DOC dissimilated	Proportion of DOC converted into landfill gas (%)	50-60%
F	Fraction by volume of CH4 in landfill gas		40-60%
16/12:	Conversion from C to CH4	Methane conversion factor	
R	Fraction recovered	Proportion of CH4 arising which does not escape diffusely	0%
OX	Oxidation factor	Factor for determining the proportion of CH4 that is oxidised	10%

*) Default values differentiated according to waste components (paper, garden waste, food waste, wood)

Handling for the purpose of emissions reporting in Germany

The IPCC method outlined is used to determine CH4 emissions. DOC, DOCF, F and R are adapted in line with the national situation.

- DOC = 18%; according to [Wallmann 1999, page 118/119]
- DOCF = 50%; according to [Rettenberger/Stegmann 1997, page 277]
- F = 50% (mean from the range of default values to IPCC)
- R = 44.4%, representative value for German landfills with due regard for landfills with high and low levels of gas collection
- OX = 10%

For the activity rate MSW, recourse is made to the statistics of the Federal Statistical Office [StaBa FS 19/ series 1]. This is updated at 3-yearly intervals.

The activity rates of the time series are specific for the reference years given. However, time-dependent adaptation of the terms DOC, DOCF and F cannot be achieved using the available data. Overall, waste management measures during the Nineties (e.g. increasing separate collection of biowaste and packaging waste) resulted in constancy of the aforementioned terms. The waste on east German landfill sites still contained very high proportions of mineral components in the early Nineties. Consequently, its contribution to total landfill gas formation in Germany was comparatively low.

The data used for calculation purposes is summarized in Table 50 below

Table 50 Basic data for calculating CH_4 emissions from municipal solid waste

Jahr	Siedlungsabfälle	DOC	DOC f	F	1-R	1-OX	CH4 Emi
1990	43379000	18%	50%	50%	56%	90%	1302411,1
1991	39000000	18%	50%	50%	56%	90%	1170936,0
1992	32000000	18%	50%	50%	56%	90%	960768,0
1993	27090000	18%	50%	50%	56%	90%	813350,2
1994	25000000	18%	50%	50%	56%	90%	750600,0
1995	22000000	18%	50%	50%	56%	90%	660528,0
1996	18824000	18%	50%	50%	56%	90%	565171,8
1997	18000000	18%	50%	50%	56%	90%	540432,0
1998	17000000	18%	50%	50%	56%	90%	510408,0
1999	16409000	18%	50%	50%	56%	90%	492663,8
2000	16000000	18%	50%	50%	56%	90%	480384,0
2001	16000000	18%	50%	50%	56%	90%	480384,0

<Legende>

Year

Municipal waste

DOC

DOCf

F

1-R

1-OX

CH4 emi

8.1.2.2 Landfilling of sewage sludge

Overall, only a few sewage sludge mono-landfills are operated in Germany. The bulk of sewage sludge is stored on municipal waste landfills. There is no further differentiation in the official statistics according to the type of landfilling of the dumped sewage sludge.

In view of this fact, the landfilling of sewage sludge is linked to the calculation method for domestic waste landfilling and is derived analogously using the following formula:

$$CH_4 \text{ (Mg/yr)} = (KS * DOC * DOC_F * F * 16/12) * (1\text{-}R) * (1 – OX)$$

Parameter	Description	German definition	Default
MSW:	Amount of sewage sludge landfilled (Mg dry matter)	Amount of sewage sludge landfilled (Mg dry mass per annum)	
DOC:	Degradable organic carbon	Proportion of degradable organic carbon in the waste (%)	30%
DOC_F:	Fraction of DOC dissimilated	Proportion of DOC converted into landfill gas (%)	Not given

Handling for the purposes of emissions reporting in Germany

In order to determine CH_4 emissions, the outlined IPCC method and the parameter values of municipal waste landfilling are used. The only exception is the sewage sludge-specific adaptation for DOC, DOC_F, F and R.

- DOC = 30%; [MUNLV 2001, page 205ff.]

- DOC_F = 10%

Explanation for determining DOC_F:

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 a mainly putrefied product from the treatment of sludge from 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 specific data on sewage sludge, the degradation rate of carbon in the MBA output cited in the literature of 10 % is used [Wallmann 1999]. The Federal Environmental Agency does not have recourse to any further information in this respect.

Specification for the period 1990-1993:

In east 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 emission potential of methane would be assumed even during the landfilling process. In [UBA 9/93] 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 is used on the portion of sewage sludge generated in east Germany up until 1994.

For the activity rate KS, recourse is made to the statistics of the Federal Statistical Office [StaBa FS 19/ series 2.1 and series 2.2]. It is updated at 3-yearly intervals. The data from the Federal Statistical Office quantifies the quantity of sewage sludge dry mass that is landfilled, but without specifying the proportion of mono-landfills. For the purposes of emissions reporting, it is assumed that this is deposited entirely on municipal waste landfill sites.

The activity rates of the time series are specific to the reference years given. The data up to 1994 is listed separately for ABL and NBL. However, time-dependent adaptation of the terms DOC and F cannot be achieved from the data available[22].

With effect from 1 June 2005, sewage sludge must no longer be landfilled. The landfilling of sewage sludge has already declined substantially in the period from 1999 to 2002.

The data used for calculation purposes is summarised in the following Table 51.

Table 34 Basic data for calculating CH_4 emissions from the landfilling of sewage sludge

[22] Statement by Mr Butz, Federal Environmental Agency, 23 January 2003

Jahr	Klärschlämme	DOC	DOC f	F	1-R	1-OX	CH4 Emi
1990	2470000	30%	18%	50%	56%	90%	44495,6
1991	2440900	30%	18%	50%	56%	90%	43971,3
1992	2010000	30%	18%	50%	56%	90%	36208,9
1993	1540000	30%	16%	50%	56%	90%	24659,7
1994	1210000	30%	14%	50%	56%	90%	16953,6
1995	1023700	30%	12%	50%	56%	90%	12294,2
1996	800000	30%	10%	50%	56%	90%	8006,4
1997	650000	30%	10%	50%	56%	90%	6505,2
1998	493392	30%	10%	50%	56%	90%	4937,9
1999	490000	30%	10%	50%	56%	90%	4903,9
2000	490000	30%	10%	50%	56%	90%	4903,9
2001	490000	30%	10%	50%	56%	90%	4903,9

<Legende>

Year

Sewage sludge

DOC

DOCf

F

1-R

1-OX

CH4 emi.

8.1.2.3 Landfilling of MBA residues

Future requirements for the 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”. MBA landfills are landfills on which residual waste is deposited following mechanical/biological treatment. From the year 2005 onwards, a growing volume of MBA residues is anticipated due to the obligation for compulsory pre-treatment of municipal wastes.

The criteria to be met by MBA residue is outlined in the Ordinance on Environmentally Compatible Storage of Waste from Human Settlements and on Biological Waste Treatment Facilities <AbfAblV>. Thanks to extensive stabilisation via pre-treatment of the residual wastes and specification of the maximum permitted TOC content of 18% of the dry mass in the MBA residue, it is to be assumed that for MBA landfills as a whole, only minimal gas formation will occur. MBA residue landfills are comparable to existing landfills which still have minimal residual gas formation. Active gas collection is no longer required or possible. However, passive degasification will remain necessary in order to preserve the stability of the landfill (by avoiding pore water pressure). In order to further minimise the methane emissions thereby released, gas-permeable but water-impermeable surface seals with an oxidation layer may be used, for example.

