# German Greenhouse Gas Inventory 1990 - 2002

## National Inventory Report 2004

**Submission under the United Nations Framework Convention on Climate Change**

## Federal Environmental Agency (Umweltbundesamt)

## Berlin, August 2004

## Contact

This report is the result of work by the Federal Environmental Agency (UBA) to develop the *National System of Emissions Inventories* (NaSE) and the *Quality System for Emissions Inventories* (QSE). The information on agriculture, 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)*.

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

http://www.umweltbundesamt.de/luft/emissionen/bericht/aktuelle-daten/index.htm

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| AGEB | Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen) |
| AK | Working group (Arbeitskreis) |
| ANCAT | Abatement of Nuisances from Civil Air Transport |
| AR | Activity rate |
| $B_0$ | Maximal $CH_4$-production capacity |
| BAFA | Federal Office of Economics and Export Control (Bundesamt für Wirtschaft und Ausfuhrkontrolle) |
| BAT | Best Available Technique |
| BEU | Balance of emissions sources for stationary and mobile combustion processes (Bilanz der Emissionsursachen für stationäre und mobile Verbrennungsprozesse) |
| BGR | Federal Institute for Geosciences and Natural Resources (Bundesanstalt für Geowissenschaften und Rohstoffe) |
| BImSchV | Statutory Ordinance under the Federal Immission Control Act |
| BML | see BMVEL |
| BMU | Federal Ministry for the Environment, Nature Conservation and Nuclear Safety |
| BMVEL | Federal Ministry of Consumer Protection, Food and Agriculture |
| BMWA | Federal Ministry of Economics and Labour |
| BMWi | see BMWA |
| BOHE | Main survey on soil use (Bodennutzungshaupterhebung) |
| BREF | BAT (Best Available Technique) Reference Documents |
| BSB | Biological oxygen demand (BOD) |
| BV Kalk | German Lime Association (Bundesverband der Deutschen Kalkindustrie) |
| BWI | Bundeswaldinventur (Federal Forest Inventory) |
| $C_{org}$ | Organic carbon stored in the soil |
| CORINAIR | Coordination of Information on the Environment, sub-project: Air |
| CORINE | Coordinated Information on the Environment |
| CRF | Common Reporting Framework |
| CSB | Chemical oxygen demand (COD) |
| D | Deutschland (Germany) |
| DESTATIS | Federal Statistical Office (Statistisches Bundesamt Deutschland) |
| DG | Landfill gas (DG) – amount formed |
| DIW | German Institute for Economic Research (Deutsches Institut für Wirtschaftsforschung) |
| DLR | German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt) |
| DMKW | Diesel-engine power stations |
| $D_N$ | N in wastewater |
| DOC | Degradable organic carbon |
| $DOC_F$ | Fraction of DOC dissimilated |
| DTKW | Steam-turbine power stations |
| EF | Emissions factor |

| | |
|---|---|
| EI | Emissions index = Emissions factor |
| $E_{KA}$ | Einwohner mit Kläranlagenanschluss (Inhabitants connected to wastewater-treatment systems) |
| EM | Emission |
| EMEP | Co-operative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air pollutants in Europe |
| EMEV | Emissions-relevant energy consumption (Emissionsrelevanter Energieverbrauch) |
| EUROSTAT | Statistiscal Office of the European Communities |
| EW | Population equivalents per year (Einwohnerwerte pro Jahr) |
| FA | Combustion systems |
| FAL | Federal Agricultural Research Institute |
| FAO | Food and Agriculture Organisation |
| FCKW | Chlorofluorocarbons (CFCs; Fluorchlorkohlenwasserstoffe) |
| F gases | Fluorinated hydrocarbons |
| FHW | District heating stations |
| FKW | Perfluorocarbons (PFCs; Fluorkohlenwasserstoffe) |
| FKZ | Research index (Forschungskennziffer) |
| GAS-EM | GASeous EMissions – A calculation programme for emissions from agriculture |
| GEREF | GERman Emission Factor Database |
| GFA | Large combustion systems (Großfeuerungsanlagen) |
| GMKW | Gas motor power plants |
| GT | Gas turbines |
| GTKW | Gas turbine power stations |
| GuD | Gas and steam turbine power stations |
| GPG | Good Practice Guidance |
| GWP | Global Warming Potential |
| HFC | Hydrofluorocarbon |
| HFCKW | Hydrochlorofluorocarbons (HCFCs; Wasserstoffhaltige Fluorchlorkohlenwasserstoffe) |
| HFKW | Hydrofluorocarbons (= HFCs; Wasserstoffhaltige Fluorkohlenwasserstoffe) |
| HQG | Hauptquellgruppe (Main source group) |
| ICAO | International Civil Aviation Organisation |
| IEA | International Energy Agency |
| IfE | Institute for Energy and Environment (Institut für Energetik und Umwelt) |
| IFEU | Institut für Energie- und Umweltforschung (Institute for Energy and Environmental Research) |
| IKW | Industrial power stations |
| IMA | Interministerial Working Group (Interministerielle Arbeitsgruppe) |
| IPCC | Intergovernmental Panel On Climate Change (Intergovernmental Panel On Climate Change) |
| K | Fuel input for power generation (direct drive) |
| KP | Kyoto Protocol |
| KS | Sewage sludge (Klärschlamm) |

| | |
|---|---|
| l | level (= Level assessment pursuant to IPCC Good Practice Guidance) |
| LF | Landwirtschaftlich genutzten Flächen (agriculturally used land) |
| LTO | Landing/take-off cycle |
| LUCF | Land-use change and forestry |
| MBA | Mechanical-biological waste treatment (Mechanisch-Biologische Abfallbehandlung) |
| MCF | Methane conversion factor |
| MFC | Factor for quality of landfill-gas management (methane correction factor) |
| MSW | Amount of municipal waste stored |
| MVA | Waste incineration plant |
| NASA | National Aeronautics and Space Administration |
| NaSE | National System of Emissions Inventories |
| NE | Not estimated |
| NEC Directive | Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on national emission ceilings for certain air pollutants |
| NFR | Nomenclature for Reporting (new format for reporting to UN ECE) |
| NIR | National Inventory Report |
| NMVOC | Non-Methane Volatile Organic Compounds |
| NO | Nitrogen monoxide |
| NO | Not occurring |
| OX | Oxidation factor; factor for determining the proportion of $CH_4$ that is oxidised |
| PF | Process furnaces |
| PFC | Perfluorocarbon |
| PS | Plant-specific |
| QK | Quality control (QC) |
| QS | Quality assurance (QA) |
| QSE | Quality System for Emissions Inventories |
| RSt | Raw steel |
| RWI | Rheinisch-Westfälisches Institut für Wirtschaftsforschung (RWI) |
| S | Fuel input for power generation |
| SAR | Synthesis and Assessment Report |
| $SF_6$ | Sulphur hexafluoride |
| SKE | Hard-coal units (Steinkohleneinheiten) |
| SNAP | Selected Nomenclature for Air Pollution |
| Federal Statistical Office (Statistisches Bundesamt) | Federal Statistical Office |
| t | trend (= trend assessment pursuant to IPCC Good Practice Guidance) |
| TA Luft | Technical instructions on air quality control; First General Administrative Provision on the Federal Immission Control Act |
| TAN | Total Ammoniacal Nitrogen |
| THG | Greenhouse gases (Treibhausgase = GHG) |
| TM | Dry mass (Trockenmasse) |
| TOC | Total Organic Carbon |
| TREMOD | Traffic Emission Estimation Model |

| | |
|---|---|
| UBA | Federal Environmental Agency (Umweltbundesamt) |
| UN ECE | United Nations Economic Commission for Europe |
| UN FCCC | United Nations Framework Convention on Climate Change |
| UN | United Nations |
| VDEW | Electricity Industry Association (Verband der Elektrizitätswirtschaft) |
| VfmD | Solid cubic meters of standing timber (Vorratsfestmeter Derbholz) |
| W | Fuel input for heat generation |
| WS | WS = Portion of a specific waste water treatment system (e.g. aerobic, anaerobic) |
| ZSE | Central System of Emissions |

# 0 SUMMARY

As a Party to the United Nations Framework on Climate Change, since 1994 Germany has been obliged to prepare, publish and regularly update national emission inventories of greenhouse gases. By adopting the Kyoto Protocol in 1997, the international community of nations reached agreement, for the first time ever, on binding aims and implementation instruments for global climate protection. This leads to very 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 an annual National Inventory Report (NIR) containing detailed and complete information on the entire process of preparation of such greenhouse-gas inventories. The purpose of such reports is to ensure the transparency of inventories and support the independent review process. The Secretariat of the Framework Convention of Climate has made submission of the inventory report a pre-requisite for performance of the agreed inventory reviews. With its inventory for 2004, Germany is submitting its second National Inventory Report. In comparison to the 2003 report (UBA, 2003c), this report contains, inter alia, substantial improvements in the following areas:

- Public electricity and heat production (CRF 1A1a)
- Petroleum refining (CRF 1A1b)
- Manufacture of solid fuels and other energy industries (CRF 1A1c)
- Pulp, paper and print (CRF 1A2D)
- Agriculture (CRF 4)
- Land-use change and forestry (CRF 5)
- Waste and wastewater (CRF 6)

In late 2002, a process of fundamental, systematic review and conversion of the NIR 2004 inventory methods was begun. This process has not yet been completed, and the Federal Environmental Agency plans to submit an updated version of the NIR 2004 by June 2004 as a basis for detailed inventory review in fall 2004. This version will contain, inter alia, additional improvements in the area of emissions calculations of energy input for briquette production. For the procedure used by the Federal Environmental Agency for calculating $CO_2$ emissions from lignite drying – a procedure still used in the present inventory report – a correction from 17 to 15 million tonnes, based on a new method calculating base-year emissions, is being discussed. Relevant consultations of the national group of experts will be completed in May 2004. Correction of activity rates would affect the entire time series from 1990-2002 – and especially the base year, 1990. Other improvements will be oriented to calculation of uncertainties.

National greenhouse gas emission inventories for the years 1990-2002 have been submitted to the Secretariat of the Framework Convention on Climate Change. This report refers to those annual emission inventories and outlines the methodology and the data sources on which the calculations are based. The report and the report tables in the Common Reporting Format (CRF) have been prepared in accordance with UNFCCC guidelines (*FCCC/CP/2002/8*) and, as far as possible, in accordance with the *IPCC Good Practice Guidance* (IPCC, 2000).

**Chapter 1** describes the National System of Emissions Inventories in Germany, which is designed to aid compliance with all reporting obligations with respect to atmospheric emissions and storage in sinks. Apart from the Kyoto Protocol requirements, this also covers

other legal obligations (the UN ECE Geneva Convention on Long-range Transboundary Air Pollution, the EU Directive on National Emission Limits) that Germany has entered into. In addition, it describes the basic principles and methods with which the emissions and sinks of the IPCC categories are calculated, and it describes the Quality System for Emissions Inventories. Over the past three years, the participating institutions have undertaken considerable efforts that have successfully reduced uncertainties and closed gaps in the data. Efforts to systematically improve the inventory continue and are being given high priority.

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

**Chapters 3 to 9** contain detailed information about the main groups of emissions sources and sinks; this information is designed to enhance the transparency of calculations of German greenhouse-gas emissions and sinks. In comparison to Germany's first National Inventory Report, from the year 2003, significant improvements with regard to transparency and clarity have been achieved. The emphasis of work in 2003 – supplementing and consolidating the existing report's descriptive sections on collection of data relative to sources and methods used, has led to improvements in the report and the inventory, while also revealing new requirements for improvement. The intensive national review process must be continued in 2004. Methodological conversions for implementing the *Good Practice Guidance* (GPG) in the inventories are taking more time than was originally expected – in part, because at the same time the relevant inventory-preparation processes are being critically reviewed and any changes always also take QC/QA requirements into account. For this reason, it continues to be the case that no sharp distinctions are made between methods descriptions and 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 procedures. More detailed information about specific relevant issues is presented in the literature listed in **Chapter 11**.

General information on uncertainties and recalculations can be found in **Chapter 10.**

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

## 0.1 Background information on greenhouse-gas inventories and climate change

Ever since the start of industrialisation, significant trans-regional and global changes in the substance balance of the atmosphere have been observed as a consequence of human activities. Worldwide, concentrations of carbon dioxide ($CO_2$) have risen by approximately 30 % compared with the levels in pre-industrial times, whilst those of methane ($CH_4$) have increased by 145 % and those of nitrous oxide ($N_2O$) by 15 %. Furthermore, a number of brand new substances such as chlorofluorocarbons (CFCs), halons, perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulphur hexafluoride ($SF_6$) have entered the atmosphere which almost never occur in nature and are generated almost exclusively by humans.

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

In the framework of the Kyoto Protocol, the European Union has committed to reducing its greenhouse-gas emissions by 8% by the 2008–2012 period, in comparison to their 1990 levels. This commitment has been divided between the EU Member States in the framework of a burden-sharing arrangement[1]. Under this agreement, Germany has agreed to reduce its emissions by 21 % in comparison to the base year and thus has agreed to make a substantial contribution to fulfillment of the EU's commitment. Consequently, Germany's relevant measures, and its calculations relative to emissions reductions, are being followed with considerable interest.

## 0.2 Greenhouse-gas emissions and their storage in sinks (with respect to GWP) over time: 1990-2002

In the framework of EU burden-sharing, the Federal Government has made a commitment to reduce Germany's emissions of all six Kyoto gases by 21 % in comparison to the base year (1990 and 1995[2]), by the end of the first commitment period, which runs from 2008 to 2012. The development of greenhouse-gas emissions in Germany since 1990 is shown in Table 1 for the various individual greenhouse gases and, graphically, in Figure 1 for all emissions, represented as $CO_2$-equivalent emissions.

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

| GREENHOUSE GAS EMISSIONS | Base year | 1990 | 1995 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|
| | $CO_2$ equivalent (Gg) | | | | | |
| Net $CO_2$ Emissions/ removals | 1.023.087,65 | 1.023.087,65 | 907.131,24 | 874.369,68 | 888.072,32 | 878.023,26 |
| $CO_2$ emissions (without LUCF) | 1.015.572,42 | 1.015.572,42 | 901.478,32 | 860.272,66 | 874.263,81 | 864.116,77 |
| $CH_4$ | 139.766,68 | 139.766,68 | 109.173,08 | 86.548,58 | 83.000,30 | 81.446,65 |
| $N_2O$ | 81.375,33 | 81.375,33 | 73.470,23 | 55.812,95 | 56.112,50 | 55.833,05 |
| HFCs | 6.359,92 | 3.510,00 | 6.359,92 | 6.630,04 | 8.129,69 | 8.247,14 |
| PFCs | 1.758,78 | 2.696,00 | 1.758,78 | 789,70 | 722,92 | 785,94 |
| $SF_6$ | 6.889,69 | 3.895,70 | 6.889,69 | 4.017,98 | 3.325,31 | 4.197,08 |
| Total (with net $CO_2$ emissions/removals) | 1.259.238,06 | 1.254.331,36 | 1.104.782,95 | 1.028.168,93 | 1.039.363,04 | 1.028.533,12 |
| Total (without $CO_2$ from LUCF) | 1.251.722,83 | 1.246.816,13 | 1.099.130,03 | 1.014.071,90 | 1.025.554,54 | 1.014.626,63 |

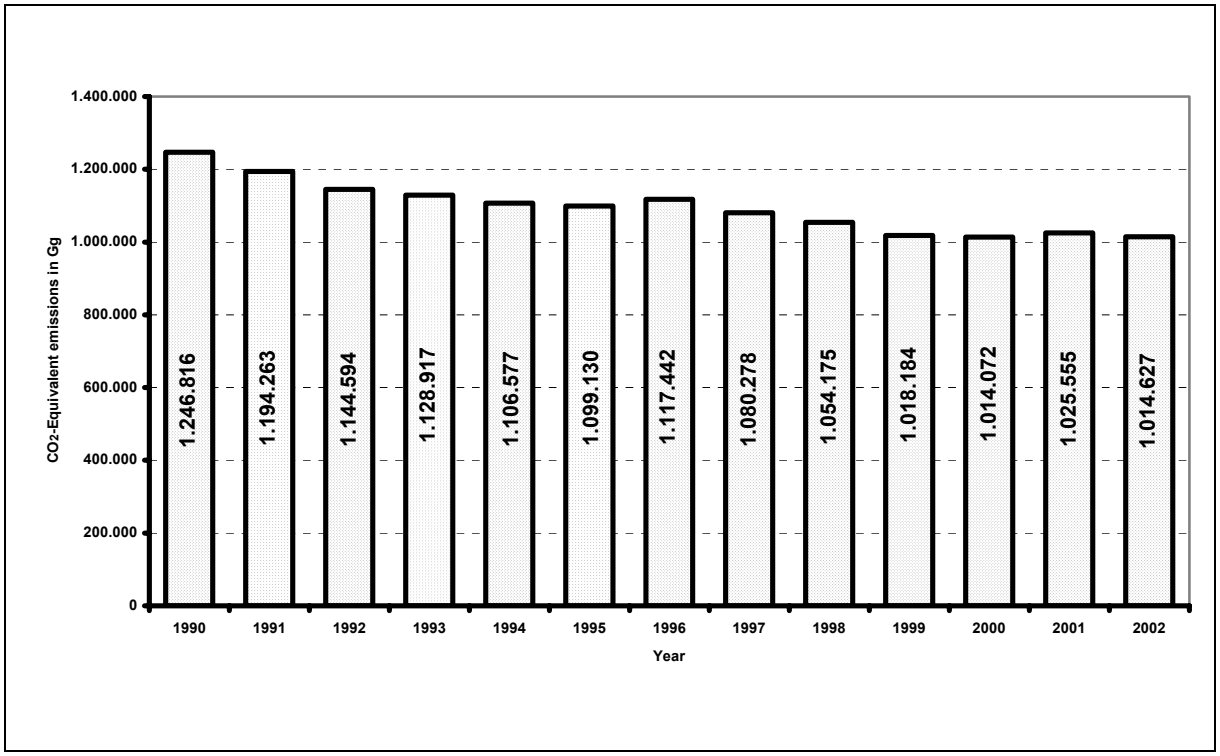


Figure 1: Overall development of greenhouse gas emissions in Germany

By 2002, Germany reduced its emissions by nearly 19 % in comparison to the base year, thereby already fulfilling much of its its commitments within the framework of European burden sharing. The individual greenhouse gases contributed to this development to varying degrees (see Table 1). This is hardly surprising given that, in any given year the various greenhouse gases account for varying proportions of total emissions (see Table 2).

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

| GREENHOUSE GAS EMISSIONS | Base year | | 1990 | | 1995 | | 2000 | | 2002 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Gg | % | Gg | % | Gg | % | Gg | % | Gg | % |
| $CO_2$ emissions (without LUCF) | 1.015.572 | 81,1 | 1.015.572 | 81,5 | 901.478 | 82,0 | 860.273 | 84,8 | 864.117 | 85,2 |
| $CH_4$ | 139.767 | 11,2 | 139.767 | 11,2 | 109.173 | 9,9 | 86.549 | 8,5 | 81.447 | 8,0 |
| $N_2O$ | 81.375 | 6,5 | 81.375 | 6,5 | 73.470 | 6,7 | 55.813 | 5,5 | 55.833 | 5,5 |
| HFCs | 6.360 | 0,5 | 3.510 | 0,3 | 6.360 | 0,6 | 6.630 | 0,7 | 8.247 | 0,8 |
| PFCs | 1.759 | 0,1 | 2.696 | 0,2 | 1.759 | 0,2 | 790 | 0,1 | 786 | 0,1 |
| $SF_6$ | 6.890 | 0,6 | 3.896 | 0,3 | 6.890 | 0,6 | 4.018 | 0,4 | 4.197 | 0,4 |
| Total (without $CO_2$ from LUCF) | 1.251.723 | | 1.246.816 | | 1.099.130 | | 1.014.072 | | 1.014.627 | |

Stationary and mobile combustion processes, accounting for over 85 % of released carbon dioxide, are the main sources of emissions. In particular, as a result of disproportionately large reductions of other greenhouse gases, $CO_2$ emissions' share of total emissions has increased by 4 % since 1990. Emissions of methane caused by animal husbandry, fuel distribution and landfill emissions account for just over 8 %. Emissions of nitrous oxide,

1 Burden-sharing agreement; adopted via Council decision 2002/358/EC
2 For HFC, PFC and $SF_6$
3 (1) Base year 1990 for $CO_2$, $CH_4$, $N_2O$; 1995 for HFC, PFC, $SF_6$

caused primarily by agriculture, industrial processes and transport, account for more than 5 % of greenhouse-gas releases. The other so-called "Kyoto" or "F" gases contribute only slightly more than 1 % to total emissions. The distribution of Germany's greenhouse-gas emissions is typical for a highly developed and industrialised country.

## 0.3 Overview of emissions estimates and trends for source and sink groups

Figure 2 shows the contributions of the various source categories to total greenhouse-gas emissions. It highlights the relative constancy of the shares of the various sources and the absolute dominance of energy-related emissions. In fact, these have continuously decreased over time. The two slight re-increases in 1996 and 2001 are attributable to climatic factors in both cases. These two years had lower winter temperatures than the other years. This resulted in higher energy consumption on heating, which in turn led to an increase in emissions.

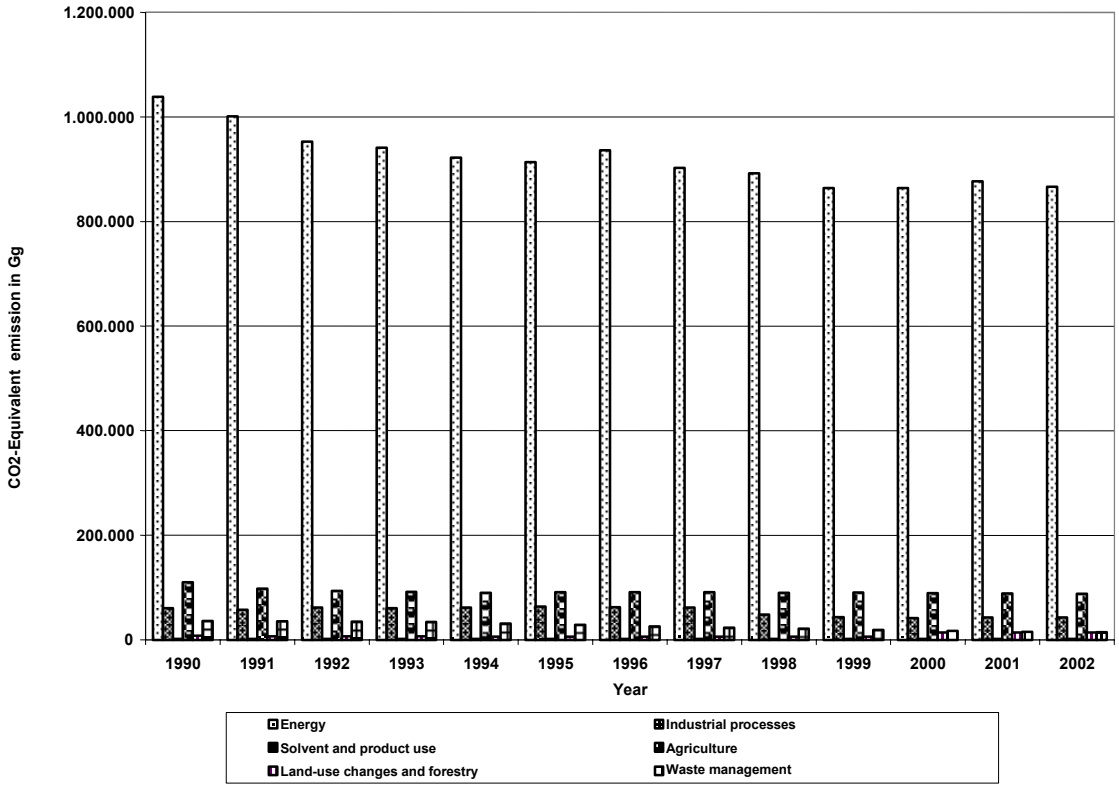


Figure 2: Development of greenhouse-gas emissions by source categories, and development of sinks, in $CO_2$ equivalents

Figure 3 shows the relative development of emissions from source 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 of measures in the field of adipic acid production in 1997 were substantial. Emissions from solvent and other product use are not very high in absolute

terms; the constancy of these emissions can be explained by the updating of the figure calculated for 1990 from the narcotic use of $N_2O$. The 2005 Inventory will provide an update in this area. The trend in emissions from agriculture essentially follows the development of livestock figures. The marked emissions trends in the areas of land-use changes and forestry are due to special aspects of methods still used in the relevant periods (use of multi-year averages for 1990-94,1995-99 and 2000 to 2002) – cf. Chapter 7.1.2.

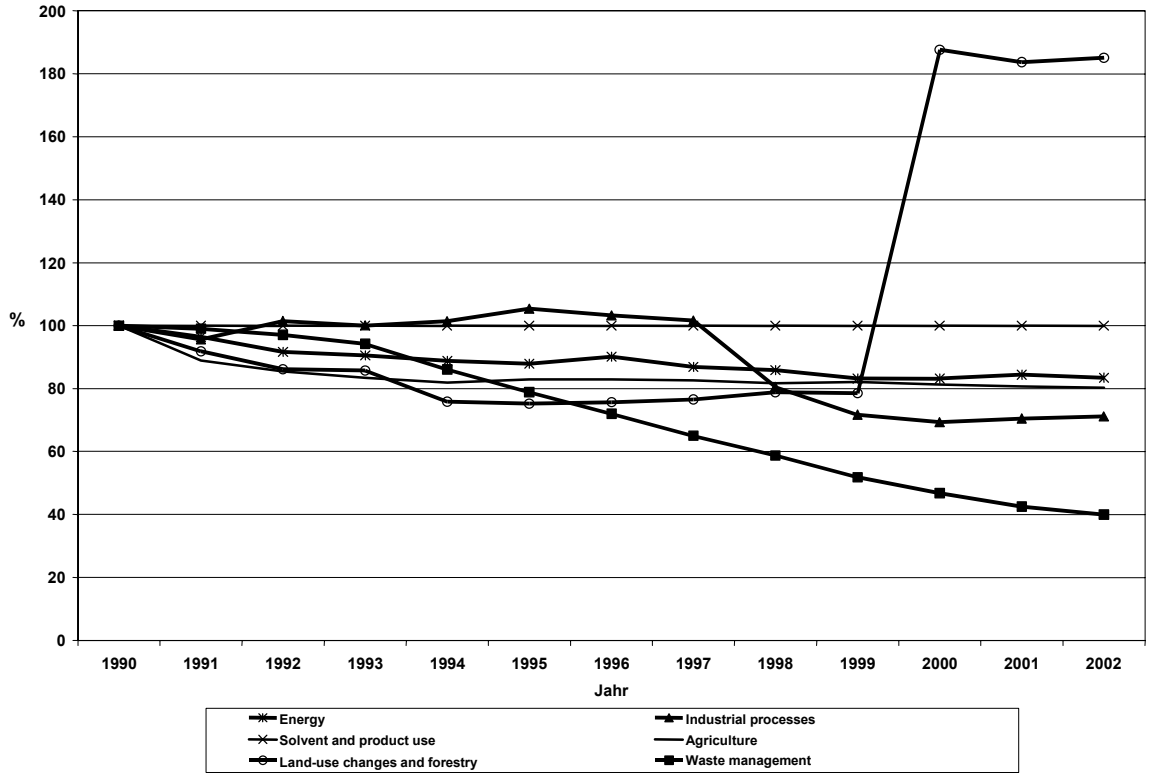


Figure 3: Development of the various greenhouse gases since 1990, by source categories

# 1 INTRODUCTION

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

### *1.1.1 The greenhouse effect*

Climate change consists of changes in average weather conditions over an extended period of time; it can occur in a particular area or even be global. Research has shown that the mean global temperature has fluctuated between 9°C and 16°C over the past millions of years. Climate change may be attributable to the following causes:

- Changes in so-called "geo-astrophysical parameters" such as solar constant, elements of the earth's orbit, etc.
- Changes in the earth's surface
- Changes in the energy balance in the system of "*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 an energetically excited state for a brief time, after which they return to their original basic state whilst emitting infrared radiation. Heat radiation occurs equally in all spatial directions – in other words, a substantial portion of this is returned to the earth's surface ("*thermal back radiation*"). So that this additional quantity of energy may nevertheless be irradiated (this must occur due to the dynamic, energetic equilibrium, at whose centre are the earth and the atmosphere), the earth must have a correspondingly higher temperature. In simplified terms, this is the nature of the greenhouse effect.

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

### *1.1.2 Climate change*

Ever since the start of industrialisation, significant supra-regional and global changes in the substance balance of the atmosphere have been observed as a consequence of human activities. Worldwide, concentrations of carbon dioxide ($CO_2$) have risen by approximately 30 % compared with the levels in pre-industrial times, whilst those of methane ($CH_4$) have increased by 145 % and those of nitrous oxide ($N_2O$) by 15 %. Furthermore, a number of brand new substances such as chlorofluorocarbons (CFCs), halons, perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulphur hexafluoride ($SF_6$) have entered the atmosphere which almost never occur in nature and are generated almost exclusively by humans.

Although the triggers of the greenhouse effect are minimal in volume terms, their effects are substantial. The increase in the concentration of greenhouse gases serves to reinforce the

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

In its most recent report of 2001, the IPCC (Intergovernmental Panel on Climate Change) ascertained, *inter alia*, that the average global air temperature has increased by between 0.4 and 0.8°C over the past 100 years. 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 recognize that the expected temperature changes would pose threats to ecosystems and to human civilisation, because the changes would take place relatively quickly, and existing systems would not be able to adapt to the new climate conditions without suffering damage.

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

At the third Conference of the Parties, held in Kyoto, legally binding obligations on emissions limitations and reductions were defined, for the first time, for industrialised countries. Pursuant to the Kyoto Protocol, industrialised nations must reduce their emissions of the six greenhouse gases carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), hydrofluorocarbons (HFC), perfluorocarbons (PFC) and sulphur hexafluoride ($SF_6$) by an average of 5.2 percent by 2012. In the framework of the Kyoto Protocol, the European Union has committed to reducing its greenhouse-gas emissions by 8% by the 2008–2012 period, in comparison to their 1990 levels. Within the EU, this commitment has been divided up between the Member States via a burden-sharing arrangement[4] whereby Germany is called on to make a substantial contribution of a 21 % emissions reduction in comparison to the base year. Consequently, Germany's relevant measures, and its calculations relative to emissions reductions, are being followed with considerable interest.

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

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

## 1.2 Institutional specifications and framework conditions for inventory preparation

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

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

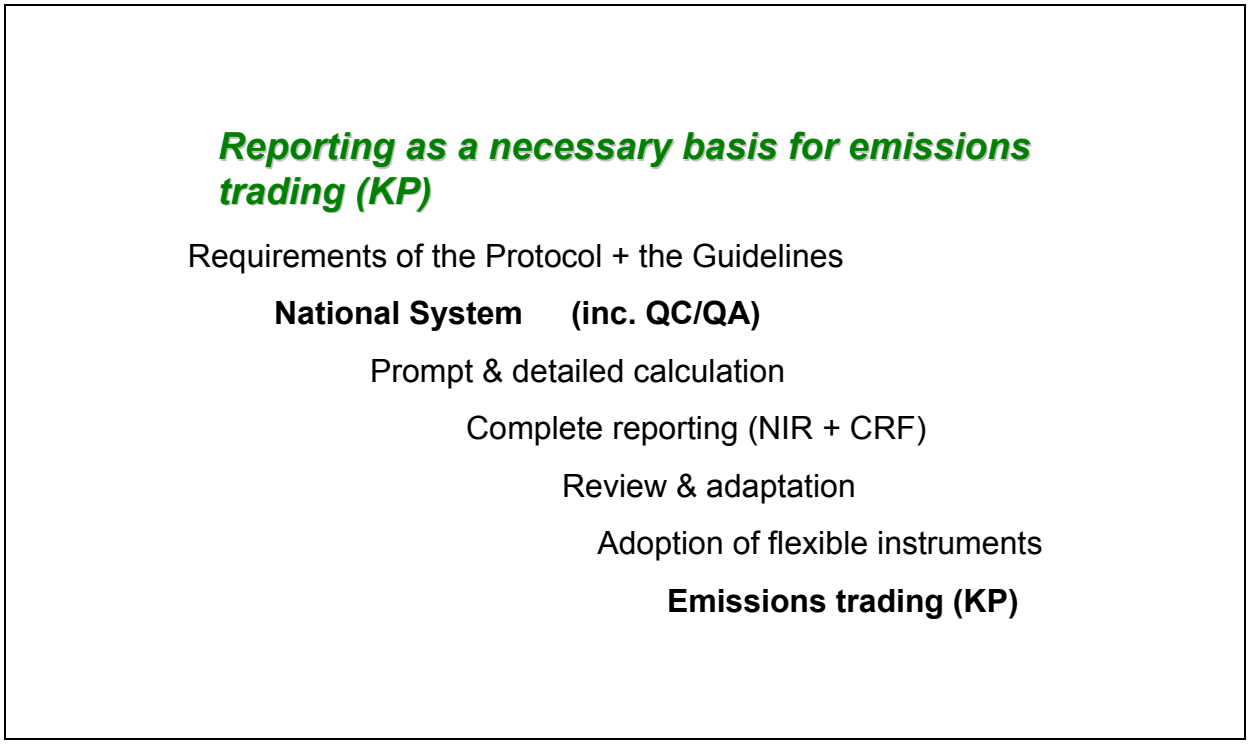


Figure 4: Pre-requisites for the use of the KP's flexible instruments

The requirements are not limited to preparation of inventories; they also comprise the entire relevant process, from data collection to reporting. Quality management plays a particularly important role. In order to create a defined framework for the process of greenhouse-gas

reporting, the Member States are obligated to establish national systems, for inventory preparation, that permit continual inventory improvement.