The anticipated gas formation potential has been examined in landfill simulation experiments. According to [IGW 1998, page 23], on the basis of various experiments, some of which differ considerably from one another in terms of methodology (e.g. installation either sealed or unsealed etc.), it can be unanimously asserted that well-stabilised waste with a respiration activity $AT_4 \leq 5$ mg O_2/g dry mass (as required under the AbfAblV) indicates a maximum gas formation potential in the range from <10 to 45 Nl/kg of dry mass. On average, a value of 30 Nl/kg of dry mass (~ 30 m³/t of dry mass) can be assumed, whereby the latter should be considered something of a conservative estimate.

According to [IGW 1998, page 23], on average, the gas formed in the landfill simulation experiments consisted of 60 % methane and 40 % carbon dioxide, thereby corresponding to the landfill gas composition of landfills in the stable methane phase. It is proposed that the values cited be used for an estimate of methane emissions.

In accordance with the requirement of the Technical Instructions on Waste from Human Settlements (TASi) for minimisation, further reduction measures are anticipated vis-à-vis the potential methane emissions, e.g. via a methane oxidation layer. In [IGW 1998, page 40] the efficiency of a methane oxidation layer was derived for the concrete application case. According to an evaluation of the literature, the methane oxidation potential was first ascertained with a main frequency focus of CH_4/m²*h. Although this is higher than the forecasted methane gas formation rate by a factor of at least 40, an efficiency level of only 75 % was used as a basis for gas oxidation (conservative estimate of the potential influence of reduced effectiveness during the cold season).

The methane oxidation layer observed in [IGW 1998] is a component of the temporary and final sealing elements which are applied to installation sites that are not currently being charged or which have been finally filled. Accordingly, as a general principle, a 75 % reduction in the methane gas formation potential is to be expected. According to [UBA 1999, page 16], concepts for surface sealing with an oxidation layer require further examination under real landfill conditions. Until more recent or more detailed findings on this are available from the planned research projects on these issues, use of the reduction factor to [IGW 1998, page 40] is recommended.

Handling for the purposes of emissions reporting

The landfilling of MBA residues is linked to the calculation method for the landfilling of municipal waste, but in view of the facts mentioned, is adapted to the specific data situation as follows:

$$CH_4 \text{ (Mg/yr)} = (\text{MBA-R} * DG * F * 16/22.4) * (1 - OX)$$

Parameter	Description
MBA-R:	Quantity of MBA residue deposited (Mg dry mass/year)
DG:	Quantity of landfill gas formed (m^3/Mg dry mass)
F	Proportion of methane in landfill gas (% v/v)
16/22.4	Methane conversion factor (gas volume => mass)
OX	Factor for determining the proportion of CH_4 that is oxidised

Thanks to the standardisation of the treatment of residual wastes in MBAs by the 30th Ordinance on the Implementation of the Federal Immission Control Act (BimSchV) and the Ordinance on Environmentally Compatible Storage of Waste from Human Settlements and on Biological Waste Treatment Facilities (AbfAblV), it can be assumed that MBA residue is a waste with a relatively constant composition, particularly with regard to the carbon content.

Similarly, it is assumed that following a certain transitional period, even the quantities landfilled will not be subject to any major annual fluctuations.

In accordance with the above comments, it can therefore be said that:

- DG = 30 m³/Mg dry mass
- F = 60%
- OX = 75%

In future, it should be possible to determine the activity rate via evaluations from the Federal Statistical Office, e.g. via the delivery records of the landfills. This waste flow is not reported by the Federal Statistical Office at present.

The current quantity of MBA residue is estimated on the basis of the existing MBAs. In chapter 5.2 "Composting of waste", a proportion of approximately 2.04 million Mg/a is estimated as the input into biological treatment of residual wastes, based on the current treatment capacities (approximately 2.4 million Mg). Deducting the quantities that are treated in stabilisation plants for subsequent thermal disposal (approximately 17 %), this produces an input quantity into the biology of the plants aimed at landfilling the MBA residue of approximately 1.7 million Mg/a.

Despite highly varied treatment techniques and, in particular, varying digestion periods, in an initial approximation a digestion loss of 30 % may be calculated[23]. As a result, the quantity of MBA residues currently incurred is estimated at approximately 1.2 million t/a. The water content may be roughly assumed at approximately 30 %[24].

The estimated values for digestion loss and water content are rough approximations which must be checked by future examinations. Similarly, future empirical results with regard to the methane oxidation rate should be observed.

The data used for calculation is summarised in the following Table 52:

Table 52 Basic data for calculating CH_4 emissions from the landfilling of sewage sludge

Jahr	MBA-Rückstände	DG	F	1-OX	CH4 Emi
1997	100000	30	60%	25%	321,4
1998	300000	30	60%	25%	964,3
1999	600000	30	60%	25%	1928,6
2000	840000	30	60%	25%	2700,0
2001	900000	30	60%	25%	2892,9

<Legende>

Year

MBA residues

DG

F

[23] Estimate by Ms Vogt, IFEU-Institut, Heidelberg, February 2003
[24] Estimate by Ms Vogt, IFEU-Institut, Heidelberg, February 2003

1-OX

CH4 emi.

8.1.2.4 Landfilling of municipal waste, sewage sludge and MBA residues

With effect from 2006, the calculation method for MBA landfills is to be added to the emissions reporting for landfills for municipal waste, and may therefore be essentially viewed as an update of the reporting under the same reporting code. The method for determining emissions for CRF 6 C is therefore comprised of the equations already mentioned above:

CH_4 (Mg/yr) = A+B+C, whereby

$A = MSW * DOC * DOC_F * F * 16/12 * (1-R) * (1 – OX)$

$B = KS * DOC * DOC_F * F * 16/12 * (1-R) * (1 – OX)$

$C = MBA\text{-}R * DG * F * 16/22.4 * (1 – OX)$

8.1.2.5 Unsanctioned landfills

This type of landfilling has been prohibited in west Germany since the late Seventies. However, as the bulk of landfill gas emissions occur in the first years of landfilling and then degressively decrease towards zero, these emissions are likely to be only marginal today.

Whether and to what extent unsanctioned landfilling was still taking place in east Germany in the base year 1990 is impossible to determine. The UBA believes that possible methane emissions from this area are covered by the gas collection rate of the municipal waste landfills, which was consciously assumed to be low[25].

Overall, it can be assumed that the principal volume flows of landfilled municipal waste in Germany with respect to the periods relevant for emissions reporting are included in the activity rates in chapter 2.1.

8.1.3 Uncertainties and time-series consistency (6.A)

The uncertainties associated with the detection of these emissions are being ascertained within the context of an on-going research project. The time series can be valued as consistent – the mere fact that waste statistics in Germany are collated and published at intervals of several years necessitates interpolation, and in the case of recent years, extrapolation, for the intervening years. During the course of an on-going research project, it is hoped that the uncertainties of the methods and results formulated here can be ascertained.

8.1.4 Source-specific QA/QC and verification (6.A)

The first quality assurance and verification occurred by commissioning a researcher to examine the calculation methods. The initial results were then discussed with the technical experts at the Federal Environmental Agency and reviewed.

For further details, refer to the planned improvements.

[25] Statement by Mr Butz, Federal Environmental Agency, 23 January 2003

8.1.5 Source-specific recalculations (6.A)

The new calculation results resulting from the outcome of the research project for the area of landfilling deviate substantially from the data published to date. This is due to the new statistics used, and the new calculation method used here for the first time.

8.1.6 Source-specific planned improvements (6.A)

Within the context of the internal review process and via the external review envisaged for next year, there are plans to review the application of the Tier 2 method. In particular, this will address the opportunities for deriving the long-term landfill statistics, which are the pre-requisite for this method.

8.2 Waste water handling (6.B)

[IPCC 2000] only requires the determination of methane emissions. In the IPCC-Guidelines [IPCC 1996, chapter 4.8.1.1] it is assumed that N_2O emissions in conjunction with waste water treatment are negligible.

8.2.1 Source category description (6.B)

8.2.1.1 Methane emissions from waste water handling

The following is given as the general formula for calculating methane emissions [IPCC 2000, chapter 5.2.1.1]:

CH_4 emissions = (organic load * EF) – methane recovery

Further factors are specified to enable more precise characterisation of the organic load discharged into waste water handling and the emission factor. Methane recovery refers primarily to closed systems of anaerobic sewage sludge treatment using biogas.

Applied to the data situation in German, the above formula may be detailed as follows:

$EM\text{-}CH_4 = EW * D * 365 * (1\text{-}SBF) * WS * MCF * B_0$, whereby

EW = Annual population figures

D = BOD_5 content (IPCC default = 0.06 kg BOD_5/E * d)

SBF = Fraction of BOD that readily settles (IPCC default = 0.5)

WS = Portion of a specific waste water treatment system (e.g. aerobic, anaerobic)

MCF = Methane conversion factor for this waste water treatment system

(methane only occurs with anaerobic degradation, IPCC default: aerobic = 0; anaerobic = 1)

B_0 = max. CH_4 production capacity (in kg CH_4/kg BOD_5; IPCC default = 0.6)

Because most waste water treatment in Germany, i.e. the biological treatment stage, is aerobic, the term MCF would = 0 and according to this formula, no methane emissions can be calculated for waste water treatment.

Data from the on-going UBA research project (FKZ 20044337)

In a current research project by the Federal Environmental Agency (UBA), measurements were conducted at a sewage treatment plant. The measurements showed that with a minimum of 128 Mg CH_4/a and a maximum of 669 Mg CH_4/a, the methane emission balance produced very low values (based on an emission factor of 48.8-254.4 mg C/m^3 at 20% CH4-C in relation to total C). The first aeration tank and the sewage treatment plant inlet were identified as the principal source of emissions. The results of the CH_4 emissions into the sewer network, which were likewise measured, are currently still under review. No measurements were conducted at the sludge treatment stage, since hardly any NMVOC is emitted. This data should be considered provisional. No quotable data will be available until after consultation with the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and presentation of the concluding report[26].

Emissions calculation in NRW study

A study by the Federal *Land* of NRW contains estimates on the emission of CH_4 and NH_3 from waste water treatment at local authority sewage treatment plants [IFEU 2001] based on the assumption that anaerobic conditions exist in part during mechanical pre-treatment.

Assumption [IFEU 2001, page 78] for the mechanical sewage treatment stage:

10% of C is eliminated, 2% of this emitted as CH_4

10% of N is eliminated, 20% of this emitted as NH_3

Additional assumptions for the biological treatment stage:

72% of the remaining N is eliminated, 1 % of this emitted as NH_3

Consequently:

Release as CH_4-C: 0.2% of C_{total} => EF-CH_4 = 1g * 0.002 *16/12 = 0.0027 g CH_4/g C_{total}

Release as NH_3-N = 2.7% of N_{total} => EF-NH_3 = 1g * 0.027 *17/14 = 0.033 g NH_3/g N_{total}

The EF-CH_4 could be incorporated into the adapted IPCC method, so that this would then read:

EM-CH_4 (g/a) = EW * D_C * 365 * EF-CH_4

EW = Population figures

D_C = C in waste water (assumption: 50 g/E * d)[27]

Applied to NH_3 this would mean:

EM-NH_3 (g/a) = EW * D_N * 365 * EF-NH_3

E_{KA} = Population connected to the sewage treatment plant

D_N = N in waste water (assumption: 11 g/E * d)

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[26] Notification by Ms Uhlmann (project manager at UBA), 17 February 2003

[27] MUNLV: *Entwicklung and Status der Abwasserbeseitigung in Nordrhein-Westfalen*. Appendix A, pdf-file (Appendix A1), page1. http://www.murl.nrw.de/sites/arbeitsbereiche/boden/munlv_abwasserwirtschaft/index.html

With a population of around 122 million (Table 4-3) this produces the following:

$EM\text{-}CH_4$ = 122,387,000 * 50 * 365 * 0.0027 * 10E-6 = 5,956 Mg/a

$EM\text{-}NH_3$ = 122,387,000 * 11 * 365 * 0.033 * 10E-6 = 16,109 Mg/a

The methane emissions calculated in this way are an order of magnitude higher than the values measured in the research project cited.

[Schmid/Puxbaum 1999]

[Schmid/Puxbaum 1999] gives a bandwidth of 0.09 to 0.18 g N_2O/ population equivalent. The figures refer to measurements at experimental plants in Austria.

8.2.1.2 Methane emissions in conjunction with sewage sludge treatment

As a general rule, the treatment of sewage sludge comprises two treatment stages:

1. **Dehydration** using
   - Mechanical techniques (chamber filter press, cyclone)
   - Evaporation in a sludge lagoon or drying beds
2. **Stabilisation**
   - Aerobic stabilisation (open basin with oxygen introduction)
   - Stabilisation in the digestion tower (anaerobic)
   - Sludge digestion in an open basin (predominantly anaerobic)

With reference to population figures, mechanical dehydration before and after treatment in the digestion tower currently represents the main treatment method (with the exception of small, rural sewage treatment plants). Moreover, the sewage sludge is generally limed prior to subsequent use, which stabilises it still further.

For the aforementioned process stages, varying degrees of emission relevance can be assumed, which can only be assessed qualitatively:

- Mechanical dehydration: Dehydration aids (polymers or single salts) are added, and subsequent liming is required for further solidification, which is thought to expel NH_3. The release of emissions may be lower in closed systems.
- Evaporation: Considerably fewer NH_3 emissions because it is operated without liming. CH_4 emissions are likely, since anaerobic conditions may prevail in part over longer periods.
- Digestion tower: The digestion tower itself has no emissions relevance, because the plant is closed and putrefaction gases are combusted. Putrefied sludge is generally dehydrated and may be additionally limed, as a result of which the expulsion of NH_3 is likely. The expelled water contains CH_4 which may subsequently escape as gas.
- Open sludge digestion: Rich in CH_4 and N_2O because primarily (see above) anaerobic conditions predominate, activity of denitrifying and methanogenic bacteria

The calculation of methane emissions to the IPCC specification requires specifications with regard to a number of parameters:

$EM\text{-}CH_4 = EW * D * 365 * SBF * WS * MCF * B_0 – R$, where

EW = population figures per annum

D = BOD_5 / population (IPCC default = 0.06 kg BSB_5/E * d)

SBF = Fraction of BOD that is readily settled (IPCC default = 0.5)

WS = Proportion of a given waste water treatment system (e.g. aerobic, anaerobic)

MCF = Methane conversion factor for this waste water treatment system

(methane is only produced with anaerobic degradation, IPCC default: aerobic = 0; anaerobic = 1)

B_0 = max. CH_4 production capacity (in kg CH_4/kg BSB_5; IPCC-Default = 0.6)

R = Proportion of collected or flared methane

In Germany, essentially, waste water is either treated aerobically (i.e. MCF = 0) or anaerobically in closed systems with gas collection (Term R). Hence according to the IPCC, with the exception of the open sludge digestion practised in east Germany in the early Nineties, there is no emissions relevance from this source area.