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

### *1.2.1 Institutional specifications for inventory preparation*

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

1. The *co-ordinating office of the National System* – the "Single National Entity" (SNE) – is located in Section II 5.3 of the Federal Environmental Agency. There is as yet no legally binding specification in this respect. The SNE is charged with serving as the central point of contact and information for all participants in the National System. It is required to provide a framework for transparent, consistent, complete, comparable and precise inventories.

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

3. A *Working Group on Emissions Reporting*, founded in 2002 within the $CO_2$ Reduction Interministerial Working Group[5] , is charged with implementing emissions-reporting requirements within federal agencies. Interministerial discussion on central tasks in emissions inventories, as identified to date, is being carried out in this framework. Coordination is being carried out by the BMU. Plans call for the working group to meet three times in 2004. At present, Working Group VI is focussing on possibilities for institutionalising the Kyoto requirements – for example via an act on implementation.

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

5. Data on forestry is supplied to the Federal Environmental Agency by the BMVEL, drawing on the relevant surveys. In October 2003, the BMVEL established a working group to focus on issues of data infrastructure, data requirements, the legal

5 Following a resolution by the Federal Government on 13 June 1990, the IWG(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 climate protection at the national level.

framework, relevant technical and specialised matters and data sources. The Federal Environmental Agency is also represented within this working group.

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

7. The *incorporation of associations* and other independent organisations has been achieved primarily via the sections of divisions I and III, at the Federal Environmental Agency, responsible for concrete issues. The *Single National Entity* provides the specialist departments with support when debating reporting requirements and determining the required data flows with the associations. Work to raise awareness and provide information has been intensified since 2003.

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

9. The average length of time required for commissioning via the UFOPLAN, from problem identification (project initiation) to solution (acceptance of the final report), is 3.5 years. Since inventories must be reviewed annually by independent experts of the Climate Secretariat, and since improvements relative to deficiency reports must be initiated promptly, the response time for eliminating priority deficiencies must be one year, however. For this reason, a separate budget position for the National System, over and above research funding, will be established within the Federal Environmental Agency. This position can then be used to fund short-term projects for inventory improvement, within the Agency's responsibility.

### *1.2.2 Framework conditions for inventory preparation*

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

Currently, the following framework applies to inventory preparation in Germany:

1. In 2002, the Federal Environmental Agency began establishing a Quality System for Emissions Inventories (QSE) that will provide the necessary framework for

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

2. The database of the Federal Environmental Agency's *Central System on Emissions* (CSE) is used for central storage of all information required for emissions calculation (methods, activity rates, emission factors) . The CSE is the main instrument for documentation and quality assurance at the data level. A more detailed description of the CSE is provided in Annex 6 (Chapter 0).

3. A binding schedule for preparation of emissions inventories and of the NIR is announced to all relevant internal and external players via the Federal Environmental Agency's Website and via publication within the NIR itself. In 2003, and for all subsequent years, the following schedule holds for inventory data (all pollutants) and for the pertinent descriptions in the National Inventory Report (initially, covering only GHG):

| | |
|---|---|
| 15 June | The Federal Environmental Agency's national co-ordinating agency (Single National Entity) requests delivery of data and report texts |
| 01 September | Deliveries from Federal Environmental Agency and from external institutions of the NaSE |
| 15 October | Validation / consultations |
| 15 November | Final editing by the Federal Environmental Agency's national co-ordinating agency (Single National Entity) |
| 30 November | Report to the ministry for initiation of ministry co-ordination |
| 31 December | Report to the European Commission (within the framework of the $CO_2$-monitoring mechanism) |
| 15 April | Report to the Secretariat of the FCCC |

## 1.3 Short description of inventory preparation

Inventory preparation is carried out under the direction of Section II 5.3 of the Federal Environmental Agency, which also serves as the Single National Entity. The process of inventory preparation is co-ordinated closely with preparation of the National Inventory Report and with execution of quality assurance procedures (cf. Figure 5).

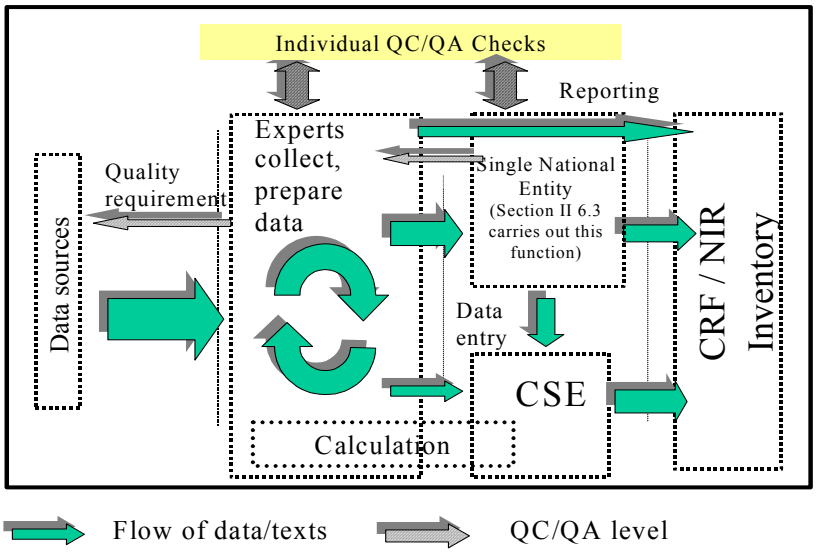


Figure 5: Current process of emissions reporting

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

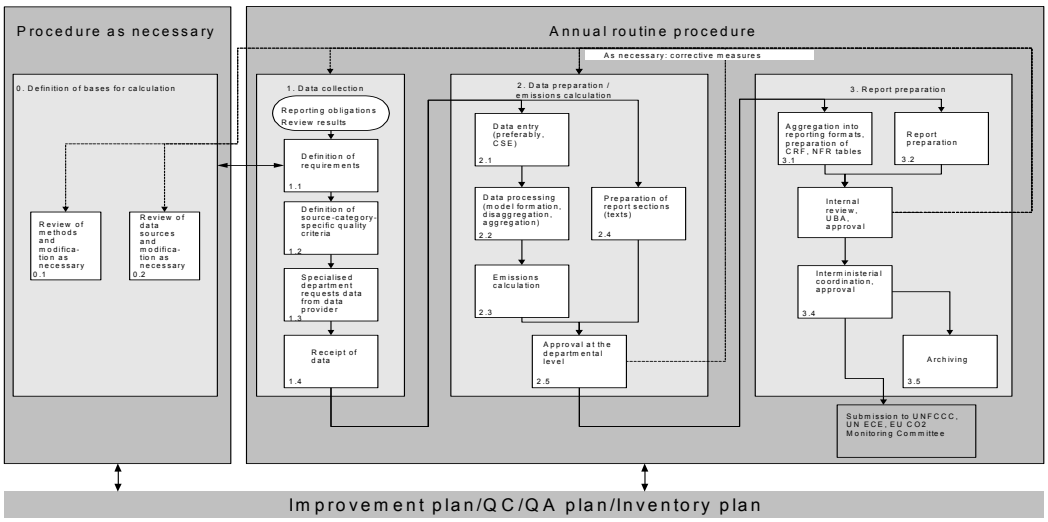


Figure 6: Overview of the overall emissions-reporting process

### *1.3.1 Definition of bases for calculation*

**Selection of calculation methods** for determining emissions affects the entire emissions-reporting process. For this reason, the overall process must begin with review of the suitability of the methods to be used. IPCC Good Practice Guidance specifies, via use of decision trees, what methods are to be used for the various source categories. In each case, such methods selection depends on whether the group in question is a key source or not. Any use of different – *Land*-specific – methods, instead of the prescribed methods, must be justified. In each case, an outline of why the method in question is of equivalent or higher value is to be provided, along with clear documentation.

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

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

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

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

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

### *1.3.2 Data collection*

Data collection and documentation takes place under the responsibility of the relevant experts. An organisation may collect data by evaluating official statistics or statistics from associations, studies, periodicals or external research projects, by conducting its own research projects, by obtaining information from relevant persons, or by accessing data exchanges between the Federal Government and the *Länder*. Often, work results obtained by other means are also reused for the purposes of emissions reporting.

Data collection comprises the following steps:

- Definition of requirements,
- Specification of the source-category-specific quality and review criteria for the data,
- Requesting of data from data providers (carried out by the relevant experts' group), and
- Receipt of data.

In each case, the National Single Entity (national co-ordinating agency) requests inventory input from the experts responsible for the source category in question, via the experts' superiors. In future, this will occur within the framework of an inventory plan. A master file, specifying the structure for such input, is provided for NIR preparation. The requirements for later data input are provided by the relevant CSE (ZSE) specifications (direct entry or fill-in of the import format). Via informational events of the Working Group on Emissions Inventories, and the Website for the Federal Environmental Agency's emissions reporting, involved experts are informed about the relevant reporting requirements, review results, current key-source analysis and current data status for each source category in question. In each case, the responsible expert must interpret the **applicable requirements** on the basis of such reference sources.

Such requirements influence the upstream process of defining the bases for calculation (review and selection of methods and data sources) – a process which always takes place when requirements have not yet been fulfilled or have changed (in future, such information will be provided in the inventory plan).

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

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

### *1.3.3 Data preparation and emissions calculation*

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

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

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

Considerable portions of **data entry and preparation** (preparation of data and emissions calculations in the narrower sense of the term) take place in the CSE/ZSE. Some QC measures at the data level can be integrated, in automatic form, within the CSE (formulation of checking conditions within the CalQlator), with the result that use of the CSE eliminates the need for manual execution of certain QC measures. Plausibility cross-checks, with simplified assumptions, should be applied to results of calculations with complex models.

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

activity rate * emission factor = emission

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

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

### *1.3.4 Report preparation*

Report preparation includes the following steps:

- Aggregation of emissions data into the relevant report formats, and preparation of data tables (CRF, NFR),
- Calculation of $CO_2$ equivalents for the greenhouse-gas emissions,
- Compilation of submitted report texts to form a report draft (NIR), and editing of the complete NIR,
- Review of the draft by the Federal Environmental Agency, followed by approval as appropriate,
- Forwarding to the BMU,
- Inter-ministerial co-ordination, followed by
- Handover to the UNFCCC Secretariat and
- Archiving.

Before emissions data can be transferred into the report tables for the Framework Convention on Climate Change (CRF = Common reporting Format) and for the UN ECE Geneva Convention on Long-range Transboundary Air Pollution (NFR = New Format on Reporting), **emissions data** from CSE time series (in the data-collection format) must be **aggregated** into the CRF/NFR source-group **report formats**. This is accomplished via hierarchical allocation within the CSE, a process that, in Annex 3, is described in detail for the various key sources. Aggregation takes place automatically.

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

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

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

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

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

The report co-ordinator **compiles the submitted report texts to form the NIR draft**. Experts in the Single National Entity (national co-ordinating agency), assigned to cover specific source categories, then carry out **internal review of the data and report sections**, on the basis of a QC checklist. The results of this review are then provided to the responsible experts, to enable these experts to revise their contributions (if necessary, following suitable consultation) accordingly. Following such revision, the report co-ordinator carries out overall editing of the NIR.

**Formal approval** of the report tables and the NIR, and of the inventory plan to be included in future, is provided via co-signing in the framework of the Federal Environmental Agency's internal co-ordination process. The documens are then **forwarded to the BMU** for **ministerial co-ordination**. The ministry arranges for translation of the NIR and for **its submission to the UNFCCC Secretariat**.

The data tables and the related NIR, in the version provided for ministerial co-ordination, are then transferred onto a CD and archived with clear identification information. The content of the CSE database used for calculation purposes is likewise copied and archived. The final

version submitted to the Secretariat of the Framework Convention on Climate is also **archived**.

## 1.4 Brief general description of methods and data sources used

### *1.4.1 Data sources*

#### 1.4.1.1 Energy

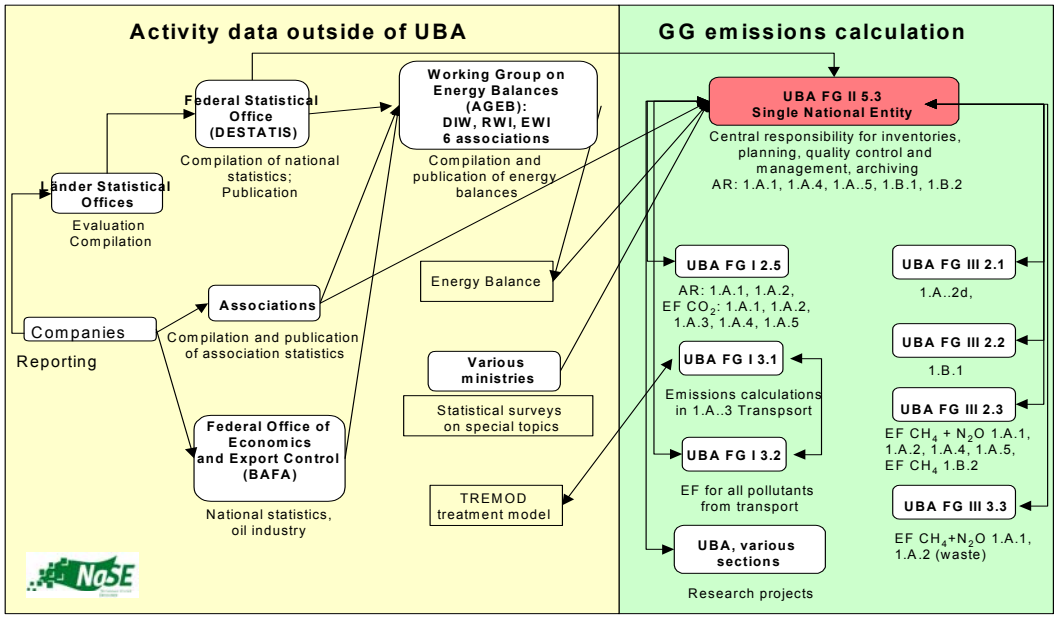


Figure 7: Responsibilities and data flows for calculation of greenhouse-gas emissions in the energy sector (ÖKO-INSTITUT, 2004a)

In all likelihood, the most important data sources for determination of activity rates in the CSE are the *"Energiebilanzen der Bundesrepublik Deutschland"* (Energy Balances of the Federal Republic of Germany, hereinafter referred to as: Energy Balance), which are published by the *Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen)*. An energy balance provides an overview of the links within Germany's energy sector, and it supports breakdowns in accordance with fuels and source categories. An energy balance receives data from a wide range of other sources. As a result, publication of energy balances is subject to some delay. The most current of the available energy balances describes the year 1999.

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

Also along with the Energy Balance, the Working Group on Emissions Balances (AGEB) also publishes "Evaluation Tables for the Energy Balance" (*Auswertetabellen zur Energiebilanz* (hereinafter referred to as: Evaluation Tables). In the area of fuels, these tables only list those fuels with the highest activity levels and aggreate lower activity levels to form sum

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

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

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

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

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

### 1.4.1.2 Industrial processes

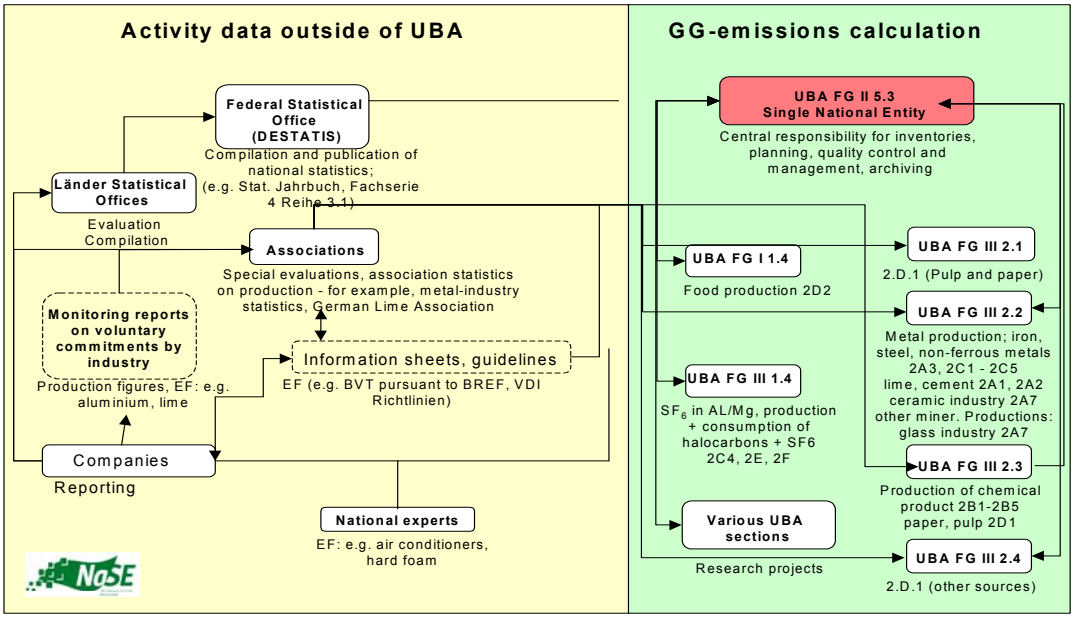


Figure 8: Responsibilities and data flows for calculation of greenhouse-gas emissions from industrial processes (ÖKO-INSTITUT, 2004a)

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

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

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

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

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

#### 1.4.1.3 Solvent and other product use

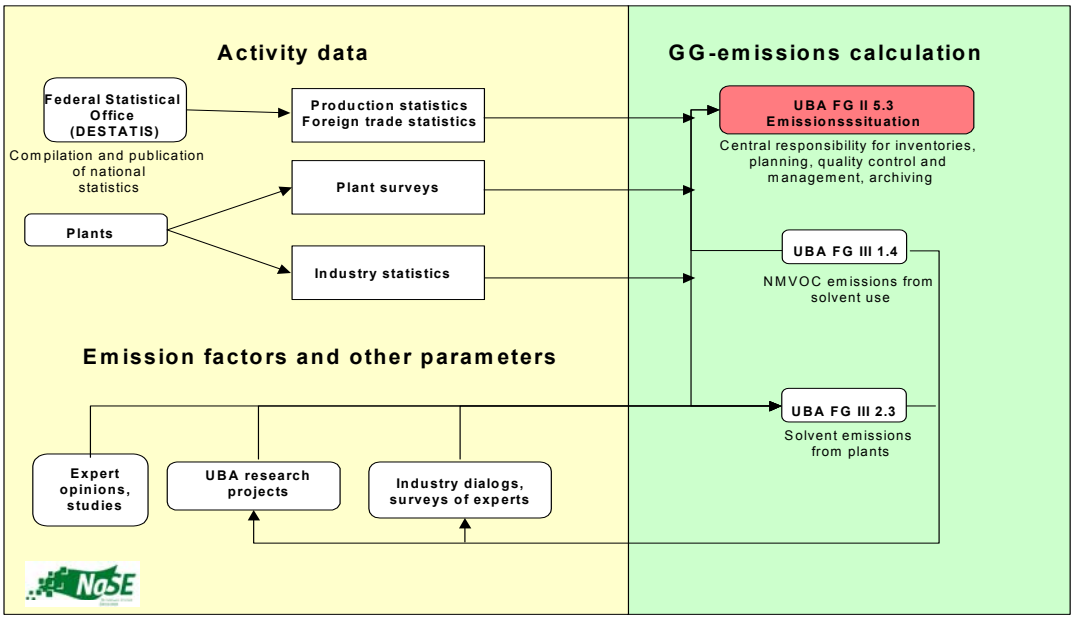


Figure 9: Responsibilities and data flows for calculation of greenhouse-gas emissions from use of solvents and other products (ÖKO-INSTITUT, 2004a)

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

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

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

### 1.4.1.4 Agriculture

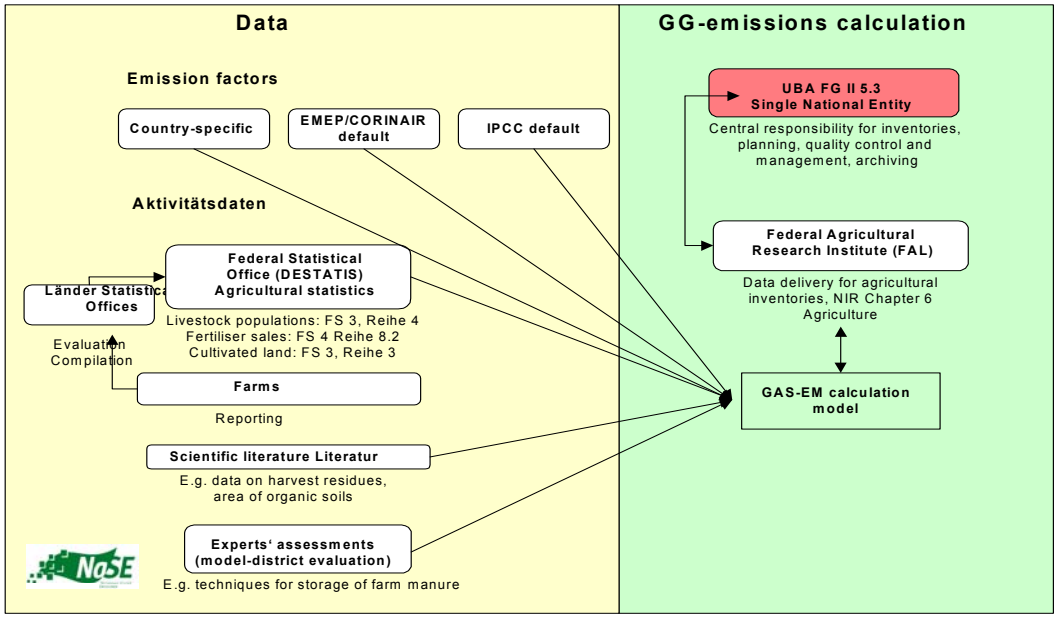


Figure 10: Responsibilities and data flows for calculation of greenhouse-gas emissions from agriculture (ÖKO-INSTITUT, 2004a)

For calculation of agricultural emissions in Germany, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and the Federal Ministry of Consumer Protection, Food and Agriculture (BMVEL) initated a joint project, and the same two ministries signed a co-operation agreement with the Federal Environmental Agency. In the framework of this co-operation, the Federal Agricultural Research Institute (FAL) is responsible for calculating GHG emissions from agriculture. Agricultural emissions are determined with help of modular tabular-calculation model (GASeous Emissions, GAS-EM) that the FAL has developed (Dämmgen et al, 2002). A joint database has also been set up in the framework of co-operation between the Federal Environmental Agency and the FAL.

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

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

### 1.4.1.5 Land-use changes and forestry

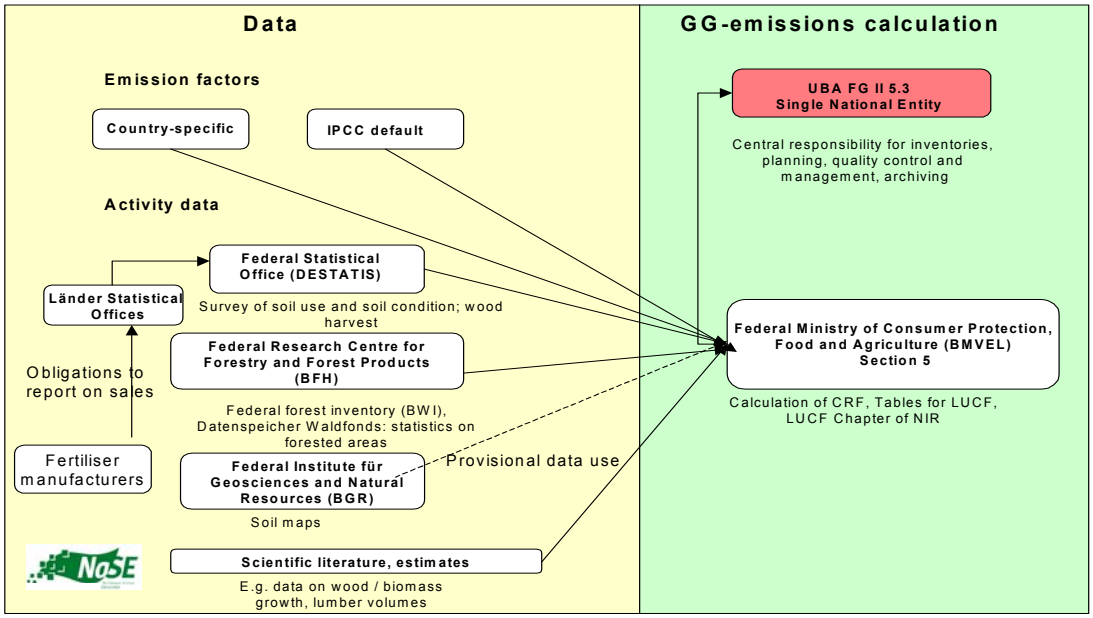


Figure 11: Responsibilities and data flows for calculation of greenhouse-gas emissions from the area of land-use changes and forestry (ÖKO-INSTITUT, 2004a)

The Federal Ministry of Consumer Protection, Food and Agriculture (BMVEL) is responsible for calculating emissions from the area of land-use changes and forestry. This responsibility derives from the ministry's basic sphere of responsibility.

The most important activity data in the area of forest management consist of forest area, the average annual biomass growth and the annual wood harvest. The data on forest area originate with the Federal Research Centre for Forestry and Forest Products (BFH), and have been taken from the federal forest inventory (BWI I), for the old Federal Länder, and from the Forest Fund database (Datenspeicher Waldfonds), for the new Federal Länder. The wood-harvest data used has been taken from the Federal Statistical Office's logging statistics. 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 authors for use in Central Europe.

In the area of forest and grassland conversion, no suitable activity data is currently available that fully complies with the applicable quality requirements. Activity data for land use and land-use changes, obtained through cadastre surveys, is only of limited use. On the other hand, the soil-use surveys managed by the Federal Statistical Office provide highly precise agricultural-lands data, differentiated by types of uses and crops. The forest activity data in this area, as described for forest-management data, are based on data from the Federal Forest Inventory and from the Datenspeicher Waldfonds database.

On the one hand, activity data for $CO_2$ emissions and $CO_2$ storage in the soil include data on liming of soils. In this area, use is made of federal fertiliser statistics on domestic sales of mineral fertilisers that contain lime and other nutrients. The fertiliser industry is legally

required to disclose its sales. On the other hand, soil carbon reserves, which have not yet been comprehensively surveyed, are also of relevance.

Carbon reserves in forest soil were determined in 1996, within the framework of a survey of the condition of forest soils, but changes over time have not been monitored. For the time being, the extent of these reserves is estimated on the basis of soil maps provided by the Federal Institute for Geosciences and Natural Resources (BGR).

#### 1.4.1.6 Waste and wastewater

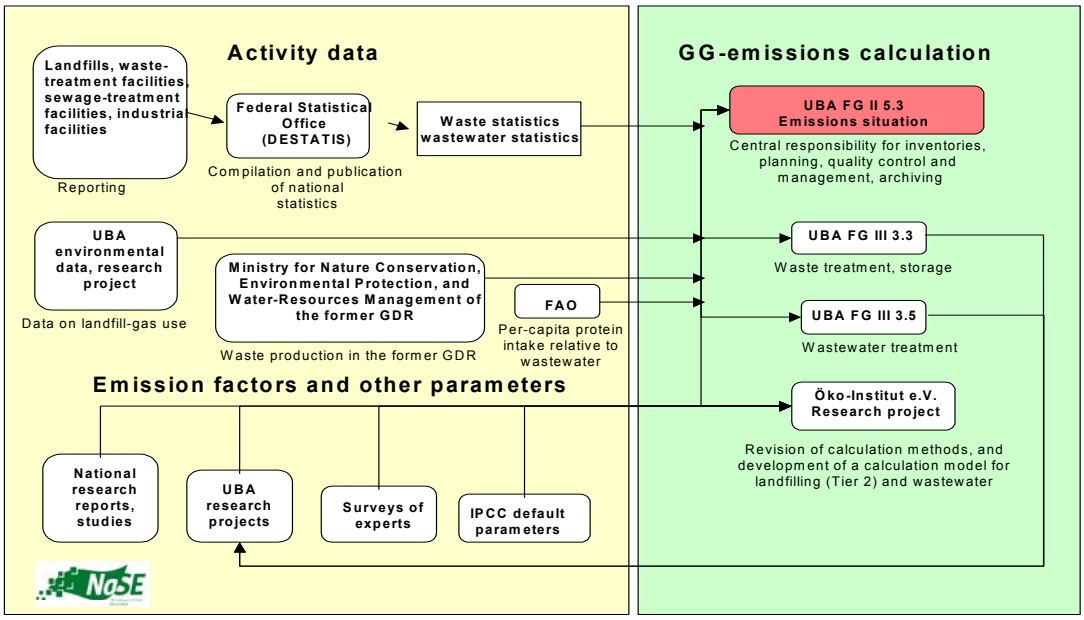


Figure 12: Data flows for calculation of greenhouse-gas emissions from the area of waste (ÖKO-INSTITUT, 2004a)

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

Activity data in the waste sector is drawn mainly from published data of the Federal Statistical Office (DESTATIS), which provides detailed, disaggreged time series. The section on waste provides precise information as to what statistical series and sources were used. The Federal Statistical Office has not published any data on amounts of waste produced in the former GDR. In this area, an official source of the former GDR's ministry for nature conservation, environmental protection and water-resources management. The calculations on landfill-gas use are based on data from the publication "Daten zur Umwelt" (environmental data), which is published regularly by the Federal Environmental Agency. For 2001, data was also taken from a current research project.

The emission factors and other parameters that enter into calculation of emissions from waste landfilling and composting were taken from national studies and research reports conducted/prepared in research projects commissioned directly by the Federal

Environmental Agency. IPCC default parameters were also used for this purpose. Individual experts were also consulted regarding a few of the relevant parameters (for example, half-life selection). The relevant chapter presents the sources for the various parameters, in detail.