[UBA 9/93]

To date, the UBA has calculated methane emissions from sludge treatment based on the assumption of a methane degassing as a result of sludge dehydration following closed anaerobic stabilisation, and also open sludge digestion (psychrophilic sludge treatment):

a) Methane degassing following closed anaerobic stabilisation

According to [UBA 9/93], based on the water solubility of methane under mesophilic temperature conditions in the digestion tower, a specific methane emission of 19l per m^3 of putrefied sewage sludge may be estimated (according to [UBA 9/93] this is a maximum estimate). The density per m^3 is approximately 1 in view of the high water content. With 5 % dry mass this produces 0.38 m^3 or 0.27 kg of methane per t of sewage sludge dry mass. According to Ms Sakaguchi, researcher on UBA project FKZ 20044337, this type of methane degassing is included in the aforementioned data.

b) Open sludge digestion

According to [UBA 9/93], open sludge digestion produces 450 m^3 of putrefaction gas per oTS of raw sludge. In relation to a tonne dry mass of rotted sludge, and assuming that the oTM content makes up 50 % of the dry mass content of the raw sludge and that during digestion 50 % of the oTS is removed, this translates into a gas production of 195 m^3. With a methane content of 65% [UBA 9/93] this corresponds to a methane emission of 195 m^3 or 139.3 kg/t sewage sludge dry mass

For the year 1991, assuming that only open sludge digestion was practised in east Germany and only closed sludge digestion was practised in west Germany, the following emissions may be calculated:

CH_4, east Germany: 313,200,000 t dry mass sewage sludge * 139.3 kg/t = 43,629 Mg methane

CH_4, west Germany: 2,642,500,000 t dry mass sewage sludge * 0.27 kg/t = 714 Mg methane

When applying this method, it would still be necessary to determine the proportions of open and closed sludge stabilisation both in west Germany and in east Germany and their development over time during the course of the Nineties.

The methane emission factors used in the UBA's Central System of Emissions (CSE) for east Germany (1990: 142 kg/t TS, 1991: 80 kg/t TS, 1992: 40 kg/t TS, 1993: 20 kg/t TS) were probably derived from such a determination of the proportions of sludge treatment methods.

8.2.1.3 N_2O emissions

IPCC contains a method for roughly calculating N_2O emissions from domestic waste water [IPCC 1996, chapter 6.4] based on the average annual per capita consumption of protein:

$$EM\text{-}N_2O\text{-}N = Protein * Frac_{NPR} * Population * EF$$

Protein = Protein consumption (kg/person/a)

EF = Emission factor (default 0.01 kg N_2O-N/kg N in waste water)

$Frac_{NPR}$ = N content in protein; default value: 16%

Assumption for Germany:

Protein = 94 g/population/d [Food Table 1991]

$Frac_{NPR}$ = 16%

From this we may calculate:

$$EM\text{-}N_2O = 94g * 16\% * 82{,}500{,}000 * 365 * 0.01 * 46/28 = 7{,}117 \text{ Mg } N_2O/a$$

However, this computational approach may only be used if no more precise determinations of N_2O emissions are implemented via the individual discharge routes of waste water and sewage sludge. As previously mentioned, waste water treatment *per se* is not considered to be a relevant N2O source. Duplication with calculation methods in the source category “Agriculture” is to be avoided.

<u>N_2O emissions from sewage treatment plants [Wicht 1995]</u>

Based on the results of a combined research project by the BMFT [Krauth 1994], emission factors were derived in [Wicht 1995].

The joint research project measured 25 local authority and 13 industrial sewage treatment plants. Over an average of the domestic sewage treatment plants examined, N_2O-N emissions totalled 0.6 % in relation to the total nitrogen in the infeed.

According to [Wicht 1995], this figure may be applied to the inhabitants connected to local authority sewage treatment plants with targeted nutrient elimination. For the year 1991, he calculates an N_2O-N emission of 1.548 Mg (~N_2O emission of 2.433 Mg). This was based on an inhabitant value of 11g N/inhabitant/d and a connection figure of 64,256,000 inhabitants.

As the statistics for industrial sewage treatment plants only contain information on the quantity of waste water treated, the emission factor ascertained for domestic sewage treatment plants was converted to the reference variable waste water volume (0.34 g N_2O-N/m^3). On this basis, an emission of 2.320 Mg N_2O-N or 3.645 Mg N_2O from industrial waste water treatment was calculated.

[UBA 9/93]

[UBA 9/93], based on [Krauth 1994], cites an emission factor of 0.07-0.08 g N_2O/m^3 of waste water treated in plants with N elimination. This factor was assumed for both domestic and industrial sewage treatment plants.

It was assumed that in 1987, 70% of domestic waste water of 8880 million m^3 and a quantity of 430 million m^3 of industrial waste water was treated in plants with N elimination. Overall, this produced a quantity of N_2O released from this source of between 430-530 Mg.

[Schulthess 1994]

[Schulthess 1994] cites a bandwidth of 0.02% to 0.07% release of N_2O-N in relation to the N load in the infeed. These figures refer to measurements on model plants in Switzerland.

[Schmid/Puxbaum 1999]

[Schmid/Puxbaum 1999] cites a bandwidth of 0.019 to 0.048 g N_2O/ population equivalent. The figures refer to measurements on trial plants in Austria.

8.2.2 Methodological issues (6.B)

According to a UBA study from the year 1991 [Fichtner 1991], sewage sludge was not dehydrated mechanically in eastern Germany, and sludge digestion took place in open basins. It is also thought that the liming of sludge prior to subsequent recovery was not generally practised.

8.2.3 Uncertainties and time-series consistency (6.B)

For the area of landfill emissions, a consolidated, consistent time series can be assumed.

8.2.4 Source-specific planned improvements (6.B)

Significant improvements are envisaged for emissions from industrial waste water treatment, which have not yet been considered in full.

In view of the vast differences in waste water from the various branches of industry, it is a question of finding a practicable approach for ascertaining their emissions. A separate case study of each individual segment of industry would appear to be both inappropriate and unfeasible. As proposed by the IPCC, we could identify the principal segments of industry (3 or 4) and report on these separately. The remaining sources could be estimated in summarised form.

Identification of the principal sources of industry could be achieved via sector-specific waste water quantities on the one hand, and the waste water relevance of the respective industrial activity on the other.

The sector-specific annual waste water quantities are taken from specialist series 19, series 2.2 from the Federal Statistical Office ("Water supply and waste water elimination in mining, quarrying and the manufacturing industry"), which are surveyed every three years. The data is differentiated according to direct and indirect dischargers, and these in turn are differentiated according to treated and untreated waste water.

With regard to the reported pollutants, those segments of industry which use large quantities of organic material are likely to be the principal sources. Here, the food industry is undoubtedly of major significance for the pollutants under investigation, whereby large differences can also be expected within the same industry, so that a further sub-classification of this segment may be expedient. The paper industry (and possibly also the wood and textile industries, if these incur significant quantities of waste water) could also be of interest.

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Calculation is performed in the same way as for domestic sewage plants. Instead of biological oxygen demand (BOD), recourse is made to chemical oxygen demand (COD). Here too, it is true to say that in view of the predominantly aerobic treatment, no methane emissions would be anticipated upon application of the IPCC method.

It will only be possible to develop an expedient method in this area once the procedure for domestic waste water treatment has been agreed and adopted. The work in the research project concentrated on the area of domestic waste water treatment. As a result, no discussions were held with UBA representatives for the area of industrial waste water treatment.

At present, the following emissions are not included at all in the inventory, or only minimally:

- Emissions from sewage sludge application,
- Emissions from waste composting (biowaste, fermentation residues and sewage sludge),
- Emissions from the application of composting residues

In this context, the research projects (IFEU) will undertake a description of the current status which will then be included in routine formulation of the greenhouse gas inventories. This is scheduled for next year.

8.3 Other sources (CRF sector 6)

At present, no emissions are calculated under this source category.

9 OTHER (CRF SECTOR 7)

At present, no greenhouse gas emissions are calculated for Germany which cannot be allocated to the envisaged source categories.

10 RECALCULATIONS AND IMPROVEMENTS

Detailed accounts of recalculations and improvements will only become available in 2005.

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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*"[28] (*Good Practice Guidance*), the Parties to the Framework Convention on Climate Change, and in future to the Kyoto Protocol as well, 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 valued 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 an error specification, as well as being 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 calculation results 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 the methods to be applied for determining the key sources in chapter 7. By analysing the inventory for one year (Tier 1 Level Assessment), analysing the time series of the inventory data (Tier 1 Trend Assessment) together with a detailed analysis of inventory data with error evaluation (Tier 2 Trend Assessment with consideration of inaccuracies), this makes it possible to identify the respective key sources.

For the identified key sources, the Parties are then required to use very detailed calculation methods, 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. To date, Germany has not yet submitted any such report.

12.1 Description of the method for determining key sources

The initial results of the key source analyses based on the two Tier 1 techniques (Level and Trend) are outlined below. We would refer you to the description of the underlying methods in the *Good Practice Guidance*.

[28] 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

Table 53: Key source categories for Germany (1990-2000) based on the Tier 1 Level Approach

Key Source Categories for Germany 2000 based on Tier 1 Level Approach					
Key Source Categories	**Gas**	**Emission** 2000 (Gg CO2 Eq.)	**Percentage** abs.	cuml	**Key Source**
Emissions from Stationary Combustion - Gas	CO2	191145	19.3	19.3	□
Mobile Combustion: Road & Other	CO2	177651	17.9	37.2	□
Emissions from Stationary Combustion - Hard coal	CO2	173535	17.5	54.7	□
Emissions from Stationary Combustion - Lignite	CO2	173040	17.5	72.2	□
Emissions from Stationary Combustion - Oil	CO2	111129	11.2	83.4	□
Emissions from Agricultural Soils	N2O	27351	2.8	86.1	□
Emissions from Mineral Production (mainly cement)	CO2	23502	2.4	88.5	□
Emissions from Enteric Fermentation in Domestic Livestock	CH4	20890	2.1	90.6	□
Emissions from Waste	CH4	16674	1.7	92.3	□
Emissions from Manure Management	N2O	13838	1.4	93.7	□
Fugitive Emissions from Coal Mining & Handling	CH4	9968	1.0	94.7	□
Total Emissions	HFCs	7700	0.8	95.5	□
Fugitive Emissions from Oil & Gas Operations	CH4	7358	0.7	96.2	
Emission from stationary Fuel Combustion	N2O	5527	0.6	96.8	
Mobile Combustion: Road & Other	N2O	5175	0.5	97.3	
Emissions from Adipic Acid Production (incl. Nitric Acid)	N2O	5089	0.5	97.8	
Emissions from Manure Management	CH4	4425	0.4	98.2	
Mobile Combustion: Aviation	CO2	4382	0.4	98.7	
Total Emissions	SF6	3442	0.3	99.0	
Emissions from Product use	N2O	1860	0.2	99.2	
Emissions from Chemical Production	CO2	1860	0.2	99.4	
Total Emissions	PFCs	1709	0.2	99.6	
Emission from Fuel Combustion	CH4	1268	0.1	99.7	
Emissions from Wastewater Handling	N2O	1240	0.1	99.8	
Mobile Combustion: Marine	CO2	877	0.1	99.9	
Emissions from Metal Production	CO2	787	0.1	100.0	
Subtotal All gases		**991421**	**100.0**		

As the result of this approach, those source categories responsible for 95 % of total national emissions (as CO2 equivalent emissions) from the volume of emissions released 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 12 key sources are identified using this approach (cf. **Fehler! Verweisquelle konnte nicht gefunden werden.**).

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 2000 in terms of the development of their contribution since 1990 are identified as key source categories (□). In this respect, it is irrelevant whether this has led to a reduction or an increase in emissions of 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 16 key sources are identified using this approach (cf. Table).

Table 54: Key source categories for Germany (1990-2000) based on the Tier 1 Trend Approach

IPCC Source Categories	Direct Green-house Gas	Base Year Estimate 1990 (Gg CO2 Eq.)	Current Year Estimate 2000 (Gg CO2 Eq.)	Trend Assess-mint	Contri-bution to Trend	Cummu-lative Total	Key Source
Emissions from Adipic Acid Production (incl. Nitric Acid)	N2O	25420	5089	3.761	22.52	22.52	□
Emission from Fuel Combustion	CH4	4492	1268	2.542	15.22	37.75	□
Mobile Combustion: Marine	CO2	2471	877	1.816	10.87	48.62	□
Fugitive Emissions from Coal Mining & Handling	CH4	25767	9968	1.585	9.49	58.11	□
Emissions from Waste	CH4	39768	16674	1.385	8.29	66.41	□
Emissions from Stationary Combustion - Lignite	CO2	343372	173040	0.984	5.89	72.30	□
Total Emissions	HFCs	2340	7700	0.696	4.17	76.47	□
Total Emissions	PFCs	2694	1709	0.576	3.45	79.92	□
Emission from stationary Fuel Combustion	N2O	8182	5527	0.480	2.88	82.80	□
Mobile Combustion: Road & Other	N2O	3193	5175	0.383	2.29	85.09	□
Emissions from Enteric Fermentation in Domestic Livestock	CH4	28035	20890	0.342	2.05	87.14	□
Mobile Combustion: Aviation	CO2	2897	4382	0.339	2.03	89.17	□
Emissions from Manure Management	N2O	17771	13838	0.284	1.70	90.87	□
Emissions from Manure Management	CH4	5665	4425	0.280	1.68	92.55	□
Emissions from Stationary Combustion - Oil	CO2	140806	111129	0.267	1.60	94.15	□
Emissions from Stationary Combustion - Gas	CO2	158041	191145	0.173	1.04	95.18	□
Emissions from Metal Production	CO2	904	787	0.149	0.89	96.08	
Total Emissions	SF6	3896	3442	0.132	0.79	96.87	
Emissions from Agricultural Soils	N2O	30926	27351	0.131	0.78	97.65	
Emissions from Chemical Production	CO2	2100	1860	0.129	0.77	98.42	
Mobile Combustion: Road & Other	CO2	156913	177651	0.117	0.70	99.12	
Emissions from Stationary Combustion - Hard coal	CO2	182332	173535	0.051	0.30	99.42	
Emissions from Mineral Production (mainly cement)	CO2	24664	23502	0.049	0.30	99.72	
Fugitive Emissions from Oil & Gas Operations	CH4	7014	7358	0.047	0.28	100.00	
Emissions from Product use	N2O	1860	1860	0.000	0.00	100.00	
Emissions from Wastewater Handling	N2O	1240	1240	0.000	0.00	100.00	
Subtotal All gases		1222765	991421	16.699			

12.1.3 Evaluation

This analysis represents an initial approach. Once the basic data used in the CSE for calculation of the emissions has been updated (with regard to their temporal expansion), the analysis is to be repeated next year. All the recommendations of the IPCC regarding the level of detail of the source categories included in the analysis can then be followed. This concerns in particular the detailed calculation of F gases (CRF 2), waste management (CRF 6), product use (CRF 3) and methane emissions from coal mining (decommissioned mines CRF 1B). Further expansion is possible in the areas of firing installations (technical delimitations) and animal husbandry (species-specific calculations).