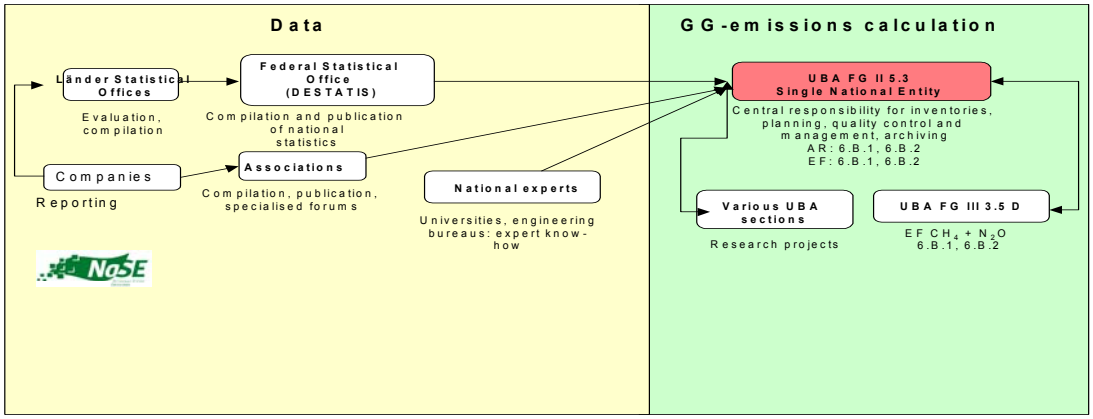


Figure 13: Data flows for calculation of greenhouse-gas emissions from the area of wastewater (ÖKO-INSTITUT, 2004a)

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

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

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

### *1.4.2 Methods*

The methods used for the individual source categories are outlined in the overview tables for the various source categories and in summary tables 3s1 and 3s2 of the CRF reporting tables. For the individual calculation methods, a distinction is made between country-specific (cs) methods and IPCC "*Tiers",* in keeping with the source category[6].

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

6 *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 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 were surveyed specifically for emissions reporting, within the context of a new R&D project, and the relevant data was collated specifically with a view to application of the IPCC methods.

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

For agriculture, emissions were calculated primarily on the basis of the COINAIR Guidebook, using IPCC default emission factors. Country-specific methods were applied only 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-related activity data, it can be assumed that Tier 1 has been used as a minimum. For other areas, too, classification will change from "country-specific" to IPCC tiers, since methodological conformity will either be ascertained or created during the course of the year. In all likelihood, the improved version of the NIR 2004, which is being prepared by early June 2004, will provide considerably more precise information in this area.

## 1.5 Brief description of key source categories

The key sources were defined by applying two Tier 1 procedures, Level (for 1990 and 2002) and Trend (for 2002, as compared to 1990), to German greenhouse-gas emissions.

For 2002, this approach identified 32 source categories, out of a total of 174 source categories studied, as main sources. Only 20 of these were identified, by both Trend and Level analysis, as key sources. In addition, 4 source categories were identified as key sources solely by Trend analysis, and 1 source category was so identified solely by Level analysis. Combination of the results of both types of analysis shows that a total of 95.2 % of greenhouse-gas emissions – 980,586.30 Gg $CO_2$-equivalent emissions – in 2002 were released by the identified key sources. Identification of these source categories was based to a degree of 85 % on release of $CO_2$, to a degree of 9.7 % on $CH_4$ emissions, to a degree of 4.1 % on release of $N_2O$ and to a degree of only about 1.2 % on F-gas emissions. This is largely in keeping with the relevant overall relationships in the greenhouse-gas inventory.

The result of the Level analysis for 1990, which is included for purposes of comparison, is largely in keeping with results for 2002. An overview of the results of the key-source analysis is provided in Table 4.

Table 4: Key sources for Germany pursuant to the Tier 1/ Tier 2 approach

| No. | IPCC SOURCE CATEGORIES | ACTIVITY | Emissions of | KEY SOURCE | | |
|---|---|---|---|---|---|---|
| | | | | LEVEL 1990 | LEVEL 2002 | TREND 2002 |
| 1 | 1A1a Public electricity and heat production | Gaseous fuels | $CO_2$ | ● | ● | ● |
| 2 | 1A1a Public electricity and heat production | Liquid fuels | $CO_2$ | ● | ● | ● |
| 3 | 1A1a Public electricity and heat production | Solid fuels | $CO_2$ | ● | ● | ● |
| 4 | 1A1b. Petroleum refining | Liquid fuels | $CO_2$ | ● | ● | ● |
| 5 | 1A1b. Petroleum refining | Solid fuels | $CO_2$ | | | ● |
| 6 | 1A1c. Manufacture of solid fuels, and other energy industries | Solid fuels | $CO_2$ | ● | ● | ● |
| 7 | 1A2a-f. Manufacturing industries and construction total | Gaseous fuels | $CO_2$ | ● | ● | ● |
| 8 | 1A2a-f. Manufacturing industries and construction total | Liquid fuels | $CO_2$ | ● | ● | ● |
| 9 | 1A2a-f. Manufacturing industries and construction total | Other fuels | $CO_2$ | | | ● |
| 10 | 1A2a-f. Manufacturing industries and construction total | Solid fuels | $CO_2$ | ● | ● | ● |
| 11 | 1A3a. Transport civil aviation | Aviation gasoline | $CO_2$ | | ● | ● |
| 12 | 1A3b. Transport road transportation | Diesel oil | $CO_2$ | ● | ● | ● |
| 13 | 1A3b. Transport road transportation | Gasoline | $CO_2$ | ● | ● | ● |
| 14 | 1A3b. Transport road transportation | Gasoline | $N_2O$ | | ● | ● |
| 15 | 1A3e. Transport other transportation | Liquid fuels | $CO_2$ | ● | | |
| 16 | 1A4a. Other sectors Commercial/institutional | Gaseous fuels | $CO_2$ | ● | ● | ● |
| 17 | 1A4a. Other sectors Commercial/institutional | Liquid fuels | $CO_2$ | ● | ● | ● |
| 18 | 1A4a. Other sectors Commercial/institutional | Solid fuels | $CO_2$ | ● | | ● |
| 19 | 1A4b. Other sectors residential | Gaseous fuels | $CO_2$ | ● | ● | ● |
| 20 | 1A4b. Other sectors residential | Liquid fuels | $CO_2$ | ● | ● | ● |
| 21 | 1A4b. Other sectors residential | Solid fuels | $CH_4$ | | | ● |
| 22 | 1A4b. Other sectors residential | Solid fuels | $CO_2$ | ● | | ● |
| 23 | 1A4c. Other sectors Agriculture/forestry/fisheries | Liquid fuels | $CO_2$ | ● | ● | |
| 24 | 1A4c. Other sectors Agriculture/forestry/fisheries | Solid fuels | $CO_2$ | ● | | ● |
| 25 | 1A5 Other, including military fuel use under this category | Liquid fuels | $CO_2$ | ● | | ● |
| 26 | 1A5 Other, including military fuel use under this category | Solid fuels | $CO_2$ | ● | | ● |
| 27 | 1B1a. Fugitive emissions from fuels and from coal mining and handling | Solid fuels | $CH_4$ | ● | ● | ● |
| 28 | 1B2b. Fugitive emissions from fuels, natural gas | Natural gas | $CH_4$ | ● | ● | |
| 29 | 2A1. Mineral products, cement production | | $CO_2$ | ● | ● | |

Table 4: Key sources for Germany pursuant to the Tier 1/ Tier 2 approach (con'd.)

| No. | IPCC SOURCE CATEGORIES | ACTIVITY | emissions of | KEY SOURCE | | |
|---|---|---|---|---|---|---|
| | | | | LEVEL 1990 | LEVEL 2002 | TREND 2002 |
| 30 | 2A2. Mineral products, lime production | | $CO_2$ | ● | ● | |
| 31 | 2B2 Chemical industry | Nitric acid production | $N_2O$ | ● | ● | |
| 32 | 2B3 Chemical industry | Adipic acid production | $N_2O$ | ● | | ● |
| 33 | 2C3. Aluminium production | | PFCs | | | ● |
| 34 | 2CE. Production of halocarbons and $SF_6$ | Production of HCFC-22 | HFCs | ● | | ● |
| 35 | 2F. Industrial processes | Consumption of halocarbons and $SF_6$ | HFCs | | ● | ● |
| 36 | 2F. Industrial processes | Consumption of halocarbons and $SF_6$ | $SF_6$ | ● | ● | |
| 37 | 4A.1. Enteric fermentation | Dairy cattle | $CH_4$ | ● | ● | |
| 38 | 4A.1. Enteric fermentation | Non-dairy cattle | $CH_4$ | ● | ● | ● |
| 39 | 4B1. Manure management | Dairy cattle | $CH_4$ | ● | ● | |
| 41 | 4B1. Manure management | Non-dairy cattle | $CH_4$ | ● | ● | |
| 42 | 4B8. Manure management | Swine | $CH_4$ | ● | ● | |
| 43 | 4D1. Agricultural soils | Direct soil emissions | $N_2O$ | ● | ● | |
| 44 | 4D3. Agricultural soils | Indirect emissions | $N_2O$ | ● | ● | |
| 45 | 6A1 Managed waste disposal on land | Solid waste disposal on land | $CH_4$ | ● | ● | ● |
| 46 | 6B1. Wastewater handling | Industrial wastewater | $CH_4$ | | | ● |

In the framework of research project 202 42 266 (UBA, 2004), Tier 2 analysis, which takes into account the uncertainties identified for the emissions data used, was also carried out.

Annex 1 of this report presents detailed explanations of the key-source analysis carried out.

## 1.6 Information on the QA/QC plan

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

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

Pursuant to the IPCC *Good Practice Guidance* requirements, the necessary QC/QA measures for emissions reporting should be summarised in a QC/QA plan. Such a QC/QA plan is to serve the primary purpose of organising, planning and monitoring such QC/QA measures.

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

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

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

Since November 2003, the National Single Entity (national co-ordinating agency) has carried out its data and report evaluations immediately upon receiving the relevant documents from source-category-specific experts. During trial operation, checking is carried out with the help of a checklist with the general criteria for checking (cf. Chap. 17.2.2.2). In general, the following materials are taken into account:

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

## 1.7 General uncertainty evaluation

As a result of the GPG's focus on continual inventory improvement, uncertainties in the inventories play an important role. The declared aim is to minimise uncertainties to the greatest possible degree, in order to maximise the inventories' accuracy. For this reason, Annex I countries are called on to quantify the uncertainties for all source categories and sinks.

The purpose of quantifying uncertainties is to enhance understanding of inventory quality, since such understanding is a necessary basis for effective inventory planning. Uncertainties are quantified for emission factors and activity data. This necessitates determination of a probability-density function for both parameters. Ideally, these functions can be determined via statistical evaluation of individual data items (such as measurements for a large number of facilities). In many cases, few relevant values are available, however, and thus the density function must be determined on the basis of experts' assessments.

Not all of the uncertainties for German greenhouse-gas inventories have been determined. Research project 202 42 266 (UBA, 2004) calls for determining uncertainties pursuant to Tier 1 and Tier 2 pursuant to Chap. 6 of GPGAUM[7)]. In determination of uncertainties in accordance with Tier 1, the uncertainties are estimated by data-providing experts of the relevant Federal Environmental Agency sections and of external institutions. This expert-

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assessment process has not yet been completed, however. Table 5 provides an overview of the current known uncertainties, as identified via completed experts' assessments:

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

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

Additional experts' assessments are to be carried out for the other source categories. For this reason, the present national inventory report includes chapters on *uncertainties and time-series consistency* for the various source categories only in cases in which source-category-specific data is available.

### *1.7.1 Procedure for determining uncertainties pursuant to Tier 1, Chap. 6 of the GPGAUM*

For determination of uncertainties pursuant to Tier 1, experts' assessments were carried out in keeping with the guidelines in the GPGAUM Chap. 6.2.5, "Expert Judgement". Experts' assessments are carried out in accordance with a manual, and they make use of the current time series in the CSE for the years 1990 and 2002 and of all relevant available information. This includes the following questions:

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

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

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

Where adequate information is available, the experts' assessment can also be made step-by-step. For example, for a given facility separate assessments can be made of emissions under peak-load operation and emissions during start-up and shut-down processes. Then, the two assessments can be combined via weighting.

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

### *1.7.2 Results of uncertainty assessment*

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

- Pursuant to the results from an R&D project (Rentz et al, 2002), the uncertainties in emission factors for indirect greenhouse gas in stationary combustion systems (CRF 1A) are relatively small. The uncertainties in emission factors for $N_2O$, on the other hand, are considerably larger, especially in facilities subject to the Technical Instructions on Air Quality Management (TA Luft).

- The uncertainties in the transport source category (primarily CRF 1 A 3) can generally be considered to be small, since precise relevant data on fuel use and vehicle fleets is available, due to taxation obligations, and since that category's emission factors have been very finely modelled and are normally determined via measurements. Some uncertainties may arise via systematic measuring errors or wrong disaggregation.

- In the source category of fugitive emissions (CRF 1 B ), the activity rates for liquid and gaseous fuels (CRF 1 B 2) include slight uncertainties of +/- 1%, resulting from the fuels' being subject to taxation. The uncertainty for flaring of natural gas, at +/- 10%, is an exception. The activity rates for coal mining (CRF 1 B 1) are also well-represented by production volumes. The uncertainties for emission factors for fugitive emissions are considerably higher. On the one hand, this results from the many different technical factors, relevant to fugitive emissions, in transport, storage and processing of oil and natural gas. On the other hand, diffuse $CH_4$ emissions from coal mining have thus far been taken into account only as lump sums.

- Considerable uncertainties must be expected in the area of industrial processes (CRF 2). Activity rates based on production figures that must be reported to the Federal Statistical Office can be subject to uncertainties, especially as a result of discrepancies between reporting structures and relevant industry definitions. Activity

rates determined from association information are subject to uncertainties that correlate, in each case, with the degree to which the relevant industrial sector in the association in question is organised. Among EF emission factors, a high degree of technical dependence, coupled with a high degree of technical diversification, points to considerable uncertainties, in part, depending on the pollutant in question. Furthermore, equipment-specific emission factors often are tied to business secrets, particularly in sectors with few market players (for example, manufacturing of chemical products (CRF 2 B)), and this tends to make operators hesitant to publish such data or provide relevant consolidated information. In addition, the uncertainties can be increased in that processes whereby non-combustion-related activities generate emissions are often very complex, in that too little is known about certain emissions-generating processes and in that too little is known about the relevant contributions of individual activities.

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

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

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

## 1.8 General checking of completeness

In 1998, the Federal Environmental Agency began to identify data gaps in the emission inventories and to examine the opportunities for closing these gaps. This work was stepped up particularly against the background of the development of the CSE, since it was important to transfer the existing decentralised data stocks on the inventories into the central database. Hence, in two R&D projects (FKZ: 298 42 759 and 298 42 289), a concept was developed for reorganisation of data records on emissions and sinks. Apart from an overall concept on data maintenance, the results included a clear representation of current reporting capabilities, as well as a catalogue of gaps. The overall documentation concept has now been integrated within the prepared CSE and, in the framework of a research project (FKZ 298 42 259), has been adapted to harmonised international reporting obligations (NFR and CRF). It is being taken into account in the national review that is now in progress. In addition, the catalogue of gaps has been updated in keeping with new research findings.

Details of completeness for the individual source categories are represented in CRF Tables 7s1, 7s2 and 7s3. A distinction is made between source-specific emissions and sinks not

occurring (NO) in Germany, source-specific emissions and sinks not estimated (NE) in Germany because they are either quantitatively irrelevant or because the necessary data for an estimate is not available, and source-specific emissions and sinks which are completely (all / full) recorded according to the current status of knowledge, or partially recorded (part).

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

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

Whereas fuel use for heat and power generation in the manufacturing sector, along with the relevant emissions, is recorded completely in the inventory, uncertainties persist in assignment of fuel use to the six source categories the inventory requires (1A2a through f). This can be partly attributed to contradictions between the Energy Balance and the Federal Statistical Office's data with regard to certain fuels (such as waste). To date, even experts in the field have been unable to resolve the discrepancies completely. These difficulties do not affect total fuel use or emissions in the manufacturing sector, however.

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

In the area of industrial processes, some use is made of production data from association statistics and of manufacturers' information. In the interest of the inventory's completeness and reliability, where emissions reporting is based on such sources, checking of source-category definitions and data-collection methods will continue to receive priority. IN the area of industrial processes, no calculations are currently being made for the source categories 2A3 (limestone and dolomite use), 2A4 (soda ash production and use), 2A5 (asphalt) and 2C2 (ferroalloys production). These source categories are not covered by the IPCC Good Practice Guidance, since the emissions from these categories are considered insignificant and since data for these source categories is usually not available. Both of the reasons that the IPCC gives for not covering these categories also apply to Germany.

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

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

In the framework of the R&D project 201 42 258, other countries' inventory data under the category "other sources" was analysed (ÖKO-INSTITUT, 2004a) in support of systematic

review of completeness of national emissions data. This study was designed to show which of the source categories other countries report on are also emissions-relevant in Germany – in order to expand German inventories accordingly, if necessary. This analysis showed that systematic review for completeness needs to be expanded, especially in the area of industrial processes, and it revealed that other countries treat geothermal systems – which Germany's reporting does not cover – as emissions-relevant. The results of this analysis will be incorporated in inventory planning.

# 2 TRENDS IN GREENHOUSE GAS EMISSIONS

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

Emissions of greenhouse gases and of SO2 in Germany, 1990-2002

Figures in Gg (CF4, C2F6 and SF6 in Mg)

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| directly acting Greenhouse gases | | | | | | | | | | | | | |
| $CO_2$ | 1015572 | 977468 | 929898 | 920187 | 906063 | 901478 | 923792 | 892423 | 884501 | 857281 | 860273 | 874264 | 864117 |
| $CH_4$ | 6656 | 6127 | 5947 | 5737 | 5510 | 5199 | 4986 | 4820 | 4560 | 4392 | 4121 | 3952 | 3878 |
| $N_2O$ | 263 | 251 | 255 | 245 | 233 | 237 | 242 | 234 | 192 | 180 | 180 | 181 | 180 |
| HFC (in $CO_2$-equivalent emissions) | 3510 | 3547 | 3677 | 4950 | 5178 | 6360 | 5768 | 6356 | 6979 | 7280 | 6630 | 8130 | 8247 |
| $CF_4$ | 355 | 308 | 278 | 260 | 214 | 224 | 214 | 161 | 172 | 137 | 72 | 69 | 76 |
| $C_2F_6$ | 42 | 38 | 36 | 35 | 31 | 32 | 34 | 32 | 34 | 31 | 24 | 18 | 20 |
| $C_3F_8$ | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 5 | 8 | 10 | 14 | 15 | 16 |
| $SF_6$ | 163 | 182 | 204 | 226 | 243 | 288 | 266 | 262 | 253 | 185 | 168 | 139 | 176 |
| $CO_2$-equivalent emissions (without CO2 from LUCF) | 1246816 | 1194263 | 1144594 | 1128917 | 1106577 | 1099130 | 1117442 | 1080278 | 1054175 | 1018184 | 1014072 | 1025555 | 1014627 |
| indirectly acting Greenhouse gases | | | | | | | | | | | | | |
| NOx (as $NO_2$) | 2815 | 2584 | 2391 | 2273 | 2108 | 1979 | 1896 | 1801 | 1744 | 1697 | 1620 | 1545 | 1479 |
| NMVOC | 3534 | 3082 | 2808 | 2582 | 2404 | 2249 | 2110 | 2042 | 1966 | 1842 | 1699 | 1594 | 1477 |
| CO | 11212 | 9528 | 8351 | 7701 | 7080 | 6580 | 6166 | 5993 | 5536 | 5200 | 4906 | 4573 | 4318 |
| aerosol precursor | | | | | | | | | | | | | |
| $SO_2$ | 5322 | 3991 | 3303 | 2941 | 2469 | 1934 | 1335 | 1036 | 833 | 733 | 631 | 640 | 608 |

Table 6 shows the total emissions, as determined for this inventory, of direct and indirect greenhouse gases and of the acid precursor $SO_2$. The associated annual progress over time, compared to the base year of the Kyoto Protocol and 1990, is depicted in Table 7. With the exception of HFCs and of $C_3F_8$, significant reductions in emissions have been achieved for all the emissions calculated here. In total, the emission of greenhouse gases, calculated as $CO_2$ equivalent emissions, decreased by nearly 19 % compared to the base year. As a result, the emissions level of the year 2000 was nearly reattained, following a short weather-related increase in 2001. In the years 1996 and 2001, which were cold by comparison to the development since 1990, additional energy had to be used for indoor heating, and this considerably increased $CO_2$ emissions in particular in these years, in comparison to the relevant previous years. This is also illustrated by Table 8 below.

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

Emissions trends in Germany with respect to the base year

| | | | | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| directly acting Greenhouse gases | base year | absolute | % | +/- % | +/- % | +/- % | +/- % | +/- % | +/- % | +/- % | +/- % | +/- % | +/- % | +/- % | +/- % |
| $CO_2$ | 1990 | 1015572 | 100,0 | -3,8 | -8,4 | -9,4 | -10,8 | -11,2 | -9,0 | -12,1 | -12,9 | -15,6 | -15,3 | -13,9 | -14,9 |
| $CH_4$ | 1990 | 6656 | 100,0 | -7,9 | -10,7 | -13,8 | -17,2 | -21,9 | -25,1 | -27,6 | -31,5 | -34,0 | -38,1 | -40,6 | -41,7 |
| $N_2O$ | 1990 | 263 | 100,0 | -4,3 | -2,8 | -6,7 | -11,3 | -9,7 | -7,7 | -10,7 | -27,0 | -31,5 | -31,4 | -31,0 | -31,4 |
| HFC (in $CO_2$-equivalent emissions) | 1995 | 6360 | 100,0 | | | | | 0,0 | -9,3 | -0,1 | 9,7 | 14,5 | 4,2 | 27,8 | 29,7 |
| $CF_4$ | 1995 | 224 | 100,0 | | | | | 0,0 | -4,2 | -27,9 | -23,0 | -38,9 | -67,8 | -69,0 | -66,2 |
| $C_2F_6$ | 1995 | 32 | 100,0 | | | | | 0,0 | 5,0 | -1,0 | 4,1 | -3,7 | -25,7 | -43,4 | -38,9 |
| $C_3F_8$ | 1995 | 1 | 100,0 | | | | | 0,0 | 131,7 | 310,7 | 547,6 | 774,7 | 1136,1 | 1165,1 | 1269,2 |
| $SF_6$ | 1995 | 288 | 100,0 | | | | | 0,0 | -7,7 | -9,0 | -12,4 | -35,9 | -41,7 | -51,7 | -39,1 |
| $CO_2$-equivalent emissions (without CO2 from LUCF) | | 1251723 | 100,0 | -4,6 | -8,6 | -9,8 | -11,6 | -12,2 | -10,7 | -13,7 | -15,8 | -18,7 | -19,0 | -18,1 | -18,9 |
| indirectly acting Greenhouse gases | | | | | | | | | | | | | | | |
| NOx (as $NO_2$) | | 2845 | 100,0 | -8,2 | -15,1 | -19,3 | -25,1 | -29,7 | -32,6 | -36,0 | -38,0 | -39,7 | -42,5 | -45,1 | -47,5 |
| NMVOC | | 3591 | 100,0 | -12,8 | -20,5 | -26,9 | -32,0 | -36,4 | -40,3 | -42,2 | -44,4 | -47,9 | -51,9 | -54,9 | -58,2 |
| CO | | 11212 | 100,0 | -15,0 | -25,5 | -31,3 | -36,9 | -41,3 | -45,0 | -46,5 | -50,6 | -53,6 | -56,2 | -59,2 | -61,5 |
| aerosol precursor | | | | | | | | | | | | | | | |
| $SO_2$ | | 5326 | 100,0 | -25,0 | -37,9 | -44,7 | -53,6 | -63,7 | -74,9 | -80,5 | -84,3 | -86,2 | -88,1 | -88,0 | -88,6 |

Emissions changes in Germany since 1990 (Percent changes compared to the previous year and 2002/base year)

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2002 / base year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| directly acting Greenhouse gases | | | | | | | | | | | | | | |
| $CO_2$ | 1015572 | -3,8 | -4,9 | -1,0 | -1,5 | -0,5 | 2,5 | -3,4 | -0,9 | -3,1 | 0,3 | 1,6 | -1,2 | -14,9 |
| $CH_4$ | 6656 | -7,9 | -2,9 | -3,5 | -4,0 | -5,6 | -4,1 | -3,3 | -5,4 | -3,7 | -6,2 | -4,1 | -1,9 | -41,7 |
| $N_2O$ | 263 | -4,3 | 1,6 | -4,1 | -4,9 | 1,8 | 2,2 | -3,3 | -18,2 | -6,2 | 0,2 | 0,5 | -0,5 | -31,4 |
| HFC | 3510 | 1,1 | 3,6 | 34,6 | 4,6 | 22,8 | -9,3 | 10,2 | 9,8 | 4,3 | -8,9 | 22,6 | 1,4 | 29,7 |
| $CF_4$ | 355 | -13,3 | -9,7 | -6,5 | -17,7 | 4,5 | -4,2 | -24,7 | 6,7 | -20,7 | -47,3 | -3,6 | 9,0 | -66,2 |
| $C_2F_6$ | 42 | -8,4 | -6,5 | -2,8 | -11,4 | 4,2 | 5,0 | -5,7 | 5,1 | -7,4 | -22,9 | -23,8 | 8,1 | -38,9 |
| $C_3F_8$ | 0 | - | - | - | - | - | 131,7 | 77,3 | 57,7 | 35,1 | 41,3 | 2,3 | 8,2 | 1269,2 |
| $SF_6$ | 163 | 11,7 | 12,1 | 10,8 | 7,5 | 18,6 | -7,7 | -1,4 | -3,7 | -26,9 | -9,0 | -17,2 | 26,2 | -39,1 |
| $CO_2$-equivalent emissions (without CO2 from LUCF) | 1246816 | -4,2 | -4,2 | -1,4 | -2,0 | -0,7 | 1,7 | -3,3 | -2,4 | -3,4 | -0,4 | 1,1 | -1,1 | -18,9 |
| indirectly acting Greenhouse gases | | | | | | | | | | | | | | |
| NOx (as $NO_2$) | 2706 | -8,2 | -7,5 | -4,9 | -7,3 | -6,1 | -4,2 | -5,0 | -3,2 | -2,7 | -4,5 | -4,6 | -4,3 | -47,5 |
| NMVOC | 3221 | -12,8 | -8,9 | -8,0 | -6,9 | -6,4 | -6,2 | -3,2 | -3,7 | -6,3 | -7,8 | -6,2 | -7,3 | -58,2 |
| CO | 11213 | -15,0 | -12,3 | -7,8 | -8,1 | -7,1 | -6,3 | -2,8 | -7,6 | -6,1 | -5,7 | -6,8 | -5,6 | -61,5 |
| aerosol precursor | | | | | | | | | | | | | | |
| $SO_2$ | 5321 | -25,0 | -17,2 | -11,0 | -16,0 | -21,7 | -31,0 | -22,4 | -19,6 | -12,0 | -13,9 | 1,4 | -5,0 | -88,6 |

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

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

By 2002, the above-described obligation to reduce greenhouse-gas emissions, in the framework of EU burden-sharing, had been largely fulfilled, via a reduction of nearly 19 %. The individual greenhouse gases contributed to this development to varying degrees (see Table 1).This is hardly surprising when one considers that the individual greenhouse gases account for varying proportions of total emissions in a given year. Emissions of the direct greenhouse gases that predominate by amount were considerably reduced; $CO_2$ emissions decreased by nearly 15 % and $CH_4$ and $N_2O$ emissions were reduced by over 41 % and by 31 %, respectively. The reasons for these reductions are found in an entire group of measures, in basic categories such as fuel conversions, enhanced economic efficiency, changes in ways of keeping animals and reductions of numbers of animals kept. These measures are discussed in detail in the discussion below of trends for the various components.

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 85 % of greenhouse gas emissions. Due to a disproportionately large decrease in other components, the proportion of total greenhouse gases attributable to $CO_2$ emissions has increased from 81.5 % to over 85 % since 1990. Emissions of methane, which are caused primarily by animal husbandry, fuel distribution and landfill emissions, account for 8 %. Emissions of nitrous oxide, caused primarily by agriculture, industrial processes and transport, account for 5.5 % of greenhouse gas releases. The other so-called "Kyoto" or "F" gases account for a total of only slightly over 1 % of total greenhouse-gas emissions. This spectrum of distribution of greenhouse-gas emissions is typical for a highly developed and industrialised country.

## 2.2 Description and interpretation of emission trends, by gas

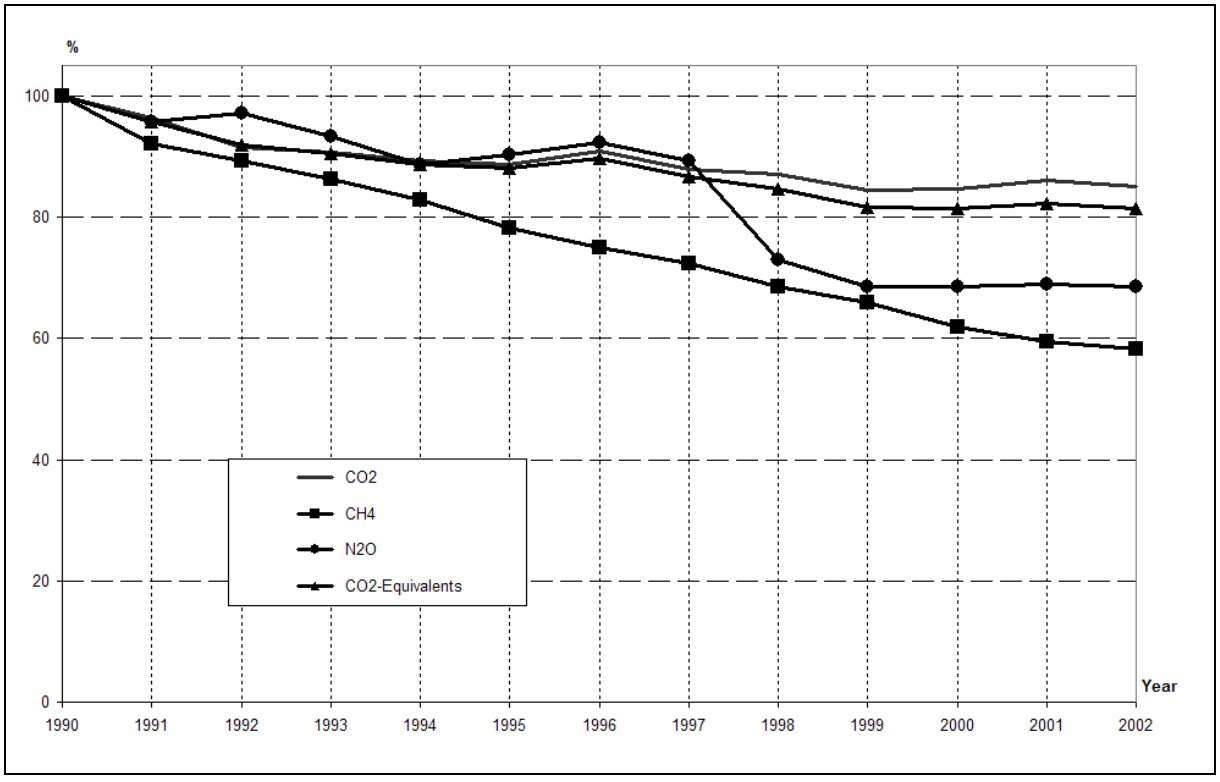



Figure 14: Relative development of greenhouse gases in comparison to 1990

Figure 14 shows the relative development of emissions of the various greenhouse gases since 1990. In the discussion, it must be remembered that the development of each of these greenhouse gases as shown here is largely dominated by specific developments in a single source category. The reduction in $CO_2$ emissions is closely linked to the development in the energy sector. In this sector, fuel conversions, efficiency improvements via construction of new facilities – especially in the new Federal Länder – and extensive energy-saving measures led to a considerable emissions decrease. For example, $CO_2$ emissions from public power and district-heat generation decreased by 17 million t since 1990. In the process, the mix of fuels used changed considerably – while emissions from use of solid and liquid fuels sank by 8 and 49 %, respectively, $CO_2$ emissions from use of gaseous fuels increased by 40 %. This trend is even more pronounced in the area of households and small consumers. In this category, emissions decreased by a total of 15 % – from 204 to 175 million t $CO_2$ – between 1990 and 2002. Whereas in 1990 these emissions were spread nearly evenly among use of solid, liquid and gaseous fuels (33, 45 and 22 %), in 2002 this spectrum had shifted considerably (2, 50 and 48 %). Similar developments have also taken place in the transport sector – although here emissions have been increasing markedly overall. $CO_2$ emissions increased from 162 to 174 million t, and use of diesel fuel increased disproportionately. In 1990 2/3 of all road-traffic emissions were caused by petrol consumption. By 2002, the ratio between petrol-related and diesel-related emissions was nearly balanced.