In the subsequent processing of the research project on quality assurance of the inventories, it will then be necessary to perform a key source identification based on the Tier 2 methodology.

13 Annex 2: Detailed discussion of methodology and data for estimating CO_2 Emissions from fossil fuel combustion

A detailed explanation of the methods and data used for calculating CO_2 emissions from the combustion of fossil fuels may be read in Chapter 3.

14 Annex 3: Other detailed methodological descriptions for individual source or sink categories (where relevant)

To date, no other detailed methodological descriptions for individual source or sink categories are available.

15 Annex 4: CO2 reference approach and comparison with the sectoral approach, and relevant information on the national energy balance

Accounts of the CO2 reference approach and a comparison with the sectoral approach and relevant information on the national energy balance can be found in chapter 3.2.10.

16 Annex 5: Assessment of completeness and (potential) sources and sinks of greenhouse gas emissions and removals excluded

Detailed comments on the assessment of completeness and potentially excluded sources and sinks of greenhouse gas emissions are not currently available.

17 Annex 6: Additional information to be considered as part of the NIR submission (where relevant) or other useful reference information

Additional information as part of the NIR submission is not currently available.

18 Annex 7: Tables 6.1 and 6.2 of the IPCC Good Practice Guidance

Calculations of uncertainties are not currently available.

19 ANNEX 8: OTHER ANNEXES

19.1 German National System of Emissions

19.1.1 Tasks for the National System

At the 7th Conference of the Parties to the Framework Convention on Climate Change, guidelines were adopted for the creation of a national system for inventory preparation under Article 5.1 of the Kyoto Protocol. With the ratification of the Kyoto Protocol by the German Federal Government, these regulations must be bindingly implemented by 1 January 2007. Article 5.1 defines the following tasks:

- Development of the national coordination office on emissions reporting (Single National Entity[29])
- Specification / documentation of institutional facilities, legal agreements, and procedures on emissions calculation and reporting
- Archiving of all inventory information
- Initiation of measures to improve the emissions inventories (National Inventory Improvement Program)

Extensive organisational scope is granted to the Parties for the concrete institutionalisation of the National System.

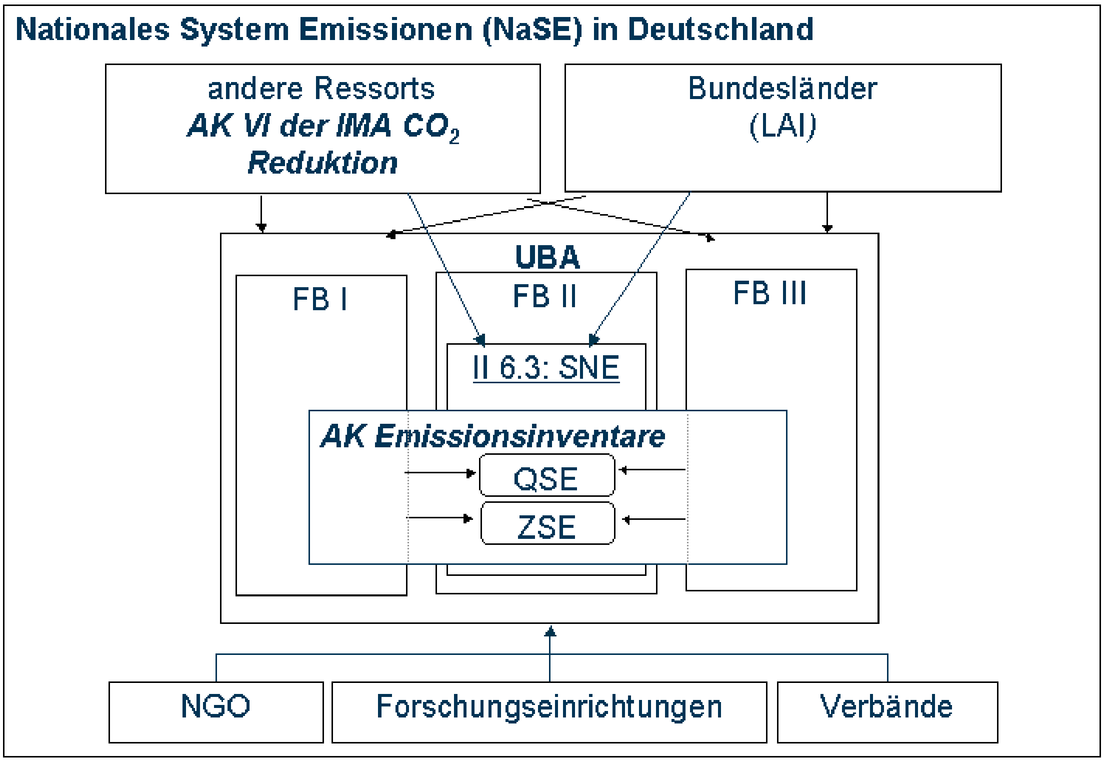
19.1.2 Development of the National System

In Germany, the National System is intended to ensure the organisation and quality assurance of the emissions inventories, and to serve 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 there are plans to implement the bulk of it by the year 2005 .

In order to provide the Federal Environmental Agency with technical support when implementing the provisions to create a National System, a research project (FKZ: 201 42 258) was initiated within the context of the UFOPLAN 2001 which it is hoped will make a significant contribution towards promptly adapting and improving the German system for inventory preparation in line with international requirements. The aim is to formulate an overall concept for implementation of the National System which makes allowance for both international requirements and the national framework conditions. In particular, it also involves the formulation of a proposal for suitable institutionalisation of the system in Germany. This must ensure that the National System is able to operate effectively with unbureaucratic yet binding procedures which ensure the required level of reliability. The requirement areas of the National System where priority action is needed in future will be 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.

[29] The coordination office (Single National Entity) should serve as the central point of contact for all participants in the national system. It should set the framework for transparent, consistent, complete, comparable and precise inventories.

However, there is no need to create the national system entirely from scratch; instead it will build on the existing structures and procedures for inventory preparation. Figure 20 shows the individual players and how they are linked to one another.



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National System of Emissions in Germany
Other departments *Federal Länder*
AK VI of the IMA on CO2 Reduction *LAI*
Federal Environmental Agency <UBA>

FB I *FB II* *FB III*

II 6.3: SNE

Working Group on Emissions Inventories

QSE

CSE

NGO *Research institutions* *Organisations*

Source: Marion Dreher – Federal Environmental Agency / Department II 6.3 – Emissions situation

Figure 20: The national system in Germany

<u>Key to abbreviation:</u>
FB – Division of the UBA
LAI – *Länder* Committee on Immission Protection

QSE – Quality System of Emissions
SNE - Single National Entity, national coordinating office
CSE – Central System of Emissions
AK VI of the IMA on CO_2 Reduction – Working Group on Emissions Reporting of the Interministerial Working Group on “CO_2 Reduction”

The ***coordinating office of the National System*** is located in department II 6.3 of the Federal Environmental Office (SNE; single national entity). It acts as a central point of contact, and 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, and checking and initiating the conclusion of legal agreements to ensure data continuity for the inventories. Central archiving will also take place here in future.