$N_2O$ emissions decreased by over 31 % in the period under consideration. The main sources were use of nitrogen-containing fertilisers in agriculture, industrial processes in the chemical sector, stationary and mobile combustion processes and animal husbandry in agriculture. Smaller amounts of emissions are caused by wastewater treatment and product use of $N_2O$ (for example, as an anesthetic). Industry has the greatest influence on emissions reductions, especially in the area of adipic acid production. In this respect, in 1997 producers in Germany completed a process of retrofitting their production systems with emissions-reduction equipment. This measure reduced total emissions by over 20 %. Decreased fertiliser use in agriculture also contributed to the reduction of total emissions.

Methane emissions are caused mainly by animal husbandry in agriculture, waste landfilling and distribution of liquid and gaseous fuels. These emissions loads play an almost negligible role in comparison to that of energy-related and process-related emissions. These emissions have been decreased by about 41 % since 1990. This trend has been the result of political environmental protection measures (green dot on recyclable products, yellow sacks for recycling pickups, increased recycling overall and increasing energy recovery from waste) that reduced amounts of waste for landfilling. A second important reason for the emissions reductions consisted of reductions of livestock populations in the new Federal Länder, especially in the first half of the 1990s. Repairs and modernisations of outdated gas-distribution networks in this part of Germany, along with introduction of vapour-recovery equipment in fuel distribution, brought about further reductions of total emissions.

## 2.3 Description and interpretation of emission trends, by source categories

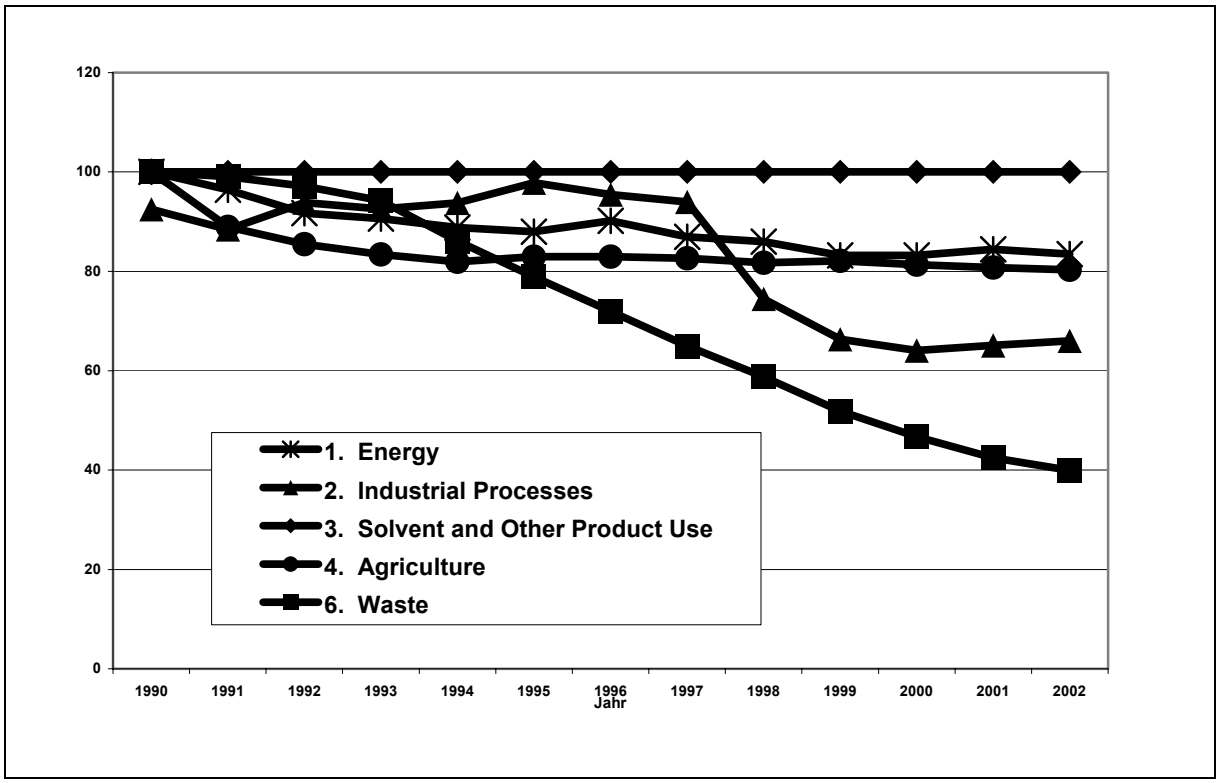



Figure 15: Relative development of greenhouse gases, by emitter groups, in comparison to 1990 [Jahr = Year]

Decreases in energy-sector emissions, in the area of combustion-related emissions, are determined primarily by $CO_2$ emissions from stationary and mobile combustion systems (cf. also the results of the key-source analysis). On the other hand, emissions of other greenhouse gases are negligible in this sector. This situation is exactly the opposite for energy-related emissions that are not combustion-related. In this area, $CO_2$ emissions play a negligible role, while emissions trends are clearly shaped by $CH_4$ emissions caused by distribution of liquid and gaseous fuels. On the whole, energy-related emissions have decreased by over 17 % since 1990. For combustion-related emissions, this has been achieved through fuel conversions and higher energy and technical efficiencies, whereas for distribution emissions it is due to modernisation of gas-distribution networks and the introduction of vapour-recovery systems in fuel distribution.

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

In the area of emissions from industrial processes, relatively constant levels of $CO_2$ emissions have been produced in the lime and cement manufacturing sector and in the iron and steel sector. The trend for this source category, in which the reduction amounts to over 30 %, has been shaped primarily by emissions-reducing measures in adipic acid production,

which have led to marked reductions in $N_2O$ emissions. Introduction of such measures, by the two producers in Germany, sharply reduced emissions in 1997.

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

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

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

The relative development of emissions of indirect greenhouse gases and $SO_2$ is graphically depicted, in each case as time series since 1990, in Figure 16 and in Table 6. Over this period, a number of significant successes have been achieved in reducing these pollutants. For example, emissions of $SO_2$ were reduced by almost 89 %, those of CO by over 61 %, those of NMVOCs by almost 59 % and those of $NO_X$ by nearly 48 %.

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

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

Descriptions of the emission calculations for these pollutants, along with additional, detailed parameters influencing the emission trends of the individual air pollutants, are provided by the Website of the Federal Environmental Agency. Beginning in 2005, an inventory report structured similarly to the NIR will be prepared in the framework of the UN ECE Geneva Convention on Long-range Transboundary Air Pollution, which also contains provisions for these ozone precursors and acidifiers.

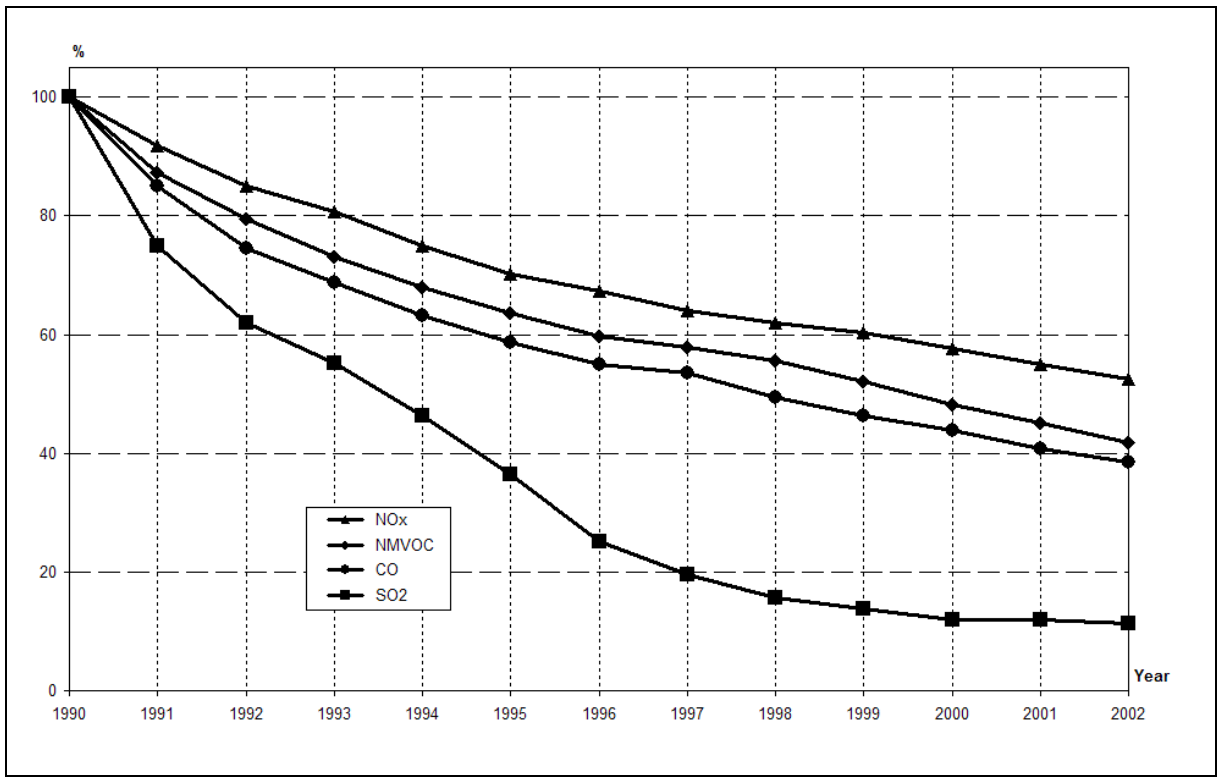



Figure 16: Relative development of emissions of indirect greenhouse gases and of $SO_2$

# 3 ENERGY (CRF 1)

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

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

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

## 3.1 Combustion of fossil fuels (1.A)

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

A: Transformation input

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

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

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

C: Final energy consumption

- Quarrying of nonmetallic minerals, other mining and manufacturing industry (line 60)
- 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 produced electricity into the public grid. This also includes industrial plants which operate their power stations together with electricity utility companies as joint power stations. The fuel input for electricity generation is reported here. This line of the energy balance also includes the fuel input in public thermal power plants attributable to electricity production.
2. ***Industrial thermal power plants*** in energy balance line 12 comprises the following operator groups:
   a. Power plants in hard coal mining
   b. Power plants in lignite mining
   c. Power plants in 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 heat generation is given. Adding lines 11 and 15 together produces the total fuel input in public thermal power plants. The district heat generated is fed into the public heating grid. These plants also supply industrial customers with process heat.
4. In energy balance line 16, ***district heat plants*** indicates the fuel input for the public district heat supply. The plants are often used to cover peak loads in district heat networks in which the basic load is met by combined heating and power stations.
5. Lines 33 to 39 and the total line 40 (***energy consumption in the transformation sector***) include the fuel input for heat generation which is needed to operate the transformation stations. In this instance, no distinction is made according to the type of heat generation. This means that fuel inputs for heat generation in combined heating and power plants, steam and hot water boilers and process firing installations are combined. There is an inconsistency in the energy balance with respect to lignite pits and briquette plants. The fuel used in combined heat and power generation to generate heat (for drying the crude lignite in lignite briquette plants) is reported together with the transformation input (line 10), even though this is only materially transformed. The emission-causing use of lignite is calculated out during data preparation.
   The fuel inputs used to generate heat in combined heat and power generation stations, together with fuel inputs used for electricity generation by the power stations of hard coal pits, lignite pits and refinery power stations, combine to form the total fuel input in such plants. Deduction, from this total, of fuel inputs for heat generation in power stations leaves the quantity of fuel used in process firing installations, steam and hot water boilers.
6. ***Final energy consumption by industry*** (line 60 of the energy balance) indicates the fuel used for heat generation which is required for both production purposes and room heating. Here too, no distinction is made according to the type of heat generation. Hence, part of the final energy consumption in these source categories, together with industrial power stations' fuel input for generating electricity, constitutes the total fuel input in such plants.

7. The data on ***final energy consumption by 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.

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

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

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

Balance of emission causes
- Sector,
- Plant type,
- Fuel,
- Immission protection provision,
- Energy balance line,
- (Where necessary: regional allocation),
- Allocation to the Central System of Emissions (CSE)

The source categories include:
- Public thermal power stations,
- Hard coal mining,
- Lignite mining,
- Deutsche Bahn AG *(German national railway),*
- Mineral oil refineries,
- District heating stations,
- Other transformation sector (may be further sub-classified)
- Quarrying of non-metallic minerals, other mining and manufacturing industry (further sub-classification planned)
- 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).

By fuels/energy sources:
- 21 energy sources

On the basis of immission protection legislation provisions, a distinction is made between:
- Facilities under the 13th Ordinance on the Execution of the Federal Immission Control Act (13. BimSchV),
- Facilities under the 17th Ordinance on the Execution of the Federal Immission Control Act (17. BimSchV),
- Facilities under the 1st Ordinance on the Execution of the Federal Immission Control Act (1. BimSchV),
- Installations under the Technical Instructions on Air Quality Control TA Luft

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

Figure 17: Characteristics of the Federal Environmental Agency's structure of the balance of emission causes, for disaggregation of the energy balance

Figure 17 shows the characteristics of the BEU (balance of emissions source) structure, and Tables 9 (Structure of the balance of emissions sources - public services) through 14 (Structure of the balance of emissions sources - iron and steel industry) show the BEU-structure itself. These basic structures are analysed in greater detail in the following account of activities. The information in Tables 9 through 14 should be read as follows:

The number in the first column corresponds to the consecutive number in the table in the *balance of emission causes*. The number in the third column is the line number of the energy balance from which the basic data for calculation in the *Balance of Emission Causes* table is

used. The column "SWK" (S = fuel input for electricity generation, W = fuel input for heat generation, K = fuel input for machine action) shows the use in question. The "file name" in the eighth column refers to the database of the *Central System of Emissions (CSE)*.

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

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

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

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

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

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

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

Table 9: Structure of the balance of emissions causes – public services

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

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

Table 10: Structure of the balance of emissions causes – coal mining

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

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

Table 11: Structure of the balance of emissions causes – other industrial power stations

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

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

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

Table 12: Structure of the balance of emissions causes – refineries

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

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

Table 13: Structure of the balance of emissions causes – other energy producers

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

Table 14: Structure of the balance of emissions causes – iron and steel industry

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

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

## *3.1.1 Public electricity and heat production (1.a.1a)*

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

| **CRF 1.A.1a** | | | | | |
|---|---|---|---|---|---|
| Key source | | Gas (MSG) | 1990 – contribution to total emissions | 2002 – contribution to total emissions | **Trend** |
| Solid fuels | l / t | $CO_2$ | 24,60 % | 28,17 % | falling |
| Gaseous fuels | l / t | $CO_2$ | 1,48 % | 2,57 % | rising |
| Liquid fuels | l / t | $CO_2$ | 0,68 % | 0,43 % | falling |

| Gas | **$CO_2$** | **$CH_4$** | **HFCs** | **PFCs** | **$SF_6$** | **$N_2O$** | **$NO_X$** | **CO** | **NMVOC** | **$SO_2$** |
|---|---|---|---|---|---|---|---|---|---|---|
| Emissions factor[8] (EF) | CS | CS | NO | NO | NO | CS | CS | CS | CS | CS |
| EF uncertainties in % | < 3 | +/-50 | - | - | - | +/-50 | | | | |
| Distribution of uncertainties [9] | T | U | - | - | - | U | | | | |
| Method for EF determination[10] | CS | Tier 2 | - | - | - | Tier 2 | | | | |

In terms of emissions levels and trend, the source category public electricity and heat production is a key source.

The figures for the uncertainty of the emission factor, and for the statistical distribution function for that uncertainty, have been estimated by the Federal Environmental Agency. The numbers themselves are based on a personal communication from an expert.

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

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 heat. District heating generation is supplemented by district heat plants with a thermal output of 21 GW. These plants supplied just under 64 PJ to the public district heat network. 56 % of district heat plants' output is produced using natural gas, 13 % is produced using hard coal and lignite, 15 % is produced using waste fuels, and 13 % is produced using mineral oil products.

### 3.1.1.2 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, while the fuel use in district heat plants is reported in line 16.

Table 9 shows how fuel use is structured in the module *"Balance of Emissions Causes"* (BEU). This structure is suitable for providing a complete overview of this sector.

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

The underlying data for the emission factors used is provided by the report on the research project "Ermittlung und Evaluierung von Emissionsfaktoren für Feuerungsanlagen in Deutschland für die Jahre 1995, 2000 und 2010" ("Determination and evaluation of emission factors for combustion plants in Germany for the years 1995, 2000 and 2010"; Rentz et al, 2002). This project has also provided the underlying data for the emission factors presented in Chapters 3.1.2, 3.1.3 and 3.1.7, whether the factors include power stations, gas turbines or conventionally fired boilers for generation of steam and hot/warm water. This project was carried out by the Franco-German Institute for Environmental Research (Deutsch-Französischen Institut für Umweltforschung – DFIU) at the University of Karlsruhe, and it was completed in early 2003. The project aim was to determine and evaluate representative emission factors for the main air pollutants produced by combustion plants in Germany that are subject to licensing requirements, and to do so for the years 1995, 2000 and 2010. This process consists primarily of analyzing and characterising the relevant emitter structures, and the pertinent emission factors, for the year 1995, and then of updating the data for the years 2000 and 2010. This procedure systematically determines emission factors for the substances $SO_2$, $NO_X$, CO, NMVOC, dust and $N_2O$. The process differentiates between 12 coal fuels, 4 liquid fuels, 7 gaseous fuels and firewood. In addition, the available data relative to emission factors of other substances is also compiled; these other substances include PAH, PCDD/F, As and Cd for combustion plants subject to licensing requirements, and $CH_4$ for gas turbines and combustion plants under the TA Luft that are subject to licensing requirements.

Determination of emission factors requires detailed analysis of all operating plants with regard to technologies used and design-specific emission behaviour. Three overarching source categories are formed: large combustion plants, combustion plants within the scope of application of the TA Luft and gas turbines. Existing plants are classified in terms of emissions-relevant characteristics, and the pertinent emission factors are determined. These so-called "technology-specific" factors can then be aggregated in an adequate manner. This database also provides the basis for estimating future emissions (changes in the overall make-up of the entire group of plants, in terms of percentage shares for various plant types). This procedure thus consists of the following steps:

1. Characterisation of the equipment-specific emissions behaviour of combustion plants. In a first step, the firing and emissions-reduction technologies used in Germany are briefly described, and the relevant emissions-determining factors are explained. On the basis of this characterisation, emission factors are derived for the various different relevant technologies, differentiated by size class and fuel type. The chosen classification is also oriented to applicable provisions under immissions-control law, an orientation that permits derived emission factors to be compared with limits applicable now or in the future.

2. Analysis of the emitter structure
   Emissions calculations must be carried out using emission factors that have the same references as the pertinent energy-input data. The latter (data) is divided by source categories that are derived from the national energy balance – cf. Chapter 3.1 – and are not based on the firing technologies used. The project has defined and analysed the following source categories: Public energy supply (CRF 1A1a), industrial power stations (CRF 1A1c for power stations in the mining sector; otherwise, CRF 1A2), district heat power stations (CRF 1A1a), refinery power stations (CRF 1A1b),

industrial combustion plants (CRF 1A1c and 1A2) and small consumers (CRF 1A4 and 1A5).
In the analysis, the various technologies' contributions to total energy use must be determined. The most important data sources for this include the power-station database of the DFIU, relevant statistics, communications of industry associations (VGB, VDEW, VIK), operator information and technical publications. Furthermore, excerpts of emissions declarations from the year 1996, as provided by some Länder authorities, were also evaluated in the present context.

3. Aggregation of emission factors
   On the basis of the percentage contributions for the various technologies – which were determined separately for the old and new Länder – the technology-specific emission factors were aggregated to form source-category-specific factors. Finally, factors for Germany as a whole were formed. The source-category-specific factors are sub-divided in accordance with the categories large combustion plants, TA Luft combustion plants and gas turbines, as well as in accordance with the fuel used. Aggregated emission factors are formed first for the reference year 1995.

4. Projections for 2000 and 2010
   For description of continuing technological development, technology-specific emission factors are again determined. These are derived from characterisation of modern technologies. An increasing contribution of low-emissions technologies to total relevant activity, thus, can be represented by suitably changing the percentage shares for the technologies under consideration. Applicable immission-control laws are used as a framework for updating for the year 2000. It is assumed that the requirements of the amended TA Luft (Technical Instructions on Air Quality Control) and of the EU directive on large combustion plants will be met by the reference year 2010.

The above-described methods, beginning with characterisation of the emissions behaviour of relevant combustion technologies and gradually leading to aggregated factors at various regional and source-category-specific levels, make it possible to represent the required factors transparently.

The chosen methods for deriving emission factors for a given reference year are shown in Figure 18 below.

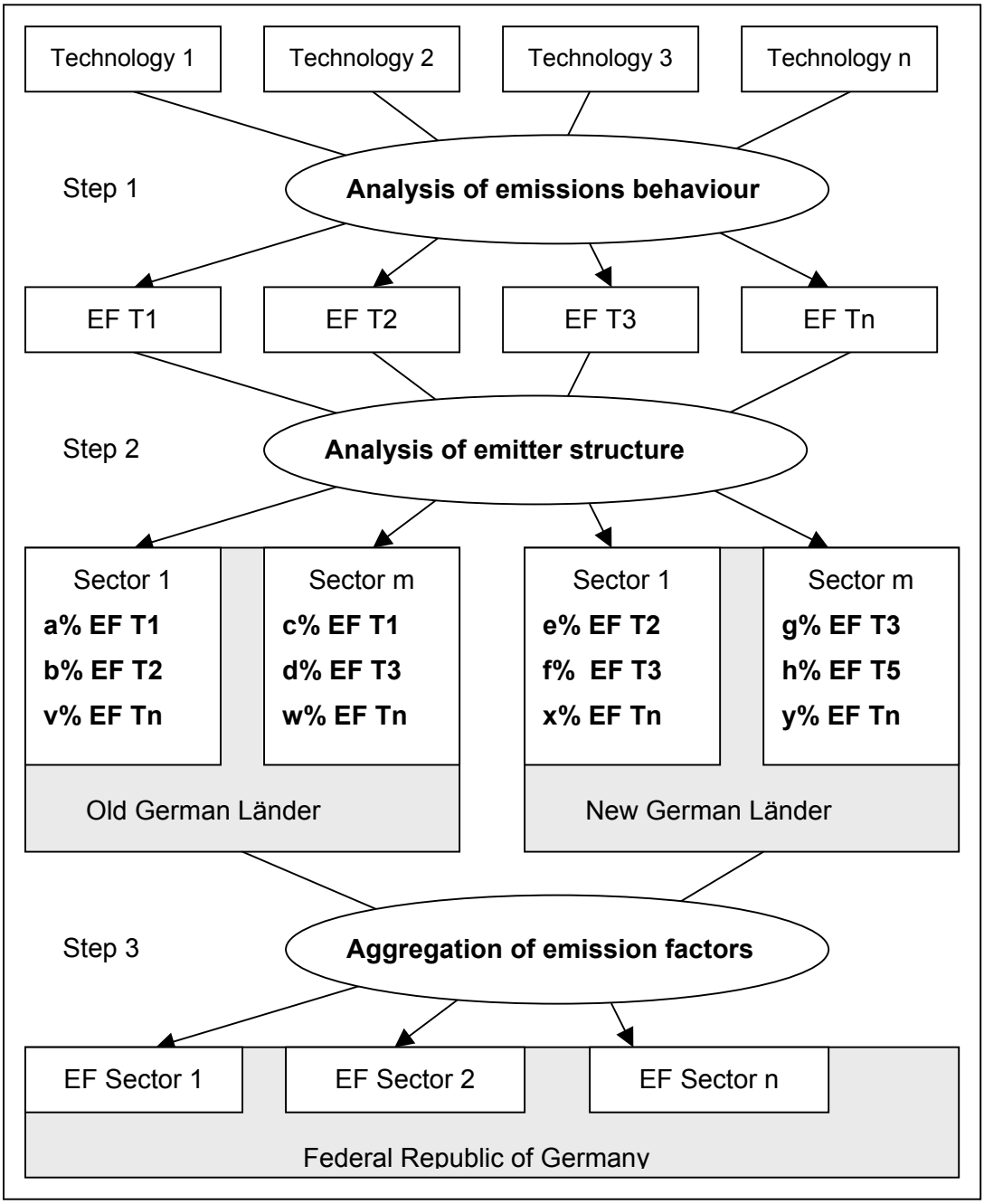



Figure 18: Methods for calculating emission factors

The origins and quality of the data are described in detail in the project report (Rentz et al, 2002). A large part of the data comes from emissions declarations of the Länder Baden-Württemberg, Brandenburg, North Rhine – Westfalia and Thuringia for 1996. The annual pollutant loads listed therein are based, depending on the pollutant concerned, on measurements from continuous monitoring, on individual measurements or on calculation on the basis of physical laws, mass balances or emission factors. In the following, the emissions declarations of the state of Baden-Württemberg are used to show, by way of illustration, what data-determination methods tend to be used for the various types of combustion plants and pollutants in question. This will then make it possible to classify the quality of the underlying

data with regard to the derived technology-specific emission factors. At the same time, the description illustrates the data-evaluation procedure. Where a sufficient amount of data for a source category is available, the relevant value range is characterised via the median and the percentile is characterised at 25 % and 75 %[11]. This produces a robust estimate that, unlike characterisation via the mean value, is not distorted by extreme values. In general, percentiles at 5 % and 95 % are also listed, to describe the distribution of values. Similar percentile evaluations were also carried out for the emissions declarations of the other Federal Länder.

In the following, a distinction is made between measured data (either continuous measurements or individual measurements) and data based on calculation or emission factors. In evaluation, therefore, individual data items are first classified as either measurements (M) or assumptions (A). This general overview, in turn, is divided into the categories of large combustion installations, TA Luft combustion installations and gas turbines. These are then further subdivided, with regard to declaration obligations, into installations subject to abbreviated (K) or complete (V) declarations. For each of the three groups of installations, evaluation and derivation of emission factors is carried out, using the example data from Baden-Württemberg and with separation by measurements and assumptions.

Table 15 provides an overview of the installation types in question and lists the relevant numbers under the 4th BimSchV and the relevant type of declaration required.

Table 15: Installation types pursuant to Annex of 4th BImSchV

| **Index** | LARGE COMBUSTION PLANTS | Type of declaration required |
|---|---|---|
| 1 01 1 | Power stations ≥ 50 MW for solid, liquid and gaseous fuels | V |
| 1 02A 1 | Combustion plants ≥ 50 MW for solid and liquid fuels | V |
| 1 02B 1 | Combustion plants ≥ 50 MW for gaseous fuels | V |
| **Index** | TA LUFT INSTALLATIONS | Type of declaration required |
| 1 02A 2 | Combustion plants 1 - < 50 MW, solid and liquid fuels (except for heating oil EL) | V |
| 1 02B 2 | Combustion plants 5 - < 50 MW heating oil EL | K |
| 1 02C 2 | Combustion plants 10 - < 50 MW for natural gas<br>Combustion plants 10 - < 50 MW, except for natural gas installations | K<br>V |
| 1 03 1 | Combustion plants > 1 MW, other fuels | V |
| **Index** | GAS-TURBINE INSTALLATIONS | Type of declaration required |
| 1 05 1 | Gas turbines ≥ 50 MW for natural gas<br>Gas turbines ≥ 50 MW, except for natural gas installations | K<br>V |
| 1 05 2 | Gas turbines < 50 MW for natural gas<br>Gas turbines < 50 MW, except for natural gas installations | K<br>V |

11 For the entire value range of a variable X, the sum-frequency distribution can be used to estimate what percentage of all units considered will have a maximal value of x. This value is termed a *quantile*: or, where percentage shares are used, as a *percentile*. The best-known percentile that separates the lower half of all values from the upper half is the 50% percentile, the so-called *median*. The 25 and 75% percentiles cut off the upper and lower quarters of the distribution. They are thus also referred to as upper and lower *quartiles* or as the first and third quartile (with the median being a sort of second quartile).

In the analyses, emissions data is differentiated by combustion technologies. Table 16 provides an overview of this technology classification based on types. Categories 110 to 118 apply mainly to solid fuels, while 120 to 125 apply to liquid fuels and 130 to 132 apply to gaseous fuels.

Table 16: Classification of sources by type of combustion installation

| Technology | |
|---|---|
| **Type** | Type meaning |
| 110 | Combustion plants for solid fuels / waste |
| 111 | Filled-shaft combustion plants |
| 112 | Combustion plants with belt feed |
| 113 | Combustion plants with pneumatic feed |
| 114 | Combustion plants with bottom feed |
| 115 | Combustion plant with mechanically moving grid |
| 116 | Dust combustion with dry-ash removal |
| 117 | Dust combustion with wet-ash removal |
| 118 | Fluidised-bed combustion |
| 120 | Combustion systems for liquid fuels / waste |
| 121 | With vaporizer burner |
| 122 | With pressurised atomiser burner |
| 123 | With steam-atomiser burner |
| 124 | With rotating atomiser burner |
| 125 | With air-atomiser burner |
| 130 | Combustion plants for gaseous fuels / waste |
| 131 | With atmospheric gas burner |
| 132 | With gas-blower burner |
| 141 | Multiple-fuel combustion plants |
| 142 | Mixed combustion plants |
| 815 | Gas turbines |

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

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

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

The uncertainty of the determined emission factors has been evaluated in the framework of the DFIU research project described in Chapter 3.1.1.2.

##### *3.1.1.3.1 Methods for determining uncertainties of emission factors*

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

Other sources of possible uncertainties can affect calculation of emissions with the help of emission factors. In the GPG framework, Chapter 6, methods adapted to data availability are proposed:

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

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

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

In general, use of *experts' assessments* is recommended in cases in which available empirical data does not suffice for quantification.

The guide on describing uncertainties in measurements (Leitfaden zur Angabe der Unsicherheit beim Messen - DIN, 1995) recommends the following systematic approach for cases in which not enough observations have been carried out to yield a meaningful result, via calculation of means and standard deviation:

On the basis of the available information, limits (upper and lower limit $a_+$ and $a_-$) are determined for the value to be determined, $X_i$. If no special findings regarding possible values of $X_i$ within this range are available, then it must be assumed that all possible values have the same probability, an assumption that corresponds to a uniform or square distribution of possible values. Then, the expected value $x_i$ lies in the middle of the estimated range. The following relationship holds for the pertinent variation:

$$u^2(x_i) = (a_+ - a_-)^2 / 12 \quad (A1)$$

For actual physical reasons, values in the vicinity of the middle of the range often have a higher probability than values near the limits. This leads to the assumption of a symmetric trapezoidal distribution, with a base line of length a+ - a- (= 2a) and a top line of length 2aβ with $0 < \beta < 1$. For $\beta = 0$, a triangular distribution results. The following relationship holds for the pertinent variation:

$$u^2(x_i) = a^2 (1 + \beta^2) / 6$$

The estimated standard deviation u is thus calculated as the positive square root of $u^2$.

The standard deviation of approximated, normally distributed values can also be roughly estimated via the interdecile range [Sachs 1992]. The following approximation holds:

$$u \approx 0{,}39 (DZ_9 – DZ_1), \quad (A2)$$

where $DZ_9$ and $DZ_1$ stand for the 90th and 10th percentiles, respectively.

The IPCC guidelines recommend that the uncertainty be given via the 95% confidence interval, which can be approximated as double the value of the standard deviation. To obtain a relative error, one determines the share of 2u in the value $X_i$. Via multiplicative linking of various independent values that are subject to uncertainties, one can calculate the *combined standard deviation* as the positive square root of the sum of variations. This approximation holds, pursuant to GPG, as long as the relative standard deviation of any component does not exceed a value of 30 %.

$$u_{total} = \sqrt{u_1^2 + u_2^2 + ... + u_n^2} \qquad \text{(A3)}$$

#### *3.1.1.3.2 Quantification of the uncertainties of emission factors for combustion plants*

For derivation of emission factors, various sets of data, of varying extensiveness depending on pollutant and source category, are available for Germany; this data can be used as a basis for determining the pertinent uncertainties. The data is classified in keeping with the main groups defined for the report – large combustion plants, combustion plants under the TA Luft and gas turbines. First, the uncertainty of the relevant technology-specific factors is evaluated. Then, the uncertainty must be taken into account that results from aggregation of these factors for the various source categories used for the emissions calculation. Finally, the uncertainty resulting from extrapolation of the emission factors for 2000 and 2010 must be taken into account.

The relationships A1 and A2 above, for determination of the standard deviation and 2u, respectively, were reviewed via examples for which a comparatively large number of individual data items is available (30 – 70) and thus the standard deviation of the relevant random sample can be calculated.

Example: $NO_X$ emissions from large combustion plants (lignite)

*New German Länder*

Random sample: n = 77;

$DZ_1$: 68.4 g/GJ; quartile 25%: 113.5 g/GJ; median: 134 g/GJ; mean value: 135.6 g/GJ;

quartile 75%: 154.5 g/GJ; $DZ_9$: 187.7 g/GJ;

Calculated standard deviation u = 45.3 g/GJ (relative error of 67.6 %)

Estimation of u pursuant to A1: 46.9 g/GJ (69.9 %)

Estimation of u pursuant to A2: 46.4 g/GJ (69.2 %)

*Old German Länder*

Random sample: n = 30;

$DZ_1$: 67.5 g/GJ; quartile 25%: 70.6 g/GJ; median: 74 g/GJ; mean value: 72.6 g/GJ;

quartile 75%: 75.9 g/GJ; $DZ_9$: 77.7 g/GJ;

Calculated standard deviation u = 6.1 g/GJ (relative error of 16.6 %)

Estimation of u pursuant to A1: 5.3 g/GJ (14.3 %)

Estimation of u pursuant to A2: 4 g/GJ (10.8 %)

The examples considered show that, especially for smaller random samples, estimation with A1 yields better agreement with the calculated standard deviation than does estimation with A2. The quantiles, the upper and lower limits, were set at 5 % and 95 %. With even smaller random samples, conventional calculation methods produce larger standard deviations. Determination of emission factors, in contrast to determination of the correctness of measurements, involves assessing the robustness of results. In actual emissions calculation, some compensation can occur through simultaneous overestimation and underestimation within the totality of all sources. For example, in example a), the individual factors are widely scattered, while the higher emission factors account for smaller shares of the relevant activities. If the random sample is considered as a complete survey, then a factor of 119 g/GJ results for the observed emission, which corresponds to a 15 g/GJ deviation from the median.

The robustness of the emissions calculation can be characterised by noting that consideration of the entire range of factors is likely to lead to overestimation of the actual uncertainty. The upper and lower boundaries of the range are thus estimated with the upper and lower quartiles. In the case of a), this produces a relative error of 18 %. This also corresponds to the order of magnitude estimated, in other studies, for the uncertainty of $NO_X$ emission factors from energy conversion.

To evaluate the uncertainty of the proposed emission factors, the upper ($a_+$) and lower ($a_-$) quartiles are determined, on the basis of the surveyed individual data, and then the standard deviation is estimated in accordance with equation (A1). Similarly, the relative uncertainty is calculated as $2u/X_i$. This procedure is used first to determine the uncertainties of the technology-specific factors. Then, these uncertainties are linked with the uncertainty resulting from aggregation to form source-category-specific factors.

In aggregation of technology-specific factors to form source-category-specific factors, the former are weighted and added in accordance with their relative contributions to the emitter structure. As a simplification, such weighting is also carried out in linking of the relative errors.

#### *3.1.1.3.3 Result for $N_2O$*

In Germany, $N_2O$ is monitored only in exceptional cases; for this reason, no relevant data from regular measurements is available. On the other hand, relevant emissions behaviour in combustion of hard coal and lignite, especially in fluidised-bed combustion, has been specifically studied over the past 15 years. For this reason, enough measurement data was available to permit systematic survey of $N_2O$ emission factors in the research project.

Individual evaluations of the uncertainties in $N_2O$ emission factors, produced in research project 299 43 142 (Rentz et al, 2002), are included in the Excel tables for transfer of emission factors into the Federal Environmental Agency's CSE database; for power stations, the evaluations are also described in the final report. Individual evaluations of the uncertainties in $N_2O$ emission factors are included in both the final report and the Excel tables for transfer of emission factors into the Federal Environmental Agency's CSE database. The great majority of values for the relative uncertainty lie within a range between 0.6 and 0.9. As part of an experts' assessment carried out by the present research team pursuant to Tier 1 GPG, Chap. 6, an upper boundary of +/- 50 % was given for the

percentage uncertainty in CRF area 1.A.1a (as well as in areas 1.A.1b, 1.A.1c and 1.A.2) (Note: when +/- ranges are used, the values must be divided by 2; cf. GPG, Chapter 6, p. 6.14); with this approach – in agreement with the selected calculation method – a uniform distribution of uncertainties is assumed.

#### *3.1.1.3.4 Result for $CH_4$*

Combustion plants in Germany are not subject to monitoring of $CH_4$ emissions; for this reason, no systematic measurement data is available in this area. For this reason, individual items of data available in Germany and Switzerland have been relied on. As a result of these database limitation, the research project did not attempt any systematic correlation with source categories treated by the project (cf. Chapter 3.1.1.2).

As part of an experts' assessment carried out by the present research team pursuant to Tier 1 GPG, Chap. 6, an upper boundary of +/- 50 % was given for the percentage uncertainty in CRF area 1.A.1a (as well as in areas 1.A.1b, 1.A.1c and 1.A.2); with this approach – as with $N_2O$ – a uniform distribution of uncertainties is assumed.

#### *3.1.1.3.5 Time-series consistency of emission factors*

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

The time series between 1995 and 2002 were reviewed in this light and assessed as consistent overall. Source-specific review of $N_2O$ emission factors with regard to consistency with the values as of 1995 remains to be carried out for the period from 1990 to 1994.

The time series of $CH_4$ emission factors for 1995 to 2002 were also reviewed and assessed as internally consistent. Values for the period from 1990 to 1994 were not reviewed for consistency with the values as of 1995, since plans call for application of the results of quality-assurance measures from Chapter 3.1.1.4 to the entire 1990-2002 time period. Changed values will be included in the inventory for the next report cycle.

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

Since the inventories, in general, are based on the energy balances for Germany prepared by the Working Group on Energy Balances, quality assurance, quality control and verification of energy inputs are carried out by reviewing the energy balance for completeness and plausibility. This procedure leads to re-allocations of fuel-use amounts within the energy balance, as well as to addition of energy inputs not listed in the energy balance – such as firewood use in the source categories households, small consumers and commerce, trade and services (cf. Chapter 13.3, 13.5.1, 13.5.2, 13.6.1, 13.7, 1.1.16).

Measures for assuring the quality of emission factors for combustion plants, as used in the framework of a research project (Rentz et al, 2002), are outlined in the methods description

in Chapter 3.1.1.2, after Figure 18. The inventory's data quality in the area of $N_2O$ emission factors was clearly improved by adopting the $N_2O$ emission factors from the research project. The situation with regard to $CH_4$ was less clear, as is described in Chapter 3.1.1.3; for this reason, in the framework of a quality review pursuant to GPG Chapter 2.2.3 carried out by Federal Environmental Agency experts, the Länder-specific emission factors determined for $CH_4$ were compared with the Tier 2 default emission factors (Table 1-15) in the IPCC Reference Manual. The aim of this review was to determine whether the DFIU data or the Tier-2 default values should be included in the inventory. The review showed that, for boiler combustion systems, the existing Tier-2 default values, on average, are lower than the Länder-specific emission factors. For natural-gas-fired gas turbines, on the other hand, the IPCC default values are considerably higher. The finding that Table 1-15 of the Reference Manual has a considerably number of gaps is even more significant, however; for example, the table does not list a single $CH_4$ value for the area of lignite-fired combustion systems, a highly significant area in Germany; in the area of gaseous fuels, the table contains only a value for natural gas – and no values for other gases. What is more, the Reference Manual contains inconsistencies between Tables 1-15 and 1-16 (cf. Chapter 3.1.7.4). As a result of all of these factors, the experts' assessment was that use of the DFIU values is clearly preferable, since such use would clearly provide the larger improvement in inventory quality, especially with regard to completeness and consistency. In the experts' opinion, this procedure and the relevant values should be classified within the Tier 2 approach.

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

Source-specific recalculations for energy data have been carried out to account for data updates in the energy balance and to account for improvements in methods. The improvements in methods were closely linked with the methodological documentation in the energy sector called for in the review report for 2003 (FCCC/WEB/IRI(3)/2003/DEU, p. 3, sub-point 8); this documentation has been considerably improved for submission of the NIR 2004, but has not yet been completed. Recalculations can thus be documented only on the basis of this methodological documentation – i.e. in the 2005 report.

For the period 1995 to 2002, $N_2O$ emissions were recalculated via use of the emission factors from the research project described in Chapter 3.1.1.2. Source-specific review of $N_2O$ emission factors, and recalculation of emission factors for $CH_4$ and $N_2O$, have not yet been completed (cf. Chapter 3.1.1.3) for the period between 1990 and 1994.

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

Plans call for reviewing, by the next report cycle, the $N_2O$ emission factors for the period between 1990 and 1994; the reviewed values will then be entered into the CSE and will permit suitable emissions recalculation for this period. Other planned efforts, to be completed by the next report cycle, include entering already reviewed $CH_4$ emission factors into the CSE and recalculating $CH_4$ emissions for the 1990-2002 period.

Plans also call for refinement of the methods designed by the DFIU for forecasting emission factors. The refined methods will then be used to review, and adjust if necessary, the values forecast for 2000 and 2010 on the basis of the 1995 emission factors. The aim of the refinement is for methods to provide a better picture of the chronological progress of modernisations of existing plants, as well as of adaptation of plants to tighter emissions standards. This work is to begin in 2004.

Longer-term plans call for enhancing precision in determination of $N_2O/CH_4$ emissions behaviour of gas turbines, via measurements and/or systematic studies. The occasions for these efforts include the circumstances described in Chapters 3.1.1.3 and 3.1.1.4 and the increasing importance of gas turbines in the energy sector, which is also due to federal climate-protection efforts (especially gas and steam systems, CHP systems). The time for the start of this improvement measure has not yet been specified.

## *3.1.2 Petroleum refining (1.A.1b)*

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

| CRF 1.A.1b | | | | | |
|---|---|---|---|---|---|
| **Key source** | | **Gas (MSG)** | **1990 – contribution to total emissions** | **2002 – contribution to total emissions** | **Trend** |
| Liquid fuels | l / t | $CO_2$ | 1,29 % | 1,83 % | rising |
| Solid fuels | t | $CO_2$ | 0,19 % | 0,05 % | falling |

| **Gas** | **$CO_2$** | **$CH_4$** | **HFCs** | **PFCs** | **$SF_6$** | **$N_2O$** | **$NO_X$** | **CO** | **NMVOC** | **$SO_2$** |
|---|---|---|---|---|---|---|---|---|---|---|
| Emissions factor[12] (EF) | CS | CS | NO | NO | NO | CS | CS | CS | CS | CS |
| EF uncertainties in % | < 1 | +/- 50 | - | - | - | +/- 50 | | | | |
| Distribution of uncertainties [13] | U | U | - | - | - | U | | | | |
| Method for EF determination[14] | CS | Tier 2 | - | - | - | Tier 2 | | | | |

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

In its trends, the petroleum refining source category is a key source, in terms of emissions levels, trends for liquid fuels and trends for solid fuels.

The figures for the uncertainty of the emission factor, and for the statistical distribution function for that uncertainty, have been estimated by the Federal Environmental Agency. The figures themselves are based on a personal communication from Mr. Struschka (IVD).

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

The refineries operate power stations with an electrical output of approximately 0.8 GW and a furnace thermal output of 4 GW. These power stations generated 5 TWh of electrical work. Process heat from these plants is drawn off for production purposes. Process heat is also produced from process furnaces with a furnace thermal output in excess of 7 GW.

### 3.1.2.2 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 inputs for the power stations for heat generation and for process combustion, both of which are reported jointly in line 38, was separated out. Table 12 (refineries) shows the plant structure used in the BEU model.

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

The emission factors for refinery power stations have been taken from the research project "Determination and evaluation of emission factors for combustion plants in Germany for the years 1995, 2000 and 2010". This project has also provided the underlying data for the emission factors presented in Chapter 3.1.1, 3.1.3 and 3.1.7, where the factors include power stations, gas turbines or conventionally fired boilers for generation of steam and hot/warm water. This project was carried out by the Franco-German Institute for Environmental Research (Deutsch-Französischen Institut für Umweltforschung – DFIU) at the University of Karlsruhe, and it was completed in early 2003. A detailed description of the procedure is provided in Chapter 3.1.1.2. The project cited does not provide any emission factors for the sub-combustion that provides process heat. To compensate for this gap, for sub-combustion the same values for $N_2O$ and $CH_4$ were chosen that are also used for refinery power stations.

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

The procedure for determining uncertainties is described in Chapter 3.1.1.3.

#### *3.1.2.3.1 Result for $N_2O$*

In Germany, $N_2O$ is monitored only in exceptional cases; for this reason, no relevant data from regular measurements is available. Individual evaluations of the uncertainties in $N_2O$ emission factors from research project 299 43 142 (Rentz et al, 2002) are included in the Excel tables for transfer of emission factors into the Federal Environmental Agency's CSE database. The values for the relative uncertainty are about 0.6. As part of an experts' assessment carried out by the present research team pursuant to Tier 1 GPG, Chap. 6, an upper boundary of +/- 50 % was given for the percentage uncertainty in CRF area 1.A.1b (as well as in areas 1.A.1a, 1.A.1c and 1.A.2) (Note: when +/- ranges are used, the values must be divided by 2; cf. GPG, Chapter 6, p. 6.14); with this approach – in agreement with the selected calculation method – a uniform distribution of uncertainties is assumed.

#### *3.1.2.3.2 Result for $CH_4$*

The results of uncertainties determination are described in Chapter 3.1.1.3.4.

#### *3.1.2.3.3 Time-series consistency of emission factors*

The results of determination of time-series consistency are described in Chapter 3.1.1.3.5.

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

Since the inventories, in general, are based on the energy balances for Germany prepared by the Working Group on Energy Balances, quality assurance, quality control and verification of energy inputs are carried out by reviewing the energy balance for completeness and plausibility. This procedure leads to re-allocations of fuel-use amounts within the energy balance, as well as to addition of energy inputs not listed in the energy balance – such as firewood use in the source categories households, small consumers and commerce, trade and services (cf. Chapter 13.3, 13.5.1, 13.5.2, 13.6.1, 13.7, 3.1.16).

Measures for assuring the quality of emission factors for combustion plants, as used in the framework of a research project (Rentz et al, 2002), are outlined in the methods description in Chapter 3.1.1.2. The inventory's data quality in the area of $N_2O$ emission factors was

clearly improved by adopting the $N_2O$ emission factors from the research project. The situation with regard to $CH_4$ was less clear, as is described in Chapter 3.1.1.3.4; for this reason, in the framework of a quality review pursuant to GPG Chapter 2.2.3 carried out by Federal Environmental Agency experts, the Länder-specific emission factors determined for $CH_4$ were compared with the Tier 2 default emission factors (Table 1-15) in the IPCC Reference Manual. The aim of this review was to determine whether the DFIU data or the Tier-2 default values should be included in the inventory. The review showed that, for boiler combustion systems, the existing Tier-2 default values, on average, are lower than the Länder-specific emission factors. For natural-gas-fired gas turbines, on the other hand, the IPCC default values are considerably higher. The finding that Table 1-15 of the Reference Manual has a number of gaps was even more significant; for example, in the area of gaseous fuels, the table lists a value solely for natural gas – it presents no values for other gases such as refinery gas. It also lacks Tier-2 default values for $CH_4$ in use of liquid fuels in gas turbines. What is more, the Reference Manual contains inconsistencies between Tables 1-15 and 1-16 (cf. Chapter 3.1.7.4). As a result of all of these factors, the experts' assessment was that use of the DFIU values is clearly preferable, since such use would clearly provide the larger improvement in inventory quality, especially with regard to completeness and consistency. In the experts' opinion, this procedure and the relevant values should be classified within the Tier 2 approach.

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

Information on source-specific recalculations is provided in Chapter 3.1.1.5.

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

Plans call for reviewing, by the next report cycle, the $N_2O$ emission factors for the period between 1990 and 1994; the reviewed values will then be entered into the CSE and will permit suitable emissions recalculation for this period. Other planned efforts, also to be completed by the next report cycle, include entering already reviewed $CH_4$ emission factors into the CSE and recalculating $CH_4$ emissions for the 1990-2002 period.

Plans also call for refinement of the methods designed by the DFIU for forecasting emission factors. The refined methods will then be used to review, and adjust if necessary, the values forecast for 2000 and 2010 on the basis of the 1995 emission factors. The aim of the refinement is for methods to provide a better picture of the chronological progress of modernisations of existing plants, as well as of adaptation of plants to tighter emissions standards. This work is to begin in 2004.

Furthermore, the emissions behaviour of sub-combustions that provide process heat is to be determined in the medium term. No definite date for the commencement of these studies has yet been set, however.

Longer-term plans call for considerably enhancing precision in determination of $N_2O/CH_4$ emissions behaviour of gas turbines, via measurements and/or systematic studies. The occasions for these efforts include the circumstances described in Chapter 3.1.2.4 and the expectation that use of gas turbines in the refinery sector will increase, just as use of such systems has been increasing in the rest of the energy sector, also as a result of federal climate-protection measures (especially with regard to gas and steam systems and CHP systems). The time for the start of this improvement measure has not yet been specified.

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

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

| CRF 1.A.1c | | | | | |
|---|---|---|---|---|---|
| Key source | | Gas (MSG) | 1990 – contribution to total emissions | 2002 – contribution to total emissions | **Trend** |
| Solid fuels | l / t | $CO_2$ | 3,65 % | 1,82 % | falling |

| **Gas** | **$CO_2$** | **$CH_4$** | **HFCs** | **PFCs** | **$SF_6$** | **$N_2O$** | **$NO_X$** | **CO** | **NMVOC** | **$SO_2$** |
|---|---|---|---|---|---|---|---|---|---|---|
| Emissions factor[15] (EF) | CS | CS | NO | NO | NO | CS | CS | CS | CS | CS |
| EF uncertainties in % | < 5 | +/-50 | - | - | - | +/- 50 | | | | |
| Distribution of uncertainties [16] | U | U | - | - | - | U | | | | |
| Method for EF determination[17] | CS | Tier 2 | - | - | - | Tier 2 | | | | |

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

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

The figures for the uncertainty of the emission factor, and for the statistical distribution function for that uncertainty, have been estimated by the Federal Environmental Agency. The figures themselves are based on a personal communication from Mr. Struschka (IVD).

This category includes hard-coal and lignite mining, coking and briquetting plants and extraction of crude oil and natural gas. In 2002, the German hard coal mining industry mined 26.1 Mt of hard coal. Coke production during the same period totalled 7.2 Mt. Production of hard coal briquettes and other coal products totalled less than 1 Mt. Hard coal mining accounts for an electrical power plant output of less than 3 GW, and a furnace thermal output of 7 GW. Heat generation in combined heat and power generation is minimal.

In 2002, 181.8 Mt of crude lignite was produced in Germany. 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 is drawn off for drying crude lignite for production of lignite products.

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

### 3.1.3.2 Methodological issues (1.A.1c)

Table 10 shows the data structure, from the *Balance of Emission Causes*, for hard coal and lignite mining.

Table 12 shows the BEU structure for oil extraction.

The sources consulted for production figures include the Energy Balance for the Federal Republic of Germany (3.1, line 21; AGEB), Statistics of the coal industry (Statistik der Kohlenwirtschaft e.V.) and Statistics of the manufacturing sector (Produktion im

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

Produzierenden Gewerbe; Fachserie 4, Reihe 3.1, Melde-Nr. 2310 10 330+350; DESTATIS). The source consulted for fuel inputs is the Energy Balance for the Federal Republic of Germany (3.2 (joulee), line 33; AGEB,).

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

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

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

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

Table 17 shows the activity rates determined; lignite coking plants are not included, since no energy inputs are available for them.

Table 17: Determination of activity rates (AR) of emissions-relevant energy consumption (EMEV) of process combustion in hard-coal coking

| Hard-coal coke production | Unit | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|
| Total 1) | 1,000 t | 11100 | 10662 | 10774 | 10325 | 8569 | 9141 | 7265 | 7226 |
| Byproduct (metallurgical) coke 2) | 1,000 t | 6306 | 5833 | 5859 | 5591 | 5195 | 5296 | 5274 | 5225 |
| Byproduct coke 3) | 1,000 t | 4794 | 4829 | 4915 | 4734 | 3374 | 3845 | 1991 | 2001 |
| Mean energy input | | | | | | | | | |
| Byproduct (metallurgical) coke | TJ/kt | 3,1 | 3,1 | 3,1 | 3,1 | 3,1 | 3,1 | 3,1 | 3,1 |
| Byproduct coke | TJ/kt | 2,95 | 2,95 | 2,95 | 2,95 | 2,95 | 2,95 | 2,95 | 2,95 |
| Energy input for hard-coal coking | | | | | | | | | |
| Byproduct (metallurgical) coke | TJ | 19548,6 | 18082,3 | 18162,9 | 17332,1 | 16104,5 | 16417,6 | 16349,4 | 16197,5 |
| Byproduct coke | TJ | 14142,3 | 14245,5 | 14499,2 | 13965,3 | 9953,3 | 11342,8 | 5873,45 | 5902,95 |
| Total | TJ | 33691 | 32328 | 32662 | 31297 | 26058 | 27760 | 22223 | 22100 |
| EMEV hard-coal coking | | | | | | | | | |
| AR blast-furnace gas 4) | TJ | 19156 | 18172 | 19193 | 16861 | 12163 | 15662 | 16189 | 16397 |
| AR coke-oven gas, city gas 5) | TJ | 14535 | 14156 | 13469 | 14436 | 13895 | 12098 | 6034 | 5703 |

1) Energy Balance, line 21; 2000/2001: Federal Statistical Office, FS4, R.3.1, Melde-Nr. 2310 10 330+350; 2002: Melde-Nr. 2310 10 300 as an additional aid

2) Statistik der Kohlenwirtschaft e.V. (ed.): Der Kohlenbergbau in der Energiewirtschaft der Bundesrepublik Deutschland im Jahre 1995 ff, overview of figures, 45; 2001/2002 Federal Statistical Office, FS4, R.8.1, Tab. 3.1, Erzeugung der Hüttenkokereien (production of metallurgical works coking plants), as an additional aid

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

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

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

The emission factors for power stations and other boiler combustion for production of steam and hot/warm water, in source category 1.A.1c, have been taken from (Rentz et al, 2002). This project has also provided the underlying data for the emission factors presented in Chapter 3.1.1, 3.1.2 and 3.1.7, where the factors include power stations, gas turbines or conventionally fired boilers for generation of steam and hot/warm water. This project was carried out by the Franco-German Institute for Environmental Research (Deutsch-Französischen Institut für Umweltforschung – DFIU) at the University of Karlsruhe, and it was completed in early 2003. A detailed description of the procedure is provided in Chapter 3.1.1.2.

Within the sector, the project differentiates between STEAG power stations, other power stations in the hard-coal mining sector, power stations in the lignite mining sector and other boiler furnaces for production of steam and hot/warm water.

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

The procedure for determining uncertainties is described in Chapter 3.1.1.3.

#### *3.1.3.3.1 Result for $N_2O$*

In Germany, $N_2O$ is monitored only in exceptional cases; for this reason, no relevant data from regular measurements is available. On the other hand, relevant emissions behaviour in combustion of hard coal and lignite, especially in fluidised-bed combustion, has been specifically studied over the past 15 years. For this reason, enough measurement data was available to permit systematic survey of $N_2O$ emission factors in the research project.

Individual evaluations of the uncertainties in $N_2O$ emission factors, produced in research project 299 43 142 (Rentz et al, 2002), are included in the Excel tables for transfer of emission factors into the Federal Environmental Agency's CSE database; for power stations, the evaluations are also described in the final report. The values for relative uncertainty are about 0.6. As part of an experts' assessment carried out by the present research team pursuant to Tier 1 GPG, Chap. 6, an upper boundary of +/- 50 % was given for the percentage uncertainty in CRF area 1.A.1c (as well as in areas 1.A.1a, 1.A.1b and 1.A.2) (Note: when +/- ranges are used, the values must be divided by 2; cf. GPG, Chapter 6, p. 6.14); with this approach – in agreement with the selected calculation method – a uniform distribution of uncertainties is assumed.

#### *3.1.3.3.2 Result for $CH_4$*

The results of uncertainties determination are described in Chapter 3.1.1.3.4.

#### *3.1.3.3.3 Time-series consistency of emission factors*

The results of determination of time-series consistency are described in Chapter 3.1.1.3.5.

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

Since the inventories, in general, are based on the energy balances for Germany prepared by the Working Group on Energy Balances, quality assurance, quality control and verification of energy inputs are carried out by reviewing the energy balance for completeness and plausibility. This procedure leads to re-allocations of fuel-use amounts within the energy balance, as well as to addition of energy inputs not listed in the energy balance – such as firewood use in the source categories households, small consumers and commerce, trade and services (cf. Chapter 13.3, 13.5.1, 13.5.2, 13.6.1, 13.7, 3.1.16).

Measures for assuring the quality of emission factors for combustion plants, as used in the framework of a research project (Rentz et al, 2002), are outlined in the methods description in Chapter 3.1.1.2. The inventory's data quality in the area of $N_2O$ emission factors was clearly improved by adopting the $N_2O$ emission factors from the research project. The situation with regard to $CH_4$ was less clear, as is described in Chapter 3.1.1.3.4; for this reason, in the framework of a quality review pursuant to GPG Chapter 2.2.3 carried out by Federal Environmental Agency experts, the Länder-specific emission factors determined for $CH_4$ were compared with the Tier 2 default emission factors (Table 1-15) in the IPCC Reference Manual. The aim of this review was to determine whether the DFIU data or the Tier-2 default values should be included in the inventory. The review showed that, for boiler combustion systems, the existing Tier-2 default values, on average, are lower than the Länder-specific emission factors. For natural-gas-fired gas turbines, on the other hand, the IPCC default values are considerably higher. The finding that Table 1-15 of the Reference Manual has a considerable number of gaps is even more significant, however; for example,

the table does not list a single $CH_4$ value for the area of lignite-fired combustion systems, a highly significant area in Germany; in the area of gaseous fuels, the table contains only a value for natural gas – and no values for other gases, such as coke-oven gas. What is more, the Reference Manual contains inconsistencies between Tables 1-15 and 1-16 (cf. Chapter 3.1.7.4). As a result of all of these factors, the experts' assessment was that use of the DFIU values is clearly preferable, since such use would clearly provide the larger improvement in inventory quality, especially with regard to completeness and consistency. In the experts' opinion, this procedure and the relevant values should be classified within the Tier 2 approach.

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

Information on source-specific recalculations is provided in Chapter 3.1.1.5.

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

Plans call for reviewing, by the next report cycle, the $N_2O$ emission factors for the period between 1990 and 1994; the reviewed values will then be entered into the CSE and will permit suitable emissions recalculation for this period. Other planned efforts, also to be completed by the next report cycle, include entering already reviewed $CH_4$ emission factors into the CSE and recalculating $CH_4$ emissions for the 1990-2002 period.

Plans also call for refinement of the methods designed by the DFIU for forecasting emission factors. The refined methods will then be used to review, and adjust if necessary, the values forecast for 2000 and 2010 on the basis of the 1995 emission factors. The aim of the refinement is for methods to provide a better picture of the chronological progress of modernisations of existing plants, as well as of adaptation of plants to tighter emissions standards. This work is to begin in 2004.

Longer-term plans call for considerably enhancing precision in determination of $N_2O/CH_4$ emissions behaviour of gas turbines, via measurements and/or systematic studies. The occasions for these efforts include the circumstances described in Chapter 3.1.3.4 and the expectation that use of gas turbines in the mining sector will increase, just as use of such systems has been increasing in the rest of the energy sector, also as a result of federal climate-protection measures (especially with regard to gas and steam systems and CHP systems). The time for the start of this improvement measure has not yet been specified.

Review of existing emission factors, and of the consistency of time series for coking plants, is planned for next year.

In the interest of broadening the database, plans call for development, with the help of relevant associations, operators and monitoring authorities, of a strategy for future data deliveries and uncertainties estimates for coking plants.

One lignite coking plant is still in operation in Germany. This coking plant's relevance for emissions reporting remains to be studied.

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

This source category consists of several sub- source categories.

| CRF 1.A.2 | | | | | |
|---|---|---|---|---|---|
| Key source | | Gas (MSG) | 1990 – contribution to total emissions | 2002 – contribution to total emissions | **Trend** |
| Solid fuels | l / t | $CO_2$ | 9,64 % | 5,97 % | falling |
| Gaseous fuels | l / t | $CO_2$ | 3,67 % | 4,81 % | rising |
| Liquid fuels | l / t | $CO_2$ | 2,28 % | 1,99 % | falling |
| Other fuels | t | $CO_2$ | 0,15 % | 0,04 % | falling |

| **Gas** | **$CO_2$** | **$CH_4$** | **HFCs** | **PFCs** | **$SF_6$** | **$N_2O$** | **$NO_X$** | **CO** | **NMVOC** | **$SO_2$** |
|---|---|---|---|---|---|---|---|---|---|---|
| Emissions factor[18] (EF) | | | | | | | | | | |
| EF uncertainties in % | | | | | | | | | | |
| Distribution of uncertainties [19] | | | | | | | | | | |
| Method for EF determination[20] | | | | | | | | | | |

In light of its emissions levels and trend, the manufacturing industry sector is a key source for solid, gaseous and liquid fuels.

Sub- source categories are considered as a group under the manufacturing-industry source category (1.A.2).

### *3.1.5 Manufacturing industry – iron and steel (1.A.2a)*

#### 3.1.5.1 Methodological issues (1.A.2a)

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

The coke input in blast furnaces, reduced by the coke equivalent, is allocated to final energy consumption. In the Balance of Emissions Causes, this coke consumption is listed in Table 14.

In terms of process procedure, the correct approach for the emission balance would be to allocate the $CO_2$ contained in blast-furnace gas to the blast furnace process and to assign oxidation of the CO contained in blast-furnace gas to combustion of blast-furnace gas. This would require the composition of the blast-furnace gas in question to be precisely known. In view of the many different types of blast-furnace-gas analysis carried out, this approach is theoretically useful but impractical. For this reason, the $CO_2$ emissions from blast-furnace gas combustion are evaluated with the $CO_2$ emission factor for hard coal coke. This helps to ensure that the $CO_2$ emissions from the blast furnace process and blast-furnace-gas combustion are no greater than the potential $CO_2$ emissions brought into blast furnaces with hard coal coke.

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

#### *3.1.5.1.1 Industrial process combustion, blast furnaces*

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

The sources consulted for production figures include the Energy Balance for the Federal Republic of Germany (lines 17 and 54; AGEB), and statistics of the manufacturing sector (Produzierendes Gewerbe. Eisen und Stahl, Fachserie 4, Reihe 8.1, Tabelle 3.25; DESTATIS). Figures for input of liquid fuels, coke-oven gas, blast-furnace gas and natural gas were taken directly from the Federal Statistical Office's statistics. These figures have been converted into TJ, using the relevant average caloric values pursuant to the Energy Balance, and then reported in the CSE as activity rates under heating oil, heavy, coke-oven/city gas, blast-furnace gas and natural gas.

The "hard-coal coke" activity rate is determined in accordance with the same principle, with the difference that, following conversion to TJ, the Federal Statistical Office's figures have to be reduced by the relevant coke-equivalent value from the Energy Balance, line 17 (cf. 3.1.5.1).

The Federal Statistical Office's figures are not suitable for determination of hard-coal input in blast-furnace operations, since those figures do not only refer to blast-furnace and sintering plants – they also include inputs for electric power generation.
The "hard coal" activity rate is thus calculated as the difference between hard-coal consumption pursuant to the Energy Balance, line 54, and that portion of solid fuels in sintering plants that is assigned to hard coal (cf. sintering plants).
The "other petroleum products" activity rate has been taken from the Energy Balance, line 54, and it comprises the plastic waste used in blast furnaces.
The further breakdown of the "heating oil, heavy" activity rate, into fractions with an average of 1.9 % or more than 2.8 % sulphur, is not relevant for emissions determination; it is part of a balance in which sales of heavy heating oil with a high sulphur content (source: Association of the German Petroleum Industry (MWV)) are distributed, in accordance with plausibility criteria, among source categories with minimal emissions relevance.

Table 18 provides an overview of the activity rates determined.