The ***Quality System of Emissions*** (QSE), currently under development, constitutes part of the Single National Entity. The QSE is currently being developed as part of a project. At the current time, all calculations on which inventory preparation is based are being reviewed to determine the extent to which they correspond to the IPCC Guidelines and the Good Practice Guidance, and whether further improvements to inventory practice are needed and possible against the background of data availability. From 2003 onwards, systematic measures will be initiated to improve emissions inventories, and for the first time a *National Inventory Improvement Plan* will be drawn up for Germany.

The second main pillar of the SNE will be the ***Central System of Emissions*** (CSE) – the central, national database for emissions calculation and reporting. The CSE is intended to meet the key requirements of transparency, consistency, completeness, comparability and accuracy formulated by both the UNFCCC and the UN ECE for the national system at data level. Procedures for emissions calculation and reporting will be documented here here.

In order to coordinate work within the Federal Environmental Agency, the national coordination office has set up a ***Working Group on Emissions Inventories***, which will incorporate all employees at the office involved in inventory preparation. Since the second half of 2002, the national coordination office 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, the resultant consequences for the UBA. Since then, internal awareness of the relevance and scope of this task has risen sharply. As well as better incorporation into inventory preparation and reporting, it is hoped that the working group will also ensure the involvement of technical experts in the review process. Since October 2002, information within the UBA has been published on the relevant intranet page. In this way, the rather more generalised information of past lectures is presented in greater depth and concretised.

For inter-departmental cooperation between Federal authorities, a new “working group on emissions reporting” (AK VI) has been created ***within the context of the interministerial working group “IMA CO_2 Reduction”***. This debates previously identified focal points in the field of emissions inventories which place requirements on other departments such as transport, agriculture and industry. By concluding a framework departmental agreement between the Federal Ministry of Consumer Protection, Food and Agriculture (BMVEL) and the BMU on the exchange of data and information and the operation of a joint database on agricultural emissions, a first inter-departmental agreement on collaboration regarding the calculation of emissions has been concluded. Moreover, BMVEL supplies all forest-related data. Collaboration with the Federal Statistical Office (DESTATIS) has also been stepped up. Here, UBA expertise has been incorporated into the formulation of the new Energy Statistics Act. Above all, the current discussions are aimed at ensuring that the requirements of emissions reporting are incorporated in full into the forthcoming amendment of the Environmental Statistics Act.

At present, the involvement of the Federal *Länder* is being ensured via the ***Länder Committee on Immission Protection*** (LAI). This is required in particular for validation of the Federal Energy Balance with the energy balances of the *Länder* and the verification process of Federal and *Länder* emissions inventories.

The incorporation of ***associations*** and other ***NGOs*** is achieved primarily via the specialist departments of divisions I and III at the Federal Environmental Agency responsible for concrete issues. The *National Coordination Office* provides the specialist departments with support when debating reporting requirements and determining the required data flows with the associations. In particular, there is intensive cooperation between the *Single National Entity* and both the Working Group on Energy Balances (AGEB) and the German Institute for Economic Research (DIW), which prepares the Federal Energy Balance on behalf of the AGEB. The educational and information work needs to be stepped up substantially from 2003 onwards.

Within the context of research and development projects, the expertise of ***research institutions*** has always been incorporated into inventory preparation. This is done both via the specialist departments of divisions I and III responsible for concrete issues, and also by unit II 6.3. The latter is aimed primarily at the harmonisation of individual results in the overall inventory, and the identification of errors and closing of gaps in emission-related activities. The Single National Entity feels that its most important task for the future is the more widespread incorporation of reporting requirements into the projects of the specialist departments so that reworking for harmonisation and quality assurance purposes will eventually become superfluous.

19.2 Quality assurance and control

19.2.1 Tasks for the Quality System of Emissions

The *Good Practice Guidance* specifies aspects of quality assurance and quality control that are to be implemented in the individual Member States. According to the IPCC, quality control should be interpreted as a system of routine technical activities for logging and controlling the quality of inventories at the preparation stage, and is intended to

- Provide routines and consistency checks to preserve data integrity, correctness and completeness
- Identify and address errors and gaps
- Document and archive inventory material and keep a record of all quality control measures

Quality control activities include general measures such as a review of

- Accuracy checks in data collection and calculation

- The application of recognised standardised procedures for emissions calculation, measurement, recording of uncertainties, archiving of all relevant information and reporting.

Higher-ranking quality control activities include the technical review of source categories, activity rates and emission factors as well as methods.

According to the *Good Practice Guidance,* quality assurance activities comprise a planned system of review routines which are carried out by persons not directly involved in inventory preparation. Following inventory preparation and after running through the review routines, further checks should be carried out, preferably by independent third parties. Reviews check whether the data quality requirements have been met, ensure that the inventories contain the best achievable emission calculations and data on sinks, and reflect the current status of knowledge and data availability. They support the effectiveness of the quality control program.

19.2.2 Current situation with the preparation of emission inventories

The preparation of emission inventories requires extensive preparatory work by the specialist in-house departments and external institutions of the National System. In the past, there was no institutionalised procedure for this cooperation, leading to deficiencies in the following points:

- Absence of clear responsibilities for individual aspects
- Lack of punctuality with data transmission
- Data transmission failed to conform to the required reporting format (different emitter structure, lack of separation between combustion-related and non-combustion-related emissions)
- Data transmission failed to conform to the database (non-CSE-compatible)
- Lack of completeness in the data (incomplete time series coverage, lack of up-to-dateness, problem pollutants)
- No consideration of uncertainties
- Incomplete or unsuitable documentation of results (results instead of calculation procedures with all the input variables required for calculation, no or inadequate description of the data source, no inventory report to date)
- Sub-optimal use of the existing current status of knowledge due to inadequate awareness of the existence or availability of data and due to incomplete or unsuitable documentation of results during data genesis

In 2002, the Federal Environmental Agency (UBA) began to systematically summarise the existing quality assurance and control measures during the preparation of emission inventories in the Quality System of Emissions (QSE), and to successively expand this against the background of the requirements of the *Good Practice Guidance*.