#### *3.1.5.1.2 Industrial process combustion, sintering plants*

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

The sources consulted for production figures include the Energy Balance for the Federal Republic of Germany (line 54; AGEB), and statistics of the manufacturing sector (Produzierendes Gewerbe. Eisen und Stahl, Fachserie 4, Reihe 8.1, Tabelle 3.25; DESTATIS). For sintering plants, the Federal Statistical Office solely lists total use of solid fuels, in 1,000 t SKE. This value is first converted into TJ, the key units for energy-related activity rates.

In a next step, the combined fuel inputs contained therein are identified on the basis of the Energy Balance, line 54, using the assumption that all figures in this line that are attributable

to solid fuels apply to process combustion in blast furnances and sintering plants. The figures for lignite briquettes pursuant to line 54 are listed as the lignite-briquettes activity rate, in TJ, and those for other lignite products are listed as the lignite-coke activity rate, also in TJ. The hard-coal activity rate in TJ is calculated from the difference between the Energy Balance value and the blast-furnace activity rate (cf. blast-furnace operations). The hard-coal activity rate in TJ, finally, is calculated from consumption of solid fuels in TJ, pursuant to the Federal Statistical Office, minus the previously determined activity rates for lignite briquettes, lignite coke and hard-coal coke. Since, for sintering plants, the Federal Statistical Office only lists use of solid fuels, even though some 0.18 GJ of gaseous fuels per tonne of finished sinter are consumed for priming, the amount of gas consumed must be determined via the sinter production. From this value, the activity rates for coke-oven/city gas, blast-furnace gas and natural gas can be calculated as equal proportions – an assumption that is supported by the relevant figures from the Energy Balance, line 54. Table 18 provides an overview of the activity rates determined.

Table 18: Determined activity rates (AR) of emissions-relevant energy consumption (EMEV) in industrial process combustion, blast furnaces and sintering plants

| **Fuel consumption of blast-furnace operations** | Unit | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **2001** | **2002** |
|---|---|---|---|---|---|---|---|---|---|
| Federal Statistical Office, FS 4, R.8.1, Tab.3.25 | | | | | | | | | |
| | | | | | | | | | |
| Coke (= hard-coal coke) | 1,000 t | 11392 | 10482 | 11372 | 10778 | 9886 | 11562 | 10871 | 11000 |
| Liquid fuels (= heating oil, heavy) | 1,000 t | 1475 | 1318 | 1374 | 1354 | 1116 | 869 | 1074 | 1030 |
| 1.9% S | 1,000 t | 1088 | 864 | 977 | 868 | 818 | 571 | 670 | 879 |
| >2.8% S | 1,000 t | 387 | 454 | 397 | 486 | 298 | 298 | 404 | 151 |
| Coke-oven gas | millions of m³ (Vn) bf | 212 | 165 | 156 | 134 | 103 | 143 | 143 | 130 |
| Blast-furnace gas | millions of m³ (Vn) bf | 1452 | 1372 | 1479 | 1435 | 1254 | 1370 | 1309 | 1310 |
| Natural gas | millions of m³ (Vn) bf | 237 | 232 | 268 | 262 | 268 | 263 | 193 | 240 |
| | | | | | | | | | |
| Calorific values of fuels, pursuant to Energy Balance | | | | | | | | | |
| Hard-coal coke | TJ/1,000 t | 28,650 | 28,650 | 28,650 | 28,650 | 28,650 | 28,650 | 28,650 | 28,650 |
| Heating oil, heavy | TJ/1,000 t | 40,557 | 40,539 | 40,968 | 40,968 | 40,921 | 40,921 | 40,404 | 40,404 |
| Coke-oven gas | TJ/ millions of m³ Hu | 31,736 | 31,736 | 31,736 | 31,736 | 31,736 | 31,736 | 31,736 | 31,736 |
| Blast-furnace gas | TJ/ millions of m³ Hu | 31,736 | 31,736 | 31,736 | 31,736 | 31,736 | 31,736 | 31,736 | 31,736 |
| Natural gas | TJ/ millions of m³ Hu | 31,736 | 31,736 | 31,736 | 31,736 | 31,736 | 31,736 | 31,736 | 31,736 |
| | | | | | | | | | |
| Coke in blast-furnace operations, DESTATIS (1) | TJ | 326381 | 300309 | 325808 | 308790 | 283234 | 331251 | 311454 | 315150 |
| Production of blast-furnace gas, DESTATIS | millions of m³ (Vn) bf | | | | | | 4724 | 4479 | 4495 |
| Hard-coal coke, EB line 17 (2) | TJ | 167889 | 152590 | 167574 | 161758 | 148837 | 166138 | 157522 | 158085 |
| AR hard-coal coke, blast furnace (3) | TJ | 158492 | 147719 | 158234 | 147032 | 134397 | 165113 | 153932 | 157065 |
| Hard-coal coke, EB line 54 (4) | TJ | 185000 | 188000 | 187772 | 188804 | 177401 | 205007 | 187485 | 166458 |
| AR hard-coal coke, sintering (5) | TJ | 26508 | 40281 | 29538 | 41772 | 43004 | 39894 | 33553 | 9393 |
| | | | | | | | | | |
| Solid fuels in sintering plants, DESTATIS | 1,000 t HCE | 1619 | 1659 | 1706 | 1832 | 1667 | 1752 | 1638 | 1540 |
| Solid fuels in sintering plants, DESTATIS (6) | TJ | 47450 | 48622 | 49999 | 53692 | 48856 | 51348 | 48007 | 45134 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Lignite briquettes, EB line 54 | TJ | 19 | 6 | 12 | | 3 | | | |
| Other lignite products, EB line 54, (= lignite coke) | TJ | 308 | 150 | 209 | 230 | 178 | 216 | 198 | 205 |
| AR hard coal, sintering (7) | TJ | 20614 | 8185 | 20240 | 11690 | 5671 | 11238 | 14256 | 35537 |
| Hard coal, EB line 54 | TJ | 55930 | 51430 | 65381 | 70128 | 73501 | 73078 | 70625 | 70625 |
| AR hard coal, blast furnace (8) | TJ | 35316 | 43245 | 45141 | 58438 | 67830 | 61840 | 56369 | 35088 |
| | | | | | | | | | |
| EMEV blast furnace | | | | | | | | | |
| AR hard coal (8) | TJ | 35316 | 43245 | 45141 | 58438 | 67830 | 61840 | 56369 | 35088 |
| AR hard-coal coke (3) | TJ | 158492 | 147719 | 158234 | 147032 | 134397 | 165113 | 153932 | 157065 |
| AR heating oil, heavy (9) | TJ | 59822 | 53430 | 56290 | 55471 | 45668 | 35560 | 43394 | 41616 |
| 1.9% S | TJ | 44126 | 35033 | 40011 | 35565 | 33468 | 23359 | 27071 | 35515 |
| >2.8% S | TJ | 15696 | 18397 | 16279 | 19906 | 12199 | 12201 | 16323 | 6101 |
| AR Other petroleum products, EB line 54 | TJ | 398 | 319 | 393 | 398 | 398 | 351 | 98 | 304 |
| AR coke-oven / city gas (10) | TJ | 6728 | 5236 | 4951 | 4253 | 3269 | 4538 | 4538 | 4126 |
| AR blast-furnace gas (10) | TJ | 46081 | 43542 | 46938 | 45541 | 39797 | 43478 | 41542 | 41574 |
| AR natural gas (10) | TJ | 7521 | 7363 | 8505 | 8315 | 8505 | 8347 | 6125 | 7617 |
| AR Total | TJ | 374179 | 354285 | 376741 | 374918 | 345531 | 354788 | 349393 | 329006 |
| | | | | | | | | | |
| Pig-iron production | 1000 t | 30012 | 27722 | 30940 | 30162 | 27934 | 30845 | 29184 | 29427 |
| Specific energy consumption per t of pig iron | GJ | 12,47 | 12,78 | 12,18 | 12,43 | 12,37 | 11,50 | 11,97 | 11,18 |
| | | | | | | | | | |
| Sinter production | 1,000 t | 28243 | 27268 | 28759 | 28883 | 26740 | 27959 | 27055 | 26104 |
| Specific gas consumption per t of finished sinter | GJ | 0,18 | 0,18 | 0,18 | 0,18 | 0,18 | 0,18 | 0,18 | 0,18 |
| Gas consumption for sinter production | TJ | 5084 | 4908 | 5177 | 5199 | 4813 | 5033 | 4870 | 4699 |
| | | | | | | | | | |
| EMEV sintering plants | | | | | | | | | |
| AR hard coal (7) | TJ | 20614 | 8185 | 20240 | 11690 | 5671 | 11238 | 14256 | 35537 |
| AR hard-coal coke (5) | TJ | 26508 | 40281 | 29538 | 41772 | 43004 | 39894 | 33553 | 9393 |
| AR lignite briquettes, EB line 54 | TJ | 19 | 6 | 12 | | 3 | | | |
| AR lignite coke, EB line 54 | TJ | 308 | 150 | 209 | 230 | 178 | 216 | 198 | 205 |
| AR coke-oven/city gas (11) | TJ | 1695 | 1636 | 1726 | 1733 | 1604 | 1678 | 1623 | 1566 |
| AR blast-furnace gas (11) | TJ | 1695 | 1636 | 1726 | 1733 | 1604 | 1678 | 1623 | 1566 |
| AR natural gas (11) | TJ | 1695 | 1636 | 1726 | 1733 | 1604 | 1678 | 1623 | 1566 |
| AR Total | TJ | 52533 | 53530 | 55176 | 58891 | 53670 | 56380 | 52876 | 49833 |
| | | | | | | | | | |
| Specific energy consumption per t of finished sinter | GJ | 1,86 | 1,96 | 1,92 | 2,04 | 2,01 | 2,02 | 1,95 | 1,91 |

(1) Hard-coal coke in 1,000 t * calorific value pursuant to Energy Balance

(2) The figures for the period 2000 to 2002 – like the values from Energy Balances of the last few year – are calculated from blast-furnace-gas production pursuant to DESTATIS, in millions of m³ (Vn) Ho*35,169 TJ/millions m³

Coke in blast-furnace operations, DESTATIS ./. Hard-coal coke, EB line 17

(4) The Energy Balance figures for 1995 (194992 TJ) and 1996 (196568 TJ) have been provisionally reduced, and the difference has been transferred to line 53, since that line lists too little hard-coal coke. The Working Group on Energy Balances has been informed about this matter.

Hard-coal coke, EB line 54 ./. AR hard-coal coke, blast furnace

(6) Solid fuels in sintering plants, DESTATIS, in 1,000 t SKE*29.308 TJ/1,000 t HCU (SKE)

(7) Solid fuels in sintering plants, DESTATIS, in TJ ./. AR hard-coal coke, sintering ./. Lignite briquettes, EB line 54 ./. Other lignite products, EB line 54

(8) Hard coal, EB line 54 ./. AR hard coal, sintering

(9) Liquid fuels (= heating oil, heavy) in 1,000 t * calorific value pursuant to Energy Balance

(10) millions of m³ (Vn) Ho*31,736 TJ/ millions of m³ Hu
(11) Gas consumption for sinter production distributed equally between coke-oven/city gas, blast-furnace gas and natural gas.

#### *3.1.5.1.3 Industrial process combustion, hot rolling mills*

In the Central System of Emissions (CSE), energy-related activity rates, emission factors and emissions of hot rolling millis are listed under the module name "INPFWA" (Industrieprozessfeuerung Warmwalzwerk = industrial process combustion, hot rolling mills).

The source for the fuel-input figures is the Federal Statistical Office: Produzierendes Gewerbe. Eisen und Stahl, Fachserie 4, Reihe 8.1, Tabelle 3.25; DESTATIS).

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

For hot rolling mills, the Federal Statistical Office lists figures for use of liquid fuels, coke-oven gas, blast-furnace gas and natural gas. These figures have been converted into TJ, using the relevant average caloric values pursuant to the Energy Balance, and then reported in the CSE as activity rates under heating oil, heavy, coke-oven/city gas, blast-furnace gas and natural gas. In the Energy Balance, these activity rates are shown in line 54. Table 19 provides an overview of the activity rates determined.

Table 19: Determined activity rates (AR) of emissions-relevant energy consumption (EMEV) in industrial process combustion, hot rolling mills

| **Fuel consumption of hot rolling mills** | **Units** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **2001** | **2002** |
|---|---|---|---|---|---|---|---|---|---|
| Federal Statistical Office, FS 4 R.8.1, Tab.3.25 | | | | | | | | | |
| Liquid fuels (= heating oil, heavy) | 1,000 t | 18 | 23 | 24 | 24 | 19 | 16 | 16 | 28 |
| Coking oven gas (= coke-oven gas) | millions of m³ (Vn) bf | 722 | 686 | 723 | 642 | 522 | 583 | 478 | 462 |
| Blast furnace gas (3) | millions of m³ (Vn) bf | 201 | 188 | 210 | 193 | 185 | 184 | 174 | 170 |
| Natural gas | millions of m³ (Vn) bf | 1384 | 1358 | 1512 | 1505 | 1528 | 1595 | 1599 | 1587 |
| | | | | | | | | | |
| Calorific values of fuels, pursuant to Energy Balance | | | | | | | | | |
| Heating oil, heavy | TJ/1,000 t | 40,557 | 40,539 | 40,968 | 40,968 | 40,921 | 40,921 | 41,404 | 41,404 |
| Coking gas | TJ/ millions of m³ Hu | 31,736 | 31,736 | 31,736 | 31,736 | 31,736 | 31,736 | 31,736 | 31,736 |
| Blast furnace gas | TJ/ millions of m³ Hu | 31,736 | 31,736 | 31,736 | 31,736 | 31,736 | 31,736 | 31,736 | 31,736 |
| Natural gas | TJ/ millions of m³ Hu | 31,736 | 31,736 | 31,736 | 31,736 | 31,736 | 31,736 | 31,736 | 31,736 |
| | | | | | | | | | |
| EMEV hot rolling mill | | | | | | | | | |
| AR heating oil, heavy (1) | TJ | 730 | 932 | 983 | 983 | 777 | 655 | 662 | 1159 |
| AR coking / city gas (2) | TJ | 22913 | 21771 | 22945 | 20375 | 16566 | 18502 | 15170 | 14662 |
| AR blast-furnace gas (2) | TJ | 6379 | 5966 | 6665 | 6125 | 5871 | 5839 | 5522 | 5395 |
| AR natural gas (2) | TJ | 43923 | 43097 | 47985 | 47763 | 48493 | 50619 | 50746 | 50365 |
| AR total | TJ | 73945 | 71767 | 78578 | 75245 | 71707 | 75615 | 72100 | 71581 |

(1) Liquid fuels (= heating oil, heavy) in 1,000 t * calorific value pursuant to Energy Balance

(2) millions of m³ (Vn) Ho*31,736 TJ/ millions of m³ Hu

(3) Figure for 2002 estimated, since it was secret (unprecedented secrecy for this statistic)

## *3.1.6 Manufacturing industries – pulp, paper and print (1.A.2d)*

### 3.1.6.1 Source category description (1.A.2d)

| CRF 1.A.2.d | | | | | |
|---|---|---|---|---|---|
| Key source | | Gas (MSG) | 1990 – contribution to total emissions | 2002 – contribution to total emissions | **Trend** |
| Cf. Chapter 3.1.4 | | | | | |

| **Gas** | **$CO_2$** | **$CH_4$** | **HFCs** | **PFCs** | **$SF_6$** | **$N_2O$** | **$NO_X$** | **CO** | **NMVOC** | **$SO_2$** |
|---|---|---|---|---|---|---|---|---|---|---|
| Emissions factor [21] | D | CS | | | | CS | CS | CS | CS | CS |
| Uncertainties | 0 | – | | | | – | | | | |
| Distribution of uncertainties [22] | | | | | | | | | | |
| Method [23] | D | CS | | | | CS | | | | |

The pulp, paper and print industry operates numerous combustion facilities of its own in order to meet its own high requirements for process heat and electrical energy (it also supplies surplus heat and electrical energy to other users). In addition to being operated with conventional types of fuels, some of these combustion facilities are also fired with solid and

21 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model

22 N = Normal, L = Log normal, T = Triangular, U = Uniform (even distribution)

23 D = IPCC default, RA = reference approach, T1 = IPPC tier 1, T1a/ T1b/ T1c = IPPC tier 1a/ 1b/ 1c, T2 = IPPC tier 2, T3 = IPPC tier 3, C = CORINAIR, CS = country-specific, M = model

liquid residual substances, from processing of raw materials such as wood (bark, for example) and used paper, as well as with biogas from wastewater treatment.

In the printing industry, energy-related emissions of climate-relevant gases occur through consumption of fuel (gas) in drying systems.

### 3.1.6.2 Methodological issues (1.A.2d)

All of the amounts of conventional fuels used are included in the Federal Energy Balance; in addition, the Federal Energy Balance, in the form expanded by the Federal Environmental Agency (Balance of Emissions Causes, cf. Chapter 13), also provides figures for the secondary fuels used in industrial thermal power stations. Where the fuels used are included in the expanded Federal Energy Balance and contain fossil carbon, the resulting emissions of climate-relevant gases are included in the national emissions inventory. Such emissions cannot be allocated to the pulp, paper and print industry and listed here, however, since the expanded Federal Energy Balance's figures for fuel input in industrial thermal power stations are not broken down by individual sub- source categories.

For the same reason, figures of the German Pulp and Paper Association (Verband Deutscher Papierfabriken - VDP) on fuel input in pulp and paper industry cannot be used here – with such use, double counts could not be avoided. Pursuant to the performance report of the association of German paper mills (VDP), 80.1 % of the primary energy used in the pulp and paper industry in 2002 (101,240 of 126,351 TJ) came from fossil fuels, and this percentage use led to a release of 6,549,802 t of fossil $CO_2$. In keeping with the *IPCC Good Practice Guidelines*, fuels from renewable resources are assigned a $CO_2$ emission factor of "0". This also applies to incineration of waste liquor from pulp production (liquor boilers), since all of the carbon in waste liquor, whether from the sulphite or sulphate procedures, comes from the wood broken down through the process. The following table shows the activity rate for liquor incineration, along with the relevant emission factors.

Table 20: Activity rate and emission factors for liquor incineration

| | Activity rate | | Emission factors | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Units | $CO_2$ | $CH_4$ | $N_2O$ | $NO_X$ | CO | NMVOC | $SO_2$ | Units |
| Incineration of sulphite | 2.266.787 | $t_{ADP}$/a | 0 | 0,032 | 0,05 | 1,37 | 0,41 | 0,032 | 4,46 | $kg/t_{ADP}$ |
| and sulphate liquor | 15.975 | TJ/a | 0 | 1,8 | 3 | 77 | 23 | 1,8 | 250 | kg/TJ |

### 3.1.6.3 Planned improvements (source-specific) (1.A.2d)

1. A Federal Environmental Agency research project, to begin in the near term, will seek to determine what percentage of the fuels listed in the expanded Federal Energy Balance is used in combustion facilities of the pulp and paper industry, as well as whether the Balance includes all amounts of the secondary fuels used by the industry. This work will then be used as a basis for developing a method for surveying fuel input in the pulp and paper industry and for calculating the resulting emissions that is consistent and that takes account of the different emissions behaviours of fuels and processes in question (differentiated emission factors).

2. For drying of paper webs, the paper industry makes some use of directly heated dryers that can exhibit increased levels of methane release because their gas burners, for technical reasons, have to be frequently switched on and off. At present, no information regarding the relevant percentages of gas used in such dryers is available; consequently,

no separate calculations are possible, and the emissions of climate-relevant gases from such dryers are under-estimated through use of the emission factors for other gas burners. Plans call for separate determination of the amounts of gas used in directly heated dryers, as well as for determination of a suitable emission factor for the operationally related increased $CH_4$ emissions resulting from such systems.

3. The precision of the emission factors used is to be reviewed and improved on the basis of measurements.

### *3.1.7 Manufacturing industry – other electricity producers (1.A.2f)*

| **CRF 1.A.2f** | | | | | |
|---|---|---|---|---|---|
| **Key source** | | **Gas (MSG)** | **1990 – contribution to total emissions** | **2002 – contribution to total emissions** | **Trend** |
| Cf. Chapter 3.1.4 | | | | | |

| **Gas** | **$CO_2$** | **$CH_4$** | **HFCs** | **PFCs** | **$SF_6$** | **$N_2O$** | **$NO_X$** | **CO** | **NMVOC** | **$SO_2$** |
|---|---|---|---|---|---|---|---|---|---|---|
| Emissions factor[24] (EF) | | CS | NO | NO | NO | CS | CS | CS | CS | CS |
| EF uncertainties in % | | +/-50 | - | - | - | +/-50 | | | | |
| Distribution of uncertainties [25] | | U | - | - | - | U | | | | |
| Method for EF determination[26] | | Tier 2 | - | - | - | Tier 2 | | | | |

The above figures refer to power stations, and to other boiler furnaces for production of steam and hot/warm water, in source category 1.A.2.

#### 3.1.7.1 Source-category description (1.A.2f)

This category includes the power stations of

- Industry (quarrying, other mining and manufacturing industry)
- Power stations belonging to Deutsche Bahn AG (German national railway)

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 industrial power stations (sub-quantity of Energy Balance line 60) are shown in Table 13. A further differentiation on the basis of industry sectors is currently being explored.

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, they generated 4.5 TWh of electrical energy. These power stations are also included in Table 11.

#### 3.1.7.2 Methodological issues (1.A.2f)

The emission factors for power stations and other boiler combustion systems for production of steam and hot/warm water in source category 1A2 have been taken from the research

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

project *Determination and evaluation of emission factors for combustion facilities in Germany for the years 1995, 2000 and 2010* (Rentz et al, 2002). This project has also provided the underlying data for the emission factors presented in Chapter 3.1.1, 3.1.2 and 3.1.3, where the factors include power stations, gas turbines or conventionally fired boilers for generation of steam and hot/warm water. This project was carried out by the Franco-German Institute for Environmental Research (Deutsch-Französischen Institut für Umweltforschung – DFIU) at the University of Karlsruhe, and it was completed in early 2003. A detailed description of the procedure is provided in Chapter 3.1.1.2.

The project breaks down the relevant sector into power stations of Deutsche Bahn AG, other industrial power stations and other boiler combustion systems for production of steam and hot/warm water.

### 3.1.7.3 Uncertainties and time-series consistency (1.A.2f)

The procedure for determining uncertainties is described in Chapter 3.1.1.3.

#### *3.1.7.3.1 Result for $N_2O$*

In Germany, $N_2O$ is monitored only in exceptional cases; for this reason, no relevant data from regular measurements is available. On the other hand, relevant emissions behaviour in combustion of hard coal and lignite, especially in fluidised-bed combustion, has been specifically studied over the past 15 years. For this reason, enough measurement data was available to permit systematic survey of $N_2O$ emission factors in the research project.

Individual evaluations of the uncertainties in $N_2O$ emission factors, produced in research project 299 43 142 (Rentz et al, 2002), are included in the Excel tables for transfer of emission factors into the Federal Environmental Agency's CSE database; for power stations, the evaluations are also described in the final report. The values for the relative uncertainty lie primarily within a range between 0.6 and 0.9. As part of an experts' assessment carried out by the present research team pursuant to Tier 1 GPG, Chap. 6, an upper boundary of +/- 50 % was given for the percentage uncertainty in CRF area 1.A.2 (as well as in areas 1.A.1a, 1.A.1b and 1.A.1c) (Note: when +/- ranges are used, the values must be divided by 2; cf. GPG, Chapter 6, p. 6.14); with this approach – in agreement with the selected calculation method – a uniform distribution of uncertainties is assumed.

#### *3.1.7.3.2 Result for $CH_4$*

The results of uncertainties determination are described in Chapter 3.1.1.3.4.

#### *3.1.7.3.3 Time-series consistency of emission factors*

The results of determination of time-series consistency are described in Chapter 3.1.1.3.5.

### 3.1.7.4 Source-specific quality assurance / control and verification (1.A.2f)

Since the inventories, in general, are based on the energy balances for Germany prepared by the Working Group on Energy Balances, quality assurance, quality control and verification of energy inputs are carried out by reviewing the energy balance for completeness and plausibility. This procedure leads to re-allocations of fuel-use amounts within the Energy Balance, as well as to addition of energy inputs not listed in the energy balance – such as

firewood use in the source categories households, small consumers and commerce, trade and services (cf. Chapter 13.3, 13.5.1, 13.5.2, 13.6.1, 13.7, 3.1.16).

Measures for assuring the quality of emission factors for combustion plants, as used in the framework of a research project (Rentz et al, 2002), are outlined in the methods description in Chapter 3.1.1.2. The inventory's data quality in the area of $N_2O$ emission factors was clearly improved by adopting the $N_2O$ emission factors from the research project. The situation with regard to $CH_4$ was less clear, as is described in Chapter 3.1.1.3.4; for this reason, in the framework of a quality review pursuant to GPG Chapter 2.2.3 carried out by Federal Environmental Agency experts, the Länder-specific emission factors determined for $CH_4$ were compared with the Tier 2 default emission factors (Table 1-16) in the IPCC Reference Manual. The aim of this review was to determine whether the DFIU data or the Tier-2 default values should be included in the inventory. The review showed that, for boiler combustion systems, the existing Tier-2 default values, on average, are somewhat lower than the Länder-specific emission factors. In the present case – in contrast to that of 1.A.1 / Table 1-15 – this also applies to gas turbines fired with natural gas. The differences are smaller, however, than those resulting from comparison in the energy sector (source categories 1.A.1) with Table 1-15. Another result was that Table 1-16 of the Reference Manual exhibits gaps – for example, for gases other than natural gas, for use of light heating oil in gas turbines and for hard-coal coke and lignite coke. What is more, the Reference Manual contains inconsistencies between Tables 1-15 and 1-16; for example: Table 1-16 lists one item more for heavy heating oil / residual oil; furthermore, it is unclear why the large natural-gas-fired gas turbines in Table 1-15 should emit 10 times as much methane as the smaller turbines in Table 1-16. On the whole, from these results experts conclude that the DFIU values are clearly to be preferred over the the Reference Manual's default Tier-2 values, since the former, especially with regard to completeness and consistency, clearly make a greater contribution to improvement of the inventory's quality. In the experts' opinion, this procedure and the relevant values should be classified within the Tier 2 approach.

#### 3.1.7.5 Source-specific recalculations (1.A.2f)

Information on source-specific recalculations is provided in Chapter 3.1.1.5.

#### 3.1.7.6 Planned improvements (source-specific) (1.A.2f)

Plans call for reviewing, by the next report cycle, the $N_2O$ emission factors for the period between 1990 and 1994; the reviewed values will then be entered into the CSE and will permit suitable emissions recalculation for this period. Other planned efforts, also to be completed by the next report cycle, include entering already reviewed $CH_4$ emission factors into the CSE and recalculating $CH_4$ emissions for the 1990-2002 period.

Plans also call for refinement of the methods designed by the DFIU for forecasting emission factors. The refined methods will then be used to review, and adjust if necessary, the values forecast for 2000 and 2010 on the basis of the 1995 emission factors. The aim of the refinement is for methods to provide a better picture of the chronological progress of modernisations of existing plants, as well as of adaptation of plants to tighter emissions standards. This work is to begin in 2004.

Other plans call for considerably enhancing precision in determination of $N_2O/CH_4$ emissions behaviour of gas turbines, via measurements and/or systematic studies. The occasions for

these efforts include the circumstances described in Chapter 3.1.7.4 and the expectation that use of gas turbines in industry will increase, just as use of such systems has been increasing in the rest of the energy sector, also as a result of federal climate-protection measures (especially with regard to gas and steam systems and CHP systems). The time for the start of this improvement measure has not yet been specified.

## *3.1.8 Transport – civil aviation (1.A.3a)*

### 3.1.8.1 Source-category description (1.A.3a)

| CRF 1.A.3 | | | | | |
|---|---|---|---|---|---|
| Key source | | Gas (MSG) | 1990 – contribution to total emissions | 2002 – contribution to total emissions | **Trend** |
| Aviation gasoline | l / t | $CO_2$ | 0,23 % | 0,41 % | rising |

| **Gas** | **$CO_2$** | **$CH_4$** | **HFCs** | **PFCs** | **$SF_6$** | **$N_2O$** | **$NO_X$** | **CO** | **NMVOC** | **$SO_2$** |
|---|---|---|---|---|---|---|---|---|---|---|
| Emissions factor[27] (EF) | CS | CS | -- | -- | -- | CS | CS | CS | CS | CS |
| EF uncertainties in % | | | | | | | | | | |
| Distribution of uncertainties [28] | | | | | | | | | | |
| Method of emissions calculation [29] | T1 | T1 | -- | -- | -- | T1 | | | | |

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

In terms of emissions origins, air transports differ considerably from land and water transports, since aircraft burn most of their fuel under atmospheric conditions that differ from those on the ground and that are not constant. The main factors that influence the combustion process in this sector include atmospheric pressure, environmental temperature and humidity – all of which are factor that vary considerably with altitude.

In addition to considering carbon dioxide, the debate on the climate effects and emissions-related environmental impacts of air transports focuses mainly on water vapour and nitrogen oxides and, secondarily, on hydrocarbons, particulates, CO and sulphur dioxide. In the framework of national emissions reporting, figures for other emissions are also required, however. The following remarks are thus refer to emissions of sulphur dioxide ($SO_2$), nitrogen oxides ($NO_X$, i.e. NO and $NO_2$), non-methane volatile organic compounds (NMVOC), methane ($CH_4$), carbon dioxide ($CO_2$) and nitrous oxide ($N_2O$ – laughing gas).

### 3.1.8.2 Methodological issues (1.A.3a)

No data on different phases of flights of aircraft operating in Germany is available. Consequently, the Tier-2-method requirements, calling for differentiation of emission factors for LTO cycles and cruising flight, cannot be fulfilled. Air transport emissions are calculated via the Tier 1 method, pursuant to equation 2.7 of IPCC GPG p. 2.57 (IPCC, 2000):

Emissions = fuel consumption * emission factor

The energy balance prepared on the basis of aircraft fuel sold in Germany provides the basis for the relevant activity data. Since the emission factor for carbon dioxide depends on the

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

fuel C content, this factor was determined, for reasons of consistency, by the Federal Environmental Agency's energy specialists who provide all combustion-related emission factors for specific fuels.

Emissions of sulphur dioxide depend exclusively on the sulphur content of the fuel in question. On the other hand, the sulphur content is subject to regional fluctuations. For reasons of consistency, this content is determined by the Federal Environmental Agency transport section that provides all fuel-relevant indexes (these were last provided in September 2003). Pursuant to measurements carried out in 1998, the sulphur concentration in fuel is about 210 ppm, i.e. 0.021 mass-percent (DÖPELHEUER, 2002). According to Shell AG (Germany) and the Association of the German Petroleum Industry (MWV)), the sulphur content of kerosine is on the order of that of low-sulphur diesel fuel – no precise, generally valid relevant data was provided, however. Since the strong reduction of the sulphur content in refinery fuel flows will also have positive influences or secondary impacts on kerosine, a kerosine sulphur content of 200 mg/kg is assumed. Assuming complete combustion, this would result in an emission factor of 0.4 g/kg. For the reader's information, it should be added that a small part of emitted sulphur dioxide is further oxidised into $SO_3$ which, in turn, reacts with water to form sulphuric acid. The values listed in the IPCC guidelines, 1.0 g/kg for cruising flight and 2.4 g/kg for the LTO cycle, are not considered up to date.

To date, emission factors for other pollutants have been determined on the basis of the research project "*Determination of exhaust emissions from air traffic over the Federal Republic of Germany"* (Federal Environmental Agency, 1989) via recalculation from emissions.

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

Table 21 shows the emission factors used to date. The first emissions-factor column uses the units g/kg fuel, which is customarily used in the air-transport sector, while the second emissions-factor column uses the units kg/TJ, which are commonly used in the framework of reporting. For purposes of emissions reporting, the determined emission factors must be converted into the corresponding energy equivalents, taking the net calorific value of kerosine into account. For this purpose, a value of 43,000 kJ/kg, as provided by the Association of the German Petroleum Industry (MWV), is used.

Table 21: Emissions factors used to date

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

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

The current calculation procedures have been verified on the basis of more current data and findings. This applies to the various emission factors used, the energy-content figures used for conversion into energy-related emission factors and the selected breakdown between national and international air transports. The IPCC's proposed emission factors were taken into account in the following considerations. On the other hand, it must be noted that the proposed emission factors were generated with an average fleet that does not reflect German air transports. This means that current findings have shown that the values cannot be used in the proposed manner. The results of the verification will serve as the basis for future, planned improvements.

Except for that for $SO_2$, the emission factors used to date for determination of air-transport emissions have all had to be revised and adjusted as a result of new information that has become available and of technological progress in aircraft engines. As described above, combustion takes place at a range of different altitudes, and thus generation of emission factors can be problematic; emission factors for higher altitudes must be correlated with the emission factors determined for the LTO cycle (landing/take-off cycle, i.e. flight movements to an altitude of 3,000 feet, or about 915 m). For example, formation of nitrogen oxides depends strongly on external conditions and on the conditions in the combustion chamber, which change with altitude.

Profound changes have occurred in connection with emissions of ***nitrogen oxides***, since efforts to make aircraft engines more fuel-efficient have led to increases in average emission factors. On the other hand, in earlier studies the effects of cruising flight were overestimated, and this is reflected in the value in Table 21. Determining the emission factor for nitrous oxide has proven to be difficult (DÖPELHEUER, 2002), (RAND, 2003), (UBA, 2001a). At this juncture, it would be more correct to speak first of nitrogen oxides in general – i.e. of the sum of nitrogen monoxide and nitrogen dioxide. In an aircraft engine, primarily nitrogen monoxide is produced; this substance, after leaving the engine, is then converted into nitrogen dioxide. For this reason, the emission factor listed below refers to the totality of all nitrogen oxides, even where complete oxidation to nitrogen dioxide effectively occurs.

The primary source of the nitrogen is the nitrogen in the air, although organically bound nitrogen in fuel also plays a role. Formation of nitrogen oxides depends on the combustion-chamber intake temperature, the combustion-chamber intake pressure, the amount of time that hot gases remain in the combustion chamber and the local equivalence level of the fuel/air mixture. Aircraft engines can be divided into different type groups, in keeping with the range of different technologies that are currently in service. Three groups of engines are differentiated: engines with high / medium / low emissions levels (RAND, 2003).

At present, reliable values are available only from the ICAO database (ICAO, 2002). These values refer only to the LTO cycle, however. The cycle is used to determine whether engines comply with binding standards under international law (to date, standards have been defined for nitrogen oxides, CO, hydrocarbons and soot). The standards are certification standards, covering flight phases of specified duration and with specified thrust, as listed below (cf. Table 22).

Table 22: Reference-phase duration for engines, pursuant to ICAO

| | Taxiing | Rolling for take-off | Climbing | Approach and landing | **Total** |
|---|---|---|---|---|---|
| Thrust | 7 % | 100 % | 85 % | 30 % | - |
| Duration | 26:00 | 0:42 | 2:12 | 4:00 | 32:54 |

Derivation of cruising-flight emission factors from LTO-cycle emission factors requires correlation methods, such as the $p^3$-$T^3$ method which is used by the German Aerospace Center (Deutsche Luft und Raumfahrt Gesellschaft - DLR), and which is oriented to temperatures and pressures at the combustion-chamber intake. Engines with higher bypass ratios have slightly lower specific nitrogen-oxide emissions (DLR, 1999).

Aircraft with "high $NO_X$ emissions" were found to have average $NO_X$ emissions of about 14.5 g/kg, while those with "medium" $NO_X$ emissions have about 13.5 g/kg and engines using technologies that provide "low" specific nitrogen-oxide emissions have about 11 g/kg (refers to values in the ICAO database, i.e. applies only to the LTO cycle) (RAND, 2003). Emissions factors for $NO_X$, HC and CO, based on various different sources, are highly relevant in this context (IPCC, 1999). On the other hand, such factors are based on the base year 1992 and on forecasts for 2015.

The table below shows figures for the years 1992 and 2015 as provided by three different research institutions. All values successively provided by DLR, NASA (National Aeronautics and Space Administration) and ANCAT (Abatement of Nuisances from Civil Air Transport) refer to entire average flights, i.e. both the LTO range and cruising flight (cf. Table 23).

Table 23: $NO_X$ emission factors for 1992 and 2015, from NASA, ANCAT and DLR[6], without military air transports

| | **1992** | **2015** |
|---|---|---|
| NASA | 12,6 | 13,7 |
| ANCAT | 14,0 | 12,4 |
| DLR | 14,2 | 12,6 |

It must be remembered that the average emission factors for $NO_X$ have risen as a result of the increases, over the past few decades, in combustion-chamber pressures and temperatures. The values determined in the DLR and ANCAT scenarios are likely to have been affected by the assumption that a large percentage of engines in 2015 will have lower specific nitrogen oxide emissions, and thus the zenith in EI ($NO_X$) (emissions index = emission factor) will have been passed by then.

On the basis of 1995, an average worldwide EI ($NO_X$) of 13.0 g/kg can be assumed (UBA, 2001a). This value is based on calculations that the DLR carried out explicitly for this study, for certain flight profiles.

The following factors should be taken into account in specifying EI ($NO_X$):

- The mean estimate for 1992 is 13.6, while that for 1995 is 13.0.
- The EI($NO_X$) has increased with respect to 1992, as a result of the increased combustion-chamber pressures and temperatures of the "average fleet". The "LTO average" of the majority of the world's current aircraft fleet is thus about 14.5 (RAND, 2003). The percentage of engines with very low specific nitrogen oxide emissions is still low.

***Consequently, a mean EI ($NO_X$) of about 14.0 g/kg can currently be assumed***. The values given in the IPCC Reference Manual (IPCC, 1996b) are considered to be too high for Germany. The primary reason for this is that the average value was determined using aircraft types (and, thus, engine types) that do not reflect the current fleet operating on intra-German routes. Furthermore, the underlying data used by the IPCC is comparatively old.

Unburned ***hydrocarbons***, along with carbon monoxide, are among the main products resulting from incomplete combustion of kerosine. Hydrocarbons are emitted primarily at low thrust levels. As engine efficiencies have improved, a process that has involved increases in combustion-chamber temperatures and pressures, the specific emission factor for unburned hydrocarbons has decreased. For example, the EI (HC) for global airline transports in 1986, for all flight phases, is given as 1.34 g/kg, while that for 1989 is 1.25 g/kg and that for 1992 is 1.12 g/kg (DLR, 1999). Studies of emitted hydrocarbons have shown that the size of hydrocarbon fractions formed in kerosine combustion decreases with increasing engine thrust. At 80 % thrust, primarily C1-C2 fractions form, while at 7 % and 30 % thrust maximum emissions of molecules with C2 and C3 fractions occur. On the other hand, at lower thrust levels, larger numbers of considerably longer hydrocarbon fractions occur. The emission factor varies considerably from thrust level to thrust level. For example, in a test run with the TF-39-1C engine, it was 18.9 g/kg at 7 % thrust and only 0.04 g/kg at 80 % thrust. The higher the thrust level, the higher the ratio of alkanes to alkenes; aromatics range between 3 and 9 %, while oxygen-containing hydrocarbons account for about 25 % (DÖPELHEUER, 2002).

In *Aviation and the Global Atmosphere, Chap. 9, Aircraft Emissions*, the IPCC lists NASA values for emission factors, for various years (all flight phases) (IPCC, 1999). The values refer to all air traffic worldwide, except for military air traffic. According to this source, in 1976 the EI (HC) was 5.1 g/kg, in 1984 it was 3.3 g/kg and in 1992 it was 2.3 g/kg. An average value of 1.0 g/kg is forecast for 2015. Since engine efficiency has been improving smoothly and continuously, without major jumps, and since the level of EI (HC) is inversely proportional to such efficiency, the average of the 1992 and 2015 values may justifiably be used as the current report value. As a result, a current EI (HC) of 1.65 g/kg is assumed for hydrocarbons with methane.

On the other hand, this includes the C1-body fraction, in addition to the larger hydrocarbon fractions. If the species in question is not a radical one, and a pure hydrocarbon is involved, this group also includes methane. To determine the methane percentage, one would have to calculate back to methane on the basis of the average load level, and of other factors – a complicated procedure due to the methodological difficulties involved. In general, therefore, no reliable scientific basis is currently available for determining EI ($CH_4$) precisely. On the other hand, the European PARTEMIS (Measurement and prediction of emissions of aerosols and gaseous precursors from gas turbine engines) project includes chromatographic studies of emitted hydrocarbon species that support conclusions regarding the emission factor of methane. The results, which will soon be published, may well make it possible to provide a more precise value.

In the mid-1990s, some measurements made with one Pratt & Whitney engine (PW 305) and one Rolls Royce engine (RB211) were published (Wiesen et al, 1994 and 1996).

Taking the available information into account, an ***emission factor of 0.04 g/kg may be assumed for methane***. Methane is already included in the aforementioned figure for hydrocarbons, however. ***The mean EI for NMVOC must thus be given as 1.61 g/kg***.

***Carbon monoxide*** results from incomplete carbon oxidation in combustion of kerosine. While the first sub-reaction involved, oxidation of carbon to carbon monoxide, is fast, the second sub-reaction, oxidation to carbon dioxide, determines the rate of the overall reaction. In combustion, part of the carbon monoxide is not completely converted.

Using a procedure similar to that used for HC, the IPCC gives an average emission factor for CO for four different years, and for all flight phases (LTO and cruising flight) (IPCC, 1999). According to the IPCC, the factor, also taking military air traffic into account, was 19.7 g/kg in 1976, 15.2 g/kg in 1984 and 11.3 g/kg in 1992. For the year 2015, NASA forecasts a value of 7.1 g/kg (IPCC, 1999). Since a continuous, largely linear decrease is also apparent in this area as well, the average of the 1992 and 2015 figures may again be taken as the current EI (CO). ***An EI figure for CO of 9.2 g/kg is thus assumed.***

Since ***carbon dioxide*** is of predominant importance among emissions, in terms of amount, care must be taken to obtain the most precise emission factor possible (DÖPELHEUER, 2002). The basis for determining the emission factor for kerosine consists of the average composition of this fuel. Kerosine consists of alkanes (about 35 % by volume), cycloalkanes (about 45 % by volume), aromatics (about 17 % by volume) and alkenes (about 1 % by volume). As a rule, the fuel's composition varies widely by region. Among the lengths of the hydrocarbon chains involved, the fraction with 11 to 12 carbon atoms predominates by amount. Taking into account kerosine's average hydrogen content, and its average mol-weight of 176 kg/mol, kerosine can be simply described via the sum formula $C_{12}H_{23}$. In complete combustion, in strict stoichiometric terms, one kg of kerosine produces 1.24 kg of water and 3.15 kg of carbon dioxide. ***The average carbon-dioxide emission factor for kerosine may thus be assumed as 3,150 g/kg.*** This value has also been confirmed in numerous publications (including IPCC, 1999).

***Nitrous oxide*** is also a product of nitrogen oxidation in the combustion chamber, and it can occur in traces. The available data for this substance is poor. The substance has also been measured in the PARTEMIS project, the results of which have not yet been published. As described above in connection with methane, in the mid-1990s measurements were published for nitrous oxide and methane, obtained during a study of a Pratt & Whitney engine (PW 305) and a Rolls Royce engine (RB211), and measured with infrared spectroscopy under various flight conditions (Wiesen et al, 1994 and 1996). These studies yielded an ***average emission factor of 0.15 g/kg for $N_2O$***. In general, it must be assumed that more $N_2O$ is produced in the combustion chamber than ammonia, since $N_2O$ is a product with a medium oxidation level. Currently, a factor of 0.1 g/kg is being used in calculations. A value of 0.32 g/kg is used in the TREMOD framework. All in all, a value of 0.15 g/kg, as given in the above publications, seems plausible.

The customary breakdown for determining the contribution made by domestic air traffic to total emissions (DESTATIS, 2002c) was obtained by allocating 80 % of determined total emissions to international air traffic. This breakdown is based on a study carried out by the

TÜV technical control association, under commission to the Federal Environmental Agency (UBA, 1989). Since then, air traffic has become more and more international, and thus the domestic share of air traffic has become relatively smaller.

The breakdown must be based on the relevant IPCC guidelines' definition for preparation of national emissions inventories. Pursuant to those guidelines, domestic air traffic includes all passenger and cargo flights that start and end on the territory of a single country. International air traffic comprises all civil air traffic that originates in other countries or that leaves the relevant country's national territory.

Domestic air travel accounted for 11.9 % of all the passengers that moved through German airports in 2002. A total of 114 million passengers were transported; of these, 13.6 million fell within the category *domestic air travel*. Including all transfer passengers, however, a total of 19.8 million passengers, or 17.4 % of all passengers, flew on intra-German routes in 2002. Under the IPCC's definitions, transfer passengers must be included, as a rule. In the area of cargo traffic, international flights accounted for 2.1 million of the total of 2.2 million t of freight transported in 2002. The national / domestic share was thus 4.5 %.

As to overall numbers of flights, in 2002 a total of 1.45 million flights were made in Germany, of which 0.339 million had destinations within Germany. This number represents a share of 23.4 %.

Another category that can be useful for calculating domestic shares of total transports, for purposes of calculating emissions, is that of seat-km (tonne-km). Here as well, no close correlation to fuel consumption may be assumed. The reasons for this include variances in fleet fuel consumption, and the relatively large fuel consumption during the LTO cycle, especially during take-off and climbing. Air freight accounted for 23.8 % of total transport performance (assuming 0.1 tkm to be equivalent to one seat-km). A total of 7.81 billion tonne-kilometers were found to have been completed in 2002. National flights accounted for 21.4 % of all passenger seat-km in 2002. The combined figure for freight and passenger km together is smaller, since most freight transports – as described above – serve international destinations.

At present, no calculation procedure is available for converting existing data into fuel-consumption figures, and no data that would support such conversion is collected; consequently, a 20 % domestic air transport share will continue to be assumed for calculation purposes. This percentage is based on the number of passengers, as a percentage of all passengers, who must be assigned to intra-German air transports (including transfers, base year 1995) (Federal Environmental Agency, 2001a). While the data on passengers, flights and seat-km for 2002 also points to this share, no correlation with fuel consumption can be derived, and such a correlation should actually be used as a calculation basis.

#### 3.1.8.4 Source-specific planned improvements (1.A.3a)

Plans call for using the emission factors derived in Chapter 3.1.8.3 in the inventory, following relevant internal consultation within the Federal Environmental Agency. For purposes of emissions reporting, the determined emission factors must be converted into the corresponding energy equivalents, taking the net calorific value of kerosine into account (cf. Table 24). The Association of the German Petroleum Industry (MWV) uses a value of 43,000

kJ/kg for this purpose (MWV, 2003). A value of 43,280 kJ/kg is provided in (DÖPELHEUER, 2002). In general, the factor factor 43,000 may be used for conversion of EI into the units [kg/TJ].

Table 24: Adjusted emission factors for civil air transports

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

## *3.1.9 Transport - road traffic (1.A.3b)*

### 3.1.9.1 Source category description (1.A.3b)

| CRF 1.A.3b | | | | | |
|---|---|---|---|---|---|
| Key source | | Gas (MSG) | 1990 – contribution to total emissions | 2002 – contribution to total emissions | **Trend** |
| Gasoline | l / t | $CO_2$ | 7,68 % | 8,15 | falling |
| Diesel oil | l / t | $CO_2$ | 4,37 % | 7,95 | rising |
| Gasoline | l / t | $CH_4$ | 0,10 % | 0,02 | falling |

| **Gas** | **$CO_2$** | **$CH_4$** | **HFCs** | **PFCs** | **$SF_6$** | **$N_2O$** | **$NO_X$** | **CO** | **NMVOC** | **$SO_2$** |
|---|---|---|---|---|---|---|---|---|---|---|
| Emissions factor[30] (EF) | CS | CS/M | - | - | - | CS/M | CS/M | CS/M | CS/M | CS/M |
| EF uncertainties in % | - | - | - | - | - | - | | | | |
| Distribution of uncertainties [31] | - | - | - | - | - | - | | | | |
| Method for EF determination[32] | T 3 | T 3 | T 3 | T 3 | T 3 | T 3 | | | | |

In terms of emissions levels and trends for the gases $CH_4$ and $CO_2$, road traffic is a key source.

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 utility vehicles and buses. For calculation purposes, the vehicle categories are broken down into so-called *vehicle layers* with the same emissions behaviour. To this end, the vehicle categories are divided by type of fuel used, vehicle size (utility vehicles / buses: weight class; passenger car / motorcycles: engine displacement) and installed pollution control equipment pursuant to EU directives on emissions legislation ("EURO norms") and traffic-location region (outside of municipalities, within municipalities, and autobahn).

Since 1990, emissions of $CH_4$, $NO_X$, CO, NMVOC and $SO_2$ from road traffic have decreased sharply, due to catalytic-converter use and engine improvements resulting from tightening of emissions laws, and due to improved fuel quality (cf. Table 25).

$N_2O$ emissions result primarily from incomplete reduction of NO to N2 in 3-way catalytic converters. They are not limited by law. Initially, growth in numbers of cars with catalytic converters caused increases in $N_2O$ emissions in comparison to the 1990 level. Newer catalytic converters are optimised to produce only small amounts of $N_2O$, however. For this reason, the decreasing trend in $N_2O$ emissions that has been observed since 2000 can be expected to continue.

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

Table 25: Road-traffic emissions, in Gg

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

### 3.1.9.2 Methodological issues (1.A.3b)

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

Non-$CO_2$ emissions are calculated with the aid of the TREMOD model ("Transport Emission Estimation Model"; IFEU, 2003b)[33]. TREMOD adopts a "*bottom-up*" (Tier 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 in keeping with the reduction technology used.

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

30 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
31 N = Normal, L = Log normal, T = Triangular, U = Uniform (even distribution)
32 D = IPCC default, RA = Reference approach, T1= IPPC tier 1, T1a/ T1b/ T1c = IPPC tier 1a/ 1b/ 1c, T2 = IPPC tier 2, T3 = IPPC tier 3, C = CORINAIR, CS = Country-specific, M = Model
33 To permit derivation and evaluation of reduction measures, TREMOD is also used to calculate the energy consumption and $CO_2$ emissions of the individual vehicle categories. The values are subsequently aligned with total consumption and total emissions of $CO_2$.

| | Without pollution-control equipment | With pollution-control equipment |
|---|---|---|
| Passenger cars / light commercial vehicles with petrol-burning engines | without regulated catalytic converter | with regulated catalytic converter |
| Passenger cars / light commercial vehicles with diesel engines, buses, heavy commercial vehicles, motorcycles | prior to Euro 1 | after Euro 1 |

For calculation with TREMOD, extensive basic data from generally accessible statistics (DIX, OJ and the Federal Motor Transport Authority (Kraftfahrt-Bundesamt) and special surveys was used, co-ordinated, and supplemented as necessary. An overview of the principal sources and key assumptions is given below. Detailed descriptions of the databases, including information on the sources used, and the calculation methods used in TREMOD, are provided in the aforementioned IFEU report.

#### *3.1.9.2.1 Real data for the years 1990-2000*

This real data refers to:

- Motor-vehicle ownership:
  For West Germany from 1990 to 1993, and for Germany as a whole from 1994, car ownership was calculated on the basis of the ownership and new registration statistics of the Federal Motor Vehicle Agency (KBA). The car ownership analysis for East Germany in 1990 was based on a detailed analysis of the Adlershof car-emissions-testing agency in 1992 and the time series in the statistical annuals of the GDR. For the period between 1991 and 1993, it was necessary to estimate the figures with the aid of numerous assumptions.
- Emission factors:
  All emission factors are listed in the "Manual of road-traffic emissions 1.2" ("Handbuch für Emissionsfaktoren des Straßenverkehrs 1.2") (INFRAS, 2003). This manual was prepared in the framework of co-operation between Germany, Switzerland and Austria in derivation of emission factors for road traffic. The emission factors in the manual originate predominantly from the measurement programmes of TÜV Rheinland (TÜV = Technical Control Association) and RWTÜV. These include fundamental surveys for the reference years 1989/1990. In these surveys, a new method was used, for both passenger cars and heavy goods vehicles, whereby emission factors were derived according to driving conduct and the traffic situation. Within the context of field monitoring data, the passenger car emission factors were updated for cars produced up to 1994. The emission factors of more recent vehicle layers (EURO II-IV) were derived jointly by experts from the automotive industry (VDA) and from scientific institutes and environmental agencies of the aforementioned Länder. In the framework of cooperative preparation of a new version of the manual (cf. Chapter 3.1.9.6), experts from the Netherlands have also participated.
- Mileage:
  The principal source is the time series of mileage of individual vehicle categories which is published continuously in "*Verkehr in Zahlen*" ("Traffic in Figures") (DIW, 2002). In differentiated mileage surveys conducted on behalf of the Federal Ministry of Transport for the years 1990 and 1993, special TREMOD requirements were taken into account: For example, the breakdown of mileage according to vehicle types and

road characteristics 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.

#### *3.1.9.2.2 Projections for 2001 and 2002*

This real data refers to:

- Development of road traffic figures:
  The total fleet figures for 2001 and 2002 were derived with the help of a relayering model implemented within TREMOD. On the basis of the development of the past years, numbers of new registrations, and the various vehicle layers' shares of the new registrations, were estimated. On the basis of the total fleet size for 2000, and using survival probabilities derived from historical data and from assumptions regarding vehicle lifetimes, the vehicle fleet was broken down by type of engine, vehicle size and type of pollution-control equipment.
- Emission factors:
  The emission factors are derived from the development in the numbers of vehicles within the individual vehicle layers. The emissions reduction achieved from the introduction of sulphur-free fuels was estimated by the Federal Environmental Agency.
- Mileage:
  Mileage was updated based on the medium-term forecast made by Prognos AG in the summer of 2002.

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

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

### 3.1.9.4 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 3.5 % and 7.0 % were calculated in the period 1994-2002. The deviations for diesel-fuel consumption ranged between 3.4 % and 10.3 %.

### 3.1.9.5 Source-specific recalculations (1.A.3b)

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

- Inclusion of emissions from operation of LP-gas-powered motor vehicles
- Assignment of relevant petroleum consumption to the "buses" vehicle category (instead of distribution among all diesel vehicles)
- Comparison of petrol and diesel-fuel consumption in 2001 with the preliminary Energy Balance 2001 (so-called "evaluation table") that is now available

The resulting differences in the 1990-2001 time series, in comparison to the relevant figures from the previous reporting year, are no more than 1.2 %. The reasons for the larger differences that occur in the time series for $N_2O$ (max. of 25 %) is that in the previous year

the TREMOD data was transferred into the CSE largely manually, and thus, clearly enough, transfer errors were made in this time series.

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

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

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

### *3.1.10 Transport – other transportation (1.A.3e)*

#### 3.1.10.1 Source category description (1.A.3e)

| **CRF 1.A.3e** | | | | |
|---|---|---|---|---|
| Key source | Gas (MSG) | 1990 – contribution to total emissions | 2002 – contribution to total emissions | **Trend** |
| Liquid fuels | $CO_2$ | 0,29 % | 0,29 % | falling |

| **Gas** | **$CO_2$** | **$CH_4$** | **HFCs** | **PFCs** | **$SF_6$** | **$N_2O$** | **$NO_X$** | **CO** | **NMVOC** | **$SO_2$** |
|---|---|---|---|---|---|---|---|---|---|---|
| Emissions factor[34] (EF) | | | | | | | | | | |
| EF uncertainties in % | | | | | | | | | | |
| Distribution of uncertainties [35] | | | | | | | | | | |
| Method for EF determination[36] | | | | | | | | | | |

In terms of its $CO_2$-emissions levels in 1990, the "other transportation" source category is a key source.

Emissions from rail traffic, coastal and inland shipping, domestic air transports and "other" forms of transport are reported under this category.

#### 3.1.10.2 Methodological issues (1.A.3e)

For all the above areas, emissions are calculated as the product of the fuels consumed and region-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.

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

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

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 travelled).

### *3.1.11 Other sectors (1.A.4)*

#### 3.1.11.1 Source category description: Households, small consumers, agriculture, forestry and fishing (1.A.4)

| CRF 1.A.4a (Commercial/Institutional) | | | | | |
|---|---|---|---|---|---|
| Key source | | Gas (MSG) | 1990 – contribution to total emissions | 2002 – contribution to total emissions | **Trend** |
| CRF 1.A.4a Commercial/institutional | | | | | |
| Gaseous fuels | l / t | $CO_2$ | 1,09 % | 2,52 % | rising |
| Liquid fuels | l / t | $CO_2$ | 2,19 % | 1,96 % | falling |
| Solid fuels | t | $CO_2$ | 1,68 % | 0,12 % | falling |
| CRF 1.A.4b (Residential) | | | | | |
| Gaseous fuels | l / t | $CO_2$ | 2,54 % | 5,59 % | rising |
| Liquid fuels | l / t | $CO_2$ | 4,50 % | 5,77 % | rising |
| Solid fuels | t | $N_2O$ | 0,03 % | 0,00 % | falling |
| Solid fuels | t | $CO_2$ | 3,32 % | 0,29 % | falling |
| CRF 1.A.4c (Agriculture/Forestry/Fisheries) | | | | | |
| Liquid fuels | l | $CO_2$ | 0,65 % | 0,57 % | falling |
| Solid fuels | t | $CO_2$ | 0,38 % | 0,01 % | falling |

| **Gas** | **$CO_2$** | **$CH_4$** | **HFCs** | **PFCs** | **$SF_6$** | **$N_2O$** | **$NO_X$** | **CO** | **NMVOC** | **$SO_2$** |
|---|---|---|---|---|---|---|---|---|---|---|
| Emissions factor[37] (EF) | CS | CS | NO | NO | NO | CS | CS | CS | CS | CS |
| EF uncertainties in %<br>- liquid fuels | | -25/<br>+50 | - | - | - | ± 35<br>% | | | | |
| EF uncertainties in %<br>- gaseous fuels | | -50 /<br>+100 | - | - | - | ± 35 | | | | |
| EF uncertainties in %<br>- solid fuels | | -50/<br>+100 | - | - | - | ± 50 | | | | |
| Distribution of uncertainties [38] | | L | - | - | - | N | | | | |
| Method for EF determination[39] | | Tier 2 | - | - | - | Tier 2 | | | | |

In source categories CRF 1.A.4a (commercial/institutional), CRF 1.A.4b (residential) and CRF 1.A.4c (agriculture/forestry/fisheries), source category 1.A.4, depending on the fuel group and pollutant involved, is a key source in terms of emissions levels and trends.

Source group 1.A.4 (other sectors) includes combustion systems in the areas *residential*, *commercial and institutional* and agriculture. The present report assigns these areas to the category of households and small consumers, since the areas include all private households, a great variety of different small-consumer groups and trade/crafts groups (metal, wood, construction trades), commerce and services, agriculture and horticulture and public institutions, but do not include groups that can be assigned to the areas of energy transformation or industry.

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

The group of combustion systems in the households and small consumers segment is very diverse with regard to installation design and size. It covers a spectrum that includes individual room furnaces for solid fuels with a rated thermal output of approximately 4 kW (e.g. fireplaces, ovens), oil and gas furnaces used to generate room heat and hot water (e.g. central heating boilers), hand-fed and automatically fed wood-burning furnaces in the commercial sector and small consumers' licensable combustion systems with a rated thermal output of several megawatts, to name but a few examples. All in all, as of 1995 over 41 million combustion systems were in place in the households and small consumers sector in Germany, while as of 2000 over 36 million such installations were in place (UBA, 2000a p. 42; UBA, 2003d p. 10). Combustion systems for solid fuels accounted for a majority of these systems, or some 14.6 million, while the group of gas-fired furnaces accounted for some 13.5 million systems and that of oil-fired furnaces accounted for some 7.9 million. The great majority of these systems (over 95%) is in place in private households (UBA, 2000a and UBA, 2003d).

#### 3.1.11.2 Methodological issues (1.A.4)

Source group 1.A.4 is based on the Energy Balance for Germany prepared by the Working Group on Energy Balances (lines 66 and 67; AGEB). For this source category, additional information from other energy balances (Federal Ministry of Defence; AGEB, 2002), along with correlation rules from an existing study (UBA, 2000a), is also required, however. With the information described, the energy balance data is further broken down and, in part, regrouped.

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

The basis for determining activity rates is the final energy consumption shown in the Energy Balance, lines 66 and 67, for households, commerce, trade services and other consumers, broken down by fuels. Since the figures in Energy Balance line 67 (commerce, trade, services and other consumers) also include consumption by military agencies, these figures must be deducted from the relevant positions in line 67 (cross-reference to source category 1.A.5.a: that section describes the stationary sources in the military sector).

The database for the emission factors used consists of UBA, 2000a. Within the context of this project, device-related and source-category-specific emission factors for combustion systems in the area of households and small consumers were calculated, with a high level of detail, for all important emissions components for the reference year 1995.

Determination of emission factors is based on a source-category-specific "bottom-up" approach that, in addition, to differentiating (sub-) source categories and fuels, also differentiates system technologies in detail. In this procedure, mean emission factors for the entire group of systems within the source categories considered are generated via aggregation of a number of different system-specific emission factors; the system-(group)-specific emission factors take into account all important technical aspects of combustion in typical systems in the various relevant individual groups. This procedure corresponds to the Tier 2 method of the IPCC Good Practice Guidance (GPG) rules.

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

- Fuel oil EL
- Fuel oil S/SA
- Natural gas
- Lignite (crude lignite, briquettes from the Rhine, Lausitz and central German regions, imported briquettes)
- Hard coal (coke, briquettes, anthracite) and
- Wood (natural wood, residual wood)

and according to the device design, age level, output category and typical mode of operation of the combustion 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 Execution of the Federal Immission Control Act (*BImSchV*) (Ordinance on small and medium-sized combustion systems) and licensable installations that are subject to the requirements of the Technical Instructions in Air Quality Control (Clean Air Directive - *TA Luft*).

The description of the plant structure for installed furnaces was prepared using statistics on residential and other buildings, statistics from the chimney-sweeping trade, and surveys by the researchers themselves in selected chimney-sweep districts of Baden-Wuerttemberg, North-Rhine Westphalia and Saxony. The emissions behaviour of the combustion systems in question was determined via a comprehensive review of the literature, in an approach that distinguished between results from test-bench studies and field measurements. Supplementary to this, experiments were conducted on furnaces using solid fuels, both on the test bench and via measurements in the field. 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 emission factors is documented schematically in the aforementioned research project.

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

A complex procedure is required to calculate reliable emission factors in this plant sector. In addition to emission figures, other information must be obtained, e.g. in order to make allowance for the relevant mode of operation (loads), plant structure and device-specific final energy consumption. In data surveys during the aforementioned research and development project, this approach was for the most part followed; nevertheless, given the sheer number of plants concerned and the wide range of combustion systems and fuels used, the data must be assumed to have a fairly large "basic uncertainty".
For some plant types, moreover, only inadequate data or no data at all was available on emissions behaviour when using certain fuels. In this respect, it is important to bear in mind that for furnaces belonging to 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.

The uncertainties listed for the emission factors for $CH_4$ and $N_2O$ (cf. the table above) were determined via experts' assessment pursuant to Tier 1 of the IPCC-GPG rules (Chapter 6; IPCC, 1996). This assessment, which is based on the emissions data obtained for the aforementioned research project, was carried out by experts from the Federal Environmental Agency, in co-operation with the University of Stuttgart's Institute of Process Engineering and Power Plant Technology (Institut für Verfahrenstechnik und Dampfkesselwesen - IVD). The following sources of error entered into the estimate for $N_2O$ and $CH_4$ :

- Meauring errors in determination of pollutant concentrations;
- Uncertainties in estimating transfer factors (systematic differences between test-bench and field measurements);
- Uncertainties resulting from having too little emissions data;
- Uncertainties resulting from use of different measuring procedures;
- Uncertainties in the plant data used (overall group structure in terms of type, age and performance and fuel consumption)

For all of these influencing factors, it provided useful to differentiate between systems burning liquid and gaseous fuels and systems burning solid fuels. All uncertainties, with the exception of the measuring error in $N_2O$ measurement, must be considered greater for systems burning solid fuels than for systems burning liquid or gaseous fuels. One reason for this is that the group of solid fuels comprises many different fuels, with different emissions behaviours (e.g. various types of lignite, hard coal and wood, from various different origins and with various different characteristics); in systems burning gaseous or liquid fuels, on the other hand, almost all emissions result from use of natural gas or light heating oil.
In gas-fired systems in particular, another error occurs in determination of start/stop emissions. During start-up/shutdown procedures, some partly unburned $CH_4$ is emitted from natural gas. These emissions depend strongly on the manner in which the systems are operated (frequency of start-ups/shutdowns). The $CH_4$ emission factors for gas-fired combustion systems are thus subject to large uncertainties.