19.2.3 Development of the Quality System of Emissions

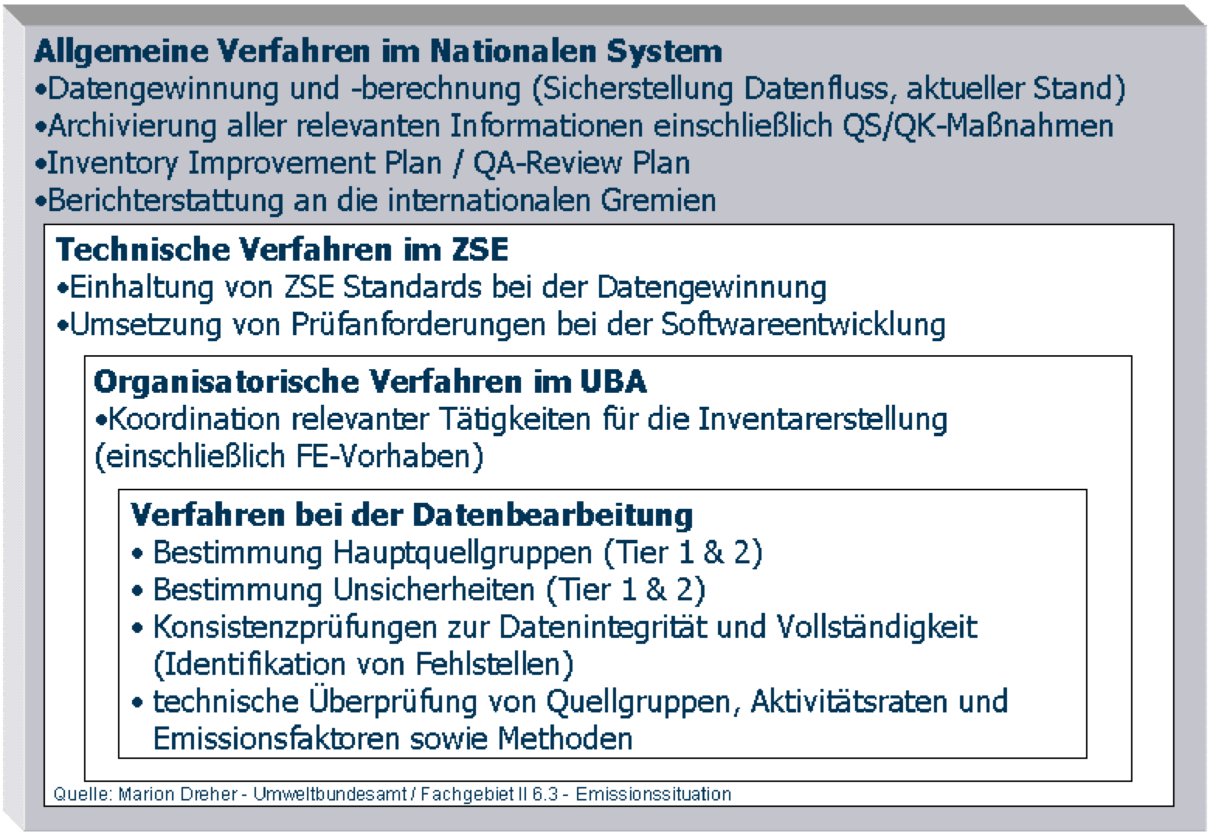
In order to provide the Federal Environmental Agency with technical support whilst implementing the requirements from the *Good Practice Guidance*, a research project (FKZ: 202 42 266) was initiated within the context of UFOPLAN 2001 which it was hoped would make a substantial contribution towards developing the CSE for the *National System for*

Emissions (*NaSE*). This was intended to meet the requirements of the IPCC, making allowance for the national situation in Germany, and adapt the internal structures and procedures of the reporting institution UBA. In terms of its procedural operations, the QSE was to be designed flexibly so that future altered requirements could be routinely incorporated (change in the requirements as the standard case).

Within the context of the project, an organisational concept is being prepared which will minimise occurrence of the deficiencies cited in Chapter 19.2.2 and specify obligations for the procedure in a transparent way. The project comprises the following key tasks:

- Formulation of a rough concept for internal and external quality assurance and control (*QA/QC plan*)
- Determination of uncertainties in accordance with Tier 1 of the *Good Practice Guidance*
- Documentation of the current quality status of inventory data for the key sources, and presentation of the deviations compared with requirements
- Determination of the required action (*Inventory Improvement Plan*)
- Implementation of the *Inventory Improvement Plans* for the UBA's own data sources with in-house employees and simultaneous determination of the uncertainties for the key sources (Tier 2)
- Presentation of the *Inventory Improvement Plans* for the external data sources in *Working Party (AG) VI Emissions Reporting of the Interministerial Working Group (IMA) on* CO_2
- Determination of key sources (*key source analysis*) in accordance with Tier 2 of the *Good Practice Guidance*
- Preparation of a detailed concept for the creation of a *Quality System for Emissions* for internal and external quality assurance and control of the *National System* (QA/QC plan).

In order that the individuals and institutions involved can be given concrete action instructions within the framework of their tasks, the requirements of the *Good Practice Guidance* in national implementation are referred more specifically to action levels (cf. Figure 21).



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General procedures in the National System
- Data collection and calculation (ensuring data flow, current status)
- Archiving all relevant information including QA/QC measures
- Inventory Improvement Plan / QA Review Plan
- Reporting to the international bodies

Technical procedures in the CSE
- Compliance with CSE standards during data collection
- Implementation of test requirements during software development

Organisational procedures at the UBA
- Coordination of relevant activities for inventory preparation (including research and development projects)

Procedures for data processing
- Determination of key sources (Tier 1 & 2)
- Determination of uncertainties (Tier 1 & 2)
- Consistency checks on data integrity and completeness (identification of gaps)
- Technical review of source categories, activity rates and emission factors as well as methods

Source: Marion Dreher – Federal Environmental Agency / division II 6.3 – Emissions situation

Figure 21: **Observation levels for the plan for internal and external quality assurance and quality control of the National System**

19.3 The database system for emissions – Central System of Emissions

19.3.1 Database structure and management

The development of a new database for emissions, the Central System of Emissions (CSE or ZSE, Zentrales System Emissionen), and a database system was initiated at the Federal Environmental Agency in 1998. The system has a modular software design which allows the integration of new methodologies. A time series-oriented data warehouse at its centre supports the handling of several databases for inventories of different contents. At the heart of the data warehouse lies a multi-dimensional classification concept for time series, which offers a high degree of flexibility in describing the contents of an emissions database. The software is client/server based, multi-user capable and runs in a Windows™ computer network.

The database system consists of two relational databases with a modular structure:

- The CSE (Central System of Emissions) contains all data records, time series and additional information of the main source categories. The information is edited here in accordance with the international and national reporting requirements. To improve the data quality of reported data and to increase transparency, the documentation of data sources is also involved in the database.
- POSO (Point Source) contains all master data and time series of large combustion plants, which are necessary for the reporting obligation of the EU-Directive 2001/80/EG on the Limitation of Emissions from Large Combustion Plant Directive, LCPD, and any additional information originating from the European Pollutant Emission Register can also be inserted. POSO can be linked with the CSE and aggregated emission data can be transferred via the reporting generator into the CSE.

19.3.2 Other software tools: the CalQlator

The CalQlator tool allows the specification of calculation procedures which estimate the emissions from other indicators by some mathematical correlation.

In a first step, the user establishes the mathematical equation system and specifies which input variables for the calculation correspond to which time series in the database and which time series are to be used to store the results.

This is achieved using the equation editor. Once the calculation procedure is defined correctly and stored in the database, it can be executed by the CSE solver.

At present, the tool is undergoing further development, so that several calculation procedures can be grouped together in a hierarchical structure. This way complex calculations can be broken up transparently into smaller blocks that are easy to control. A status system should indicate whether the results of a calculation are up-to-date or whether the calculation has to be re-launched. The execution of calculations should also be scheduled.

The results of the calculation can be incorporated in reports by establishing a link to the resulting time series of the calculation procedure.

19.3.3 Other software tools: the Analyst

The report generator, the so-called Analyst, enables the output of the necessary data in the appropriate reporting format. The Analyst is Excel-based and thus allows the user to create his report templates in a familiar environment.

The major difference is that the reported values are not copied into the sheet but are inserted by establishing a hot link to the database.

At present, the new UNFCCC software of the CRF tables is integrated into the Analyst.

The combination of the different mathematical and statistical functions of the Calqlator and the Analyst is a very powerful instrument for performing quality assurance of the data material.

19.3.4 Data flow

At present the CSE database is filled with expert information on emissions, emission factors and activity rates as well as primary information from the main source categories energy, transport, agriculture, production processes etc. Further information is compiled by the Federal Statistical Office in Germany, other relevant institutes and by owners of industrial plants. This relationship and the link to other industries will be organized in future in the National System, which will coordinate the data flow.

The expert information or input data are imported into the respective databases via import-interfaces. Before the data is imported it is checked for plausibility and consistency by the administrator of the databases.