As to the distribution of uncertainties, in a first approximation, a normal distribution is assumed for $N_2O$ emission factors. Given the considerably larger uncertainties for $CH_4$ (up to 100%) in comparison to those for $N_2O$, on the other hand, it must be assumed that deviations toward larger values in this area are considerably more pronounced than those toward smaller values. For this reason, a log-normal distribution must be assumed for $CH_4$, for all fuels.

In the aforementioned research project, the emission factors for $CH_4$ and $N_2O$ were determined in five-year steps for the period 1995 (reference year) through 2020. With this approach, no changes result for most of these emission factors for the period until 2002. The $CH_4$ emission factors were forecast to decrease slightly only in the area of use of some solid fuels (lignite, wood). This is due primarily to modernisation of existing systems (replacement of old systems with new systems with lower emissions) and, in part, to changes in fuel-consumption structures (sharply decreasing use of eastern German lignite since 1990). In a good approximation, constant emission factors for this period may be assumed for $N_2O$, which is largely fuel-dependent in small combustion systems.

The time series from 1995 to 2002 for the $CH_4$ and $N_2O$ emission factors was reviewed in this light and assessed as consistent overall (remark: existing, smaller gaps in CSE time series, for certain "special fuels", such as crude lignite and city gas, have no influence on total

emissions, due to the small amounts of these fuels that are consumed). Source-specific review, with possible recalculation of emission factors, remains to be carried out for $CH_4$ and $N_2O$ for the period 1990 to 1995 (cf. Chapter 3.1.11.5).

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

For the purposes of quality assurance, in the context of the aforementioned research and development project, all the input data used from literature and from the research company's own investigations was examined with a view to validity. The review included comparisons with confirmed data and plausibility checks. As a general principle, when describing the emissions behaviour of combustion systems, emissions data was included in subsequent calculations only if the relevant literature sources contained complete, undisputed data on the fuel used, the design of the furnace, and the furnace's operating mode during measurements. Records were kept, by the research company, of all key materials used for inventory preparation (UBA, 2000a).

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

Furthermore, data was compared with that for Austria, whose plant and fuel-consumption structures are similar to those of Germany (Ritter et al, 2001). The results included good agreement of emission factors, with lower discrepancies overall than seen in the default-value comparison.

### 3.1.11.5 Source-specific recalculations (1.A.4)

A source-specific review of emission factors for $CH_4$ and $N_2O$ showed that the relevant time series are consistent for the period 1995 to 2002 (cf. Chap. 3.2.10.3). Source-specific review, along with any then necessary recalculation of emission factors for $CH_4$ and $N_2O$, has not yet been completed for the time between 1990 and 1995. It may be assumed, however, that the emission factors for the pollutants in question decreased markedly in this period for all types of combustion. This is due to modernisation and replacement of considerable numbers of existing systems, especially in the new federal Länder; furthermore, considerable changes in fuel-consumption structures occurred in the area of solid fuels.

### 3.1.11.6 Source-specific planned improvements (1.A.4)

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

Review, and possible revision, of emission factors for the time period between 1990 and 1995 is planned for next year.

### *3.1.12 Comparison with the $CO_2$ reference procedure*

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

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

#### 3.1.12.1 Methodological issues

The basic principle of the reference approach is to produce an aggregated carbon balance for the energy sector. The quantity of carbon emitted from the energy sector (per annum) is then calculated as the difference between the quantities of carbon input and output with the energy resources (cf. Figure 19).

The carbon inputs are linked to imports of primary energy resources (such as petroleum, natural gas) and secondary energy resources (e.g. heating oil, motor gasoline, coke) and to domestic production of primary energy resources. Carbon outputs are linked to exports of primary and secondary energy resources and bunkering (fuel consumption by marine shipping and international air traffic). The reference approach therefore includes adjustments to the carbon balance to allow for non-emissions-relevant quantities of carbon. These take account of carbon output in combustion residues containing carbon (*fraction of carbon oxidised)* and long-term-fixed carbon in downstream products from the non-energy-related consumption of energy resources (*fraction of carbon stored*; e.g. use of naphtha in plastics production).

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

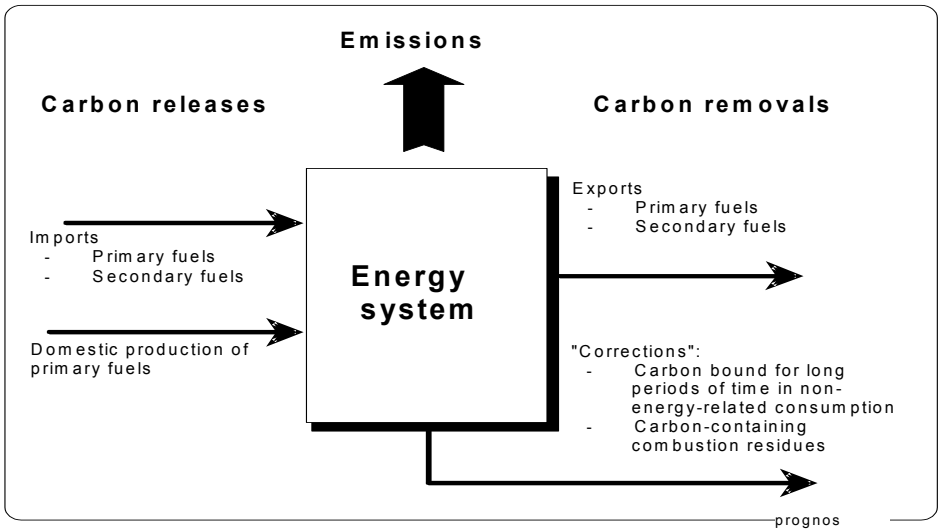



Figure 19: Basic principle of the IPCC reference procedure (Prognos, 2000)

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

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

#### *3.1.12.1.1 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, rich coal, forge coal, lean coal and anthracite coal. The same breakdown is also used when applying the IPCC approach. However, as this system differs from the IPCC classification of hard coal ("*bituminous coal*") into anthracite, coke coal and others, only one collective category, *bituminous coal*, is shown in the IPCC tables. Differentiated calculation for domestic production, by types of coal, is carried out in a special calculation.

The same applies to hard coal imports: imported coal has different characteristic values, depending on its country of origin. Based on the foreign trade statistics of the Federal Statistical Office and 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.

#### *3.1.12.1.2 Lignite*

The IPCC procedure only envisages one category in this area, "*lignite*". In order to make allowance for the particular significance of lignite in Germany, 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 coal-mining-industry statistics.

- Amongst imports, a distinction is made between lignite and hard lignite (Czech Republic), in keeping with the Energy Balance.
- Exports and stock changes are not further differentiated and are taken from the data in the Energy Balance.

#### *3.1.12.1.3 Natural gas*

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

#### *3.1.12.1.4 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 %.[40] 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, in applying the IPCC Reference Approach for calculating the carbon content in crude oil imports, a special calculation was envisaged and implemented on the basis of principal importing countries and qualities as well as oil fields (analogous to the procedure for hard coal and natural gas). The quantities given (crude oil imports on the basis of production regions and types) are not published, but may be obtained from the industry association, *Association of the German Petroleum Industry* (MWV), in Hamburg. There is no data available on the carbon content of the individual crude oil types, since this does not represent a relevant factor in petroleum processing. Nevertheless, there is an empirical correlation between the specific weight of petroleum and its carbon content (MARLAND et al, 1983). The carbon content of the individual crude oil types has been estimated on the basis of this correlation and of published data on specific gravity ("API Gravity"[41]).

### 3.1.12.2 Databases

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

**Energy data:** Energy data is based on the currently available (1990 to 1999) energy balances of the Working Group on Energy Balances (AGEB). As these balances are not yet available for the years 2001 and 2002, we were unable to apply the Reference Approach

40) The global average is approximately 84.5 %.
41) The specific weights are available for all varieties, with the exception of Russian oil (OIL & GAS JOURNAL DATA BOOK 1997). Average values were used for Russian petroleum.

here. A review, carried out in 2003, of application of data in the promptly published evaluation tables for the Energy Balance turned up no potential for improvement, since this data is available only a form aggregated for all fuel groups, and since data on changes in existing systems, and on the inport-/export-related substance streams for fuels – a key component of the reference procedure – will be published only with the detailed Energy Balance.

For the main primary fuels of petroleum, natural gas, hard coal and lignite, in the Reference Procedure a further differentiation is made on the basis of type or geographical origin. Data obtained from the energy statistics of the respective associations is used for this purpose.

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

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

#### 3.1.12.3 Results

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

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

Around 2/3 of these deviations are attributable to differences in the emission factors or average carbon contents of the energy resources, which cannot be calculated as precisely with the Reference Approach as with the source-category-specific approach. The remainder of the deviations are attributable to systematic differences between the two methods at the level of underlying energy consumption – specifically, in consideration of non-energy-related consumption, waste incineration, statistical differences and losses in the transformation sector of the energy system, including energy consumption by natural-gas-pipeline compressors (cf. Figure 20).

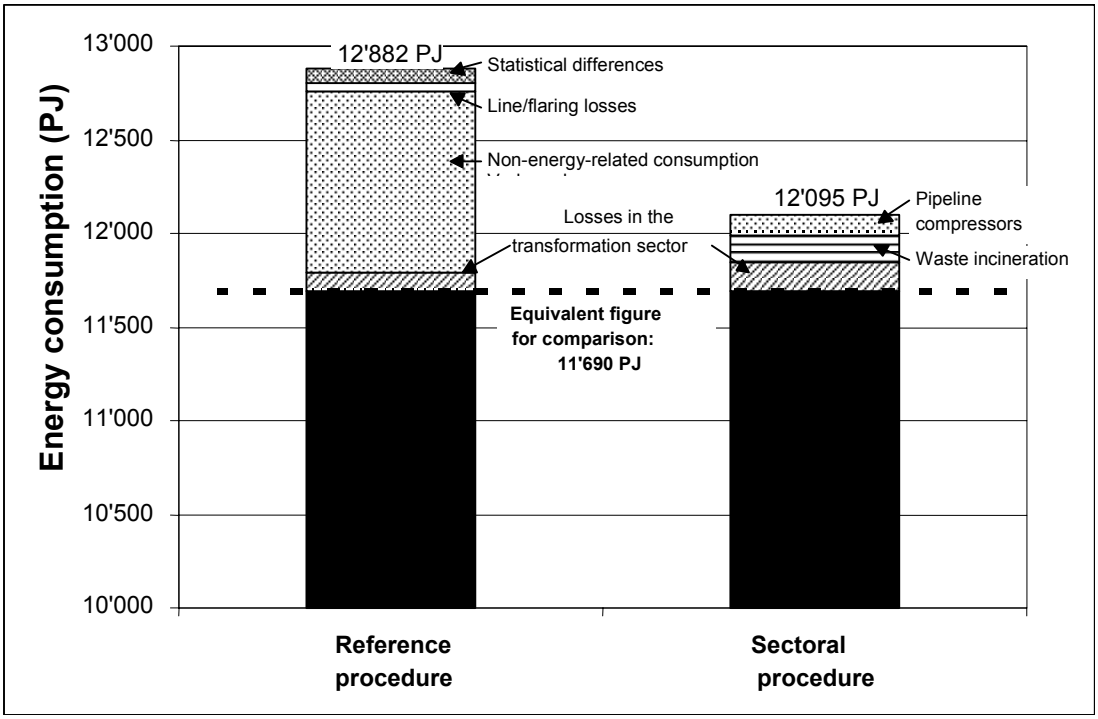



Figure 20: Systematic differences between the reference approach and the source-category-specific approach (1990)

### 3.1.12.4 Planned improvements

In Germany, as well as in most other countries where coal is highly significant as an energy resource, 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.

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

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

### *3.1.13 Emissions from international transports*

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

The activity rates for international marine bunkers may be taken directly from the Energy Balance. The reason why this energy-consumption data is listed separately is that fuel purchased in ports is taxed differently.

In the area of international air-traffic emissions, no official breakdown is available, within the framework of German energy statistics, of relevant amounts of fuel consumed. Here, total fuel taxes on aircraft fuels are recorded under domestic sales. One distinction is made in that in the time series this fuel consumption data is broken down consistently, into 20 % for domestic aviation and 80 % for international aviation. This ratio, which initially was an experts' estimate, has since been confirmed as a conservative estimate within the context of a research project for the year 1996 (cf. Chapter 3.1.8.2.). Overall, this estimate must be considered to be very conservative, since it breaks down the strong growth in air transports into consistent shares for national and international air transports. In actual practice, this strong growth, over the last 12 years, has most likely taken place very predominantly in the international air transports sector.

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

### *3.1.14 Bunkering*

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

### *3.1.15 Military*

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

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

### *3.1.16 Quality assurance / control and verification (1.A)*

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

This is achieved by comparing the calculation results with data:

- from EUROSTAT
- from IEA (source-category-specific procedure and Reference Procedure)
- from the $CO_2$ calculations performed at *Länder* level.

Table 26 presents the results of the various $CO_2$ calculation approaches for comparison. For visualisation purposes, the data is also presented graphically, on a comparative basis over time, in Figure 21. This approach reveals the key development trends in all calculation approaches, including the Reference Approach, albeit at differing levels. In order to illustrate these level differences, the relative deviations in the data records created by the varying calculations are also depicted.

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

## CO2 EMISSIONS COMPARISON: UNFCCC INVENTORY AND VARIOUS INDEPENDENT RESULTS

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **DIW results** | **986,8** | **951,1** | **902,9** | **893,0** | **877,2** | **872,4** | **896,4** | **864,5** | **855,7** | **828,7** | **830,7** | **849,1** | **833,6** |
| **Deviation of DIW results from UBA** | -0,2 | -0,3 | -0,3 | -0,3 | -0,4 | -0,4 | -0,4 | -0,4 | -0,5 | -0,4 | -0,5 | -0,2 | -0,9 |
| **EUROSTAT** | 943,0 | 918,5 | 877,1 | 870,2 | 857,6 | 863,3 | 870,1 | 827,8 | 824,2 | 802,3 | NE | NE | NE |
| **Deviation of EUROSTAT results from UBA** | -4,9 | -3,8 | -3,2 | -3,0 | -2,7 | -1,5 | -3,4 | -4,9 | -4,3 | -3,7 | NE | NE | NE |
| **IEA Statistics, Sectoral Approach** | 964,1 | 941,5 | 892,6 | 884,9 | 871,8 | 870,0 | 908,4 | 879,7 | 861,9 | 830,7 | 833,0 | NE | NE |
| **Deviation of IEA results from UBA** | -2,6 | -1,3 | -1,5 | -1,3 | -1,0 | -0,7 | 0,9 | 1,3 | 0,3 | -0,2 | -0,2 | NE | NE |
| **IEA Statistics, Reference Approach** | 968,7 | 937,5 | 897,5 | 883,7 | 870,7 | 870,4 | 895,5 | 870,4 | 863,6 | 826,3 | 820,1 | NE | NE |
| **Deviation of IEA RA results from UBA** | -2,1 | -1,7 | -0,9 | -1,4 | -1,1 | -0,7 | -0,5 | 0,3 | 0,4 | -0,7 | -1,8 | NE | NE |
| **Deviation of IEA RA results from UBA RA** | -5,2 | -4,7 | -4,1 | -4,6 | -4,2 | -2,9 | -3,1 | -2,5 | -2,0 | -2,5 | NE | NE | NE |
| **Results of German Länder** | | | | | | | | | 906,5 | 901,8 | NE | NE | NE |
| **Deviation of German Länder results from UBA** | | | | | | | | | 2,7 | 5,1 | NE | 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) | NE (5) |
| **Deviation of RA results from UBA** | 2,9 | 2,8 | 3,1 | 3,1 | 2,9 | 2,2 | 2,5 | 2,7 | 2,4 | 1,7 | NE (5) | NE (5) | NE (5) |

| GREENHOUSE GAS SOURCE AND SINK CATEGORIES | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (Gg) | | | | | | | | | | | | |
| **1. Energy** | **988.859,2** | **953.634,4** | **905.592,8** | **896.073,9** | **880.359,2** | **876.060,4** | **900.109,3** | **868.129,2** | **859.727,0** | **832.139,0** | **835.011,1** | **850.617,8** | **841.417,5** |
| A. Fuel Combustion (Sectoral Approach) | 988.859,2 | 953.634,4 | 905.592,8 | 896.073,9 | 880.359,2 | 876.060,4 | 900.109,3 | 868.129,2 | 859.727,0 | 832.139,0 | 835.011,1 | 850.617,8 | 841.417,5 |
| 1. Energy Industries | 413.944,9 | 401.073,7 | 378.992,2 | 368.922,8 | 365.659,9 | 355.210,9 | 360.843,5 | 342.847,1 | 345.118,9 | 331.377,0 | 344.171,0 | 349.400,3 | 356.788,2 |
| 2. Manufacturing Industries and Construction | 196.315,0 | 172.612,3 | 159.331,4 | 147.573,2 | 149.298,3 | 149.911,0 | 144.167,4 | 144.165,6 | 138.562,0 | 135.440,9 | 135.611,8 | 132.869,0 | 132.032,7 |
| 3. Transport | 162.359,6 | 165.953,5 | 171.660,9 | 176.532,6 | 172.898,8 | 176.563,4 | 176.661,2 | 177.158,9 | 180.426,6 | 186.066,6 | 182.348,6 | 178.224,1 | 176.387,6 |
| 4. Other Sectors | 204.413,8 | 205.529,6 | 189.183,2 | 197.903,7 | 187.747,9 | 190.346,4 | 215.266,6 | 200.904,7 | 192.551,0 | 176.630,9 | 170.512,0 | 188.199,2 | 174.261,6 |
| 5. Other | 11.826,0 | 8.465,4 | 6.425,1 | 5.141,6 | 4.754,2 | 4.028,7 | 3.170,6 | 3.053,0 | 3.068,5 | 2.623,6 | 2.367,7 | 1.925,2 | 1.947,3 |
| B. Fugitive Emissions from Fuels | NE | 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 | NE |
| 2. Oil and Natural Gas | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE | NE |
| **2. Industrial Processes** | **26.713,2** | **23.833,7** | **24.305,2** | **24.112,9** | **25.704,1** | **25.417,9** | **23.683,1** | **24.293,4** | **24.773,8** | **25.142,1** | **25.261,5** | **23.646,0** | **22.699,3** |
| A. Mineral Products | 23.511,4 | 21.330,6 | 21.945,1 | 21.885,1 | 23.494,7 | 22.816,9 | 21.104,6 | 21.733,1 | 22.152,0 | 22.554,0 | 22.546,2 | 20.943,8 | 19.961,0 |
| B. Chemical Industry | 2.190,2 | 1.559,9 | 1.535,8 | 1.473,2 | 1.521,9 | 1.815,0 | 1.791,1 | 1.778,4 | 1.785,2 | 1.721,4 | 1.835,0 | 1.811,0 | 1.845,6 |
| C. Metal Production | 1.011,6 | 943,2 | 824,3 | 754,6 | 687,6 | 786,0 | 787,4 | 781,9 | 836,6 | 866,7 | 880,3 | 891,3 | 892,7 |
| D. Other Production | NE | 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 | NO |
| **3. Solvent and Other Product Use** | **NE** | **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** | **NE** |
| **5. Land-Use Change and Forestry (3)** | **7.515,2** | **6.904,4** | **6.477,4** | **6.441,9** | **5.699,3** | **5.652,9** | **5.687,0** | **5.750,8** | **5.925,3** | **5.900,9** | **14.097,0** | **13.808,5** | **13.906,5** |
| **6. Waste** | **0,0** | **0,0** | **0,0** | **0,0** | **0,0** | **0,0** | **0,0** | **0,0** | **0,0** | **0,0** | **0,0** | **0,0** | **0,0** |
| **7. Other *(please specify)*** ... | **NO** | **NO** | **NO** | **NO** | **NO** | **NO** | **NO** | **NO** | **NO** | **NO** | **NO** | **NO** | **NO** |
| **Total Emissions/Removals with LUCF (4)** | **1.023.087,7** | **984.372,5** | **936.375,4** | **926.628,7** | **911.762,7** | **907.131,2** | **929.479,4** | **898.173,4** | **890.426,0** | **863.182,1** | **874.369,7** | **888.072,3** | **878.023,3** |
| **Total Emissions without LUCF(4)** | **1.015.572,4** | **977.468,1** | **929.898,0** | **920.186,8** | **906.063,3** | **901.478,3** | **923.792,4** | **892.422,6** | **884.500,7** | **857.281,1** | **860.272,7** | **874.263,8** | **864.116,8** |
| **Memo Items:** | | | | | | | | | | | | | |
| **International Bunkers** | **19.569,2** | **18.101,4** | **17.818,2** | **19.917,2** | **19.874,7** | **20.420,4** | **21.008,8** | **22.018,2** | **22.088,4** | **23.341,7** | **24.548,4** | **24.265,2** | **24.583,0** |
| Aviation | 11.589,4 | 11.366,7 | 12.200,2 | 12.891,8 | 13.398,4 | 13.887,1 | 14.536,9 | 15.096,7 | 15.523,1 | 16.656,2 | 17.582,4 | 17.168,0 | 16.990,4 |
| Marine | 7.979,8 | 6.734,7 | 5.618,1 | 7.025,5 | 6.476,3 | 6.533,3 | 6.471,8 | 6.921,6 | 6.565,3 | 6.685,5 | 6.966,0 | 7.097,2 | 7.592,6 |
| **Multilateral Operations** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** |
| **$CO_2$ Emissions from Biomass** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** | **NE** |

(1) IEA OECD Statistics "CO2 Emissions from fuel combustion 1971 - 2000" Edition 2002, Paris
(2) AG Länderenergiebilanzen, UBA Analyse; also includes emissions from energy consumption for international transports
(3) Take the net emissions as reported in Summary 1.A of this common reporting format. Please note that for the purposes of reporting, the 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) Due to a lack of detailed figures (Energy Balance), UBA was unable to use the CO2 reference procedure for 2000 and 2001!

Table 26: Comparison of $CO_2$ inventories with other independent national and international results for $CO_2$ emissions

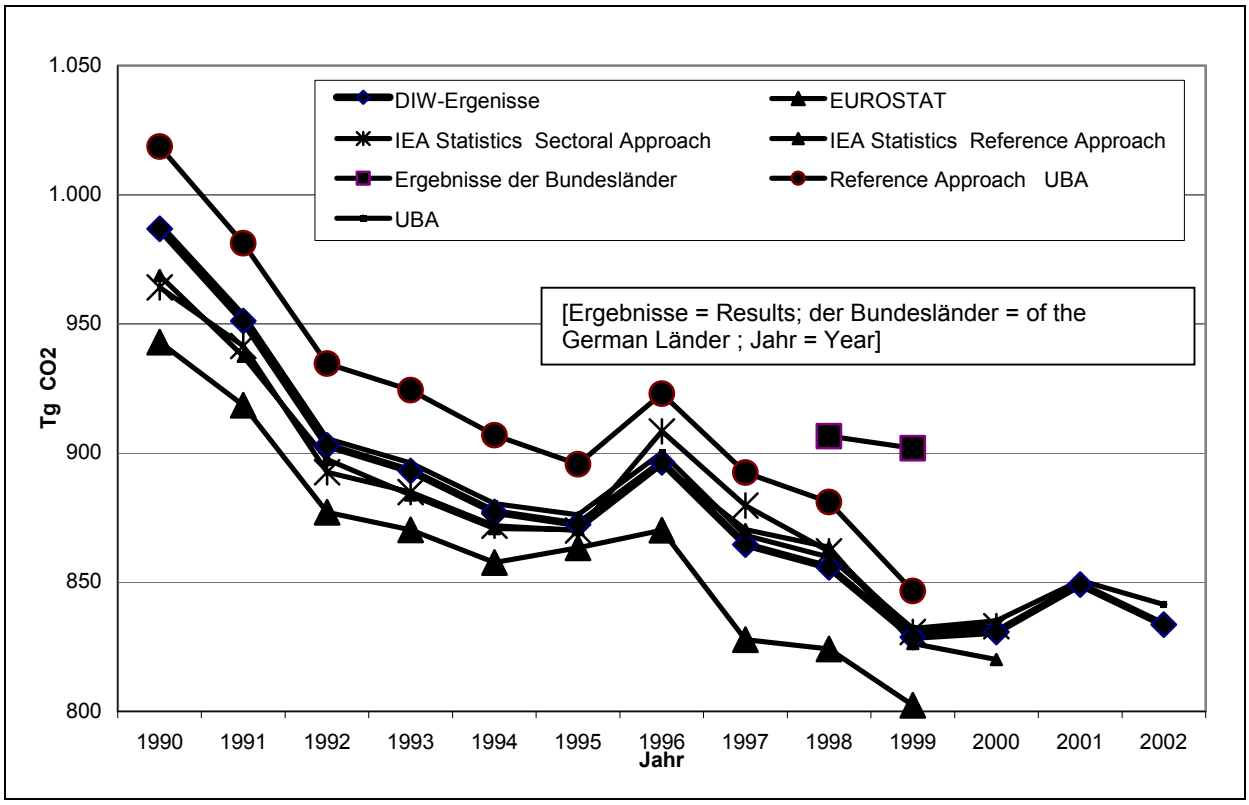



Figure 21: $CO_2$ emissions in Germany for the years 1990-2002 – Comparison of national and international calculation results

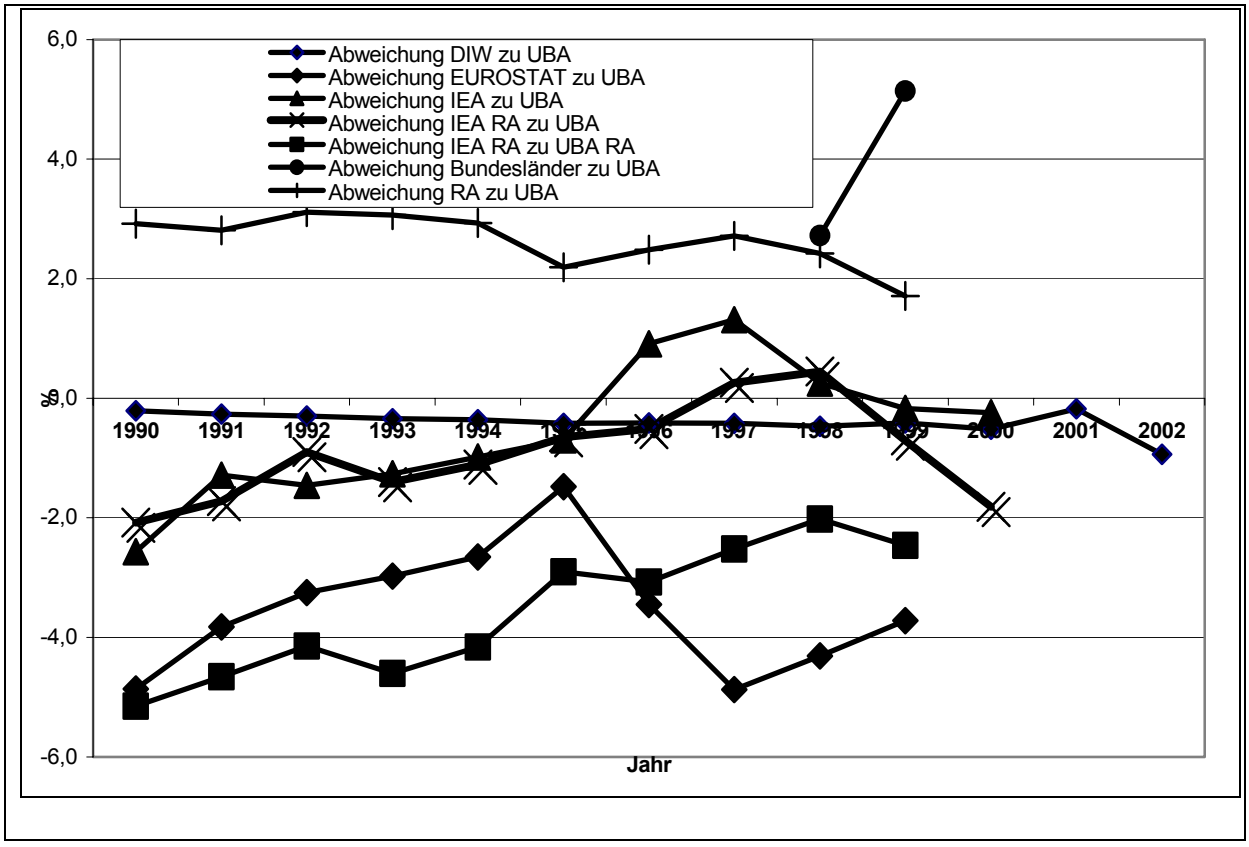



Figure 22: $CO_2$ emissions in Germany for the years 1990-2002 – Comparison of relative deviations of national and international calculation results [Abweichung = Deviation; zu = from; Bundesländer = German Länder; Jahr = Year]

#### 3.1.16.1 Comparison with the EUROSTAT results

The calculations performed by EUROSTAT deviate inconsistently, in terms of their trend, from the detailed national data (cf. Table 27). On average, the results are more than 3 % below the UBA data. The fluctuation in these 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 the German Institute for Economic Research (DIW; in Berlin) and the Ökoinstitut, to carry out a relevant research project to be co-funded by EUROSTAT itself. The initial results from this project (DIW 2002), which is not yet complete, are compiled below.

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

Specifically, the following five questionnaires are sent out:

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

Cologne, and the overall process is co-ordinated with the responsible Department at the BMWi (now the Federal Ministry of Economics and Employment, BMWA).

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

#### *3.1.16.1.1 Reasons for discrepancies in the energy data used*

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

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

Initial consequences have been drawn from problems arising in the past (cf. also chapter 3.1.16.1.2): for example, close collaboration and co-operation has since been agreed between all the parties involved, as a result of which data from the individual questionnaires will now be compiled at the BMWA in an initial provisional energy balance, prepared in close collaboration with the institutions supplying the data, the Federal Statistical Office and the Working Group on Energy Balances (AGEB), and then forwarded to EUROSTAT/IEA. This balance is essentially based on the "evaluation tables" prepared by the AGEB in which, depending on the availability of data, largely detailed information for the preceding year is compiled, in the early summer, on primary energy consumption, non-energy-related consumption and final energy consumption, by source category and energy source.

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

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

The conversion coefficients used for the net calorific values may lead to considerable differences in results, particularly where the $CO_2$ factors relate to energy units and not to natural units. As a general principle, energy balances are based on net calorific value, but 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 crude lignite can vary widely according to type and origin). Consequently, it is necessary to examine the type of data concerned and its respective sources.

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

A comparison of the amounts listed in the two energy balances revealed a number of discrepancies, some of them considerable. By way of example, Table 27 below shows the discrepancies for 1998.

Table 27: Differences between the energy balance data of EUROSTAT and of the Working Group on Energy Balances (AGEB), for the balance year 1998

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

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

Specifically, it is noticeable that there are substantial differences between the two balances for *hard coal*, primarily with regard to production, removals from stocks 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 equivalents. However, this difference diminishes considerably if values are compared in terajoules or crude-oil equivalents.

Energy sources such as tar and benzene, which are listed by the Working Group on Energy Balances (AGEB) under "*Coal derivatives*", are not considered separately by EUROSTAT. Unlike EUROSTAT, these energy sources are included in German energy balances in the calculation of primary energy consumption, and are assigned solely to non-energy-related consumption.

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

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

As well as publishing a balance in the respective units (tonnes, kWh and terajoules [TJ]), EUROSTAT also produces another balance in tonnes of crude oil equivalent – but not in terajoules – and a table of conversion coefficients. However, in the table with conversion coefficients only figures with very broad ranges are provided for major energy sources such as hard coal, lignite and crude oil. For this reason, the conversion coefficients actually used by EUROSTAT for Germany had to be derived from data in tonnes and in tonnes of crude oil 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 EUROSTAT coefficients for crude lignite, 8,840 kJ/kg, and for imports of hard lignite, 13,461 kJ/kg, both lie below the respective coefficients used by the AGEB, 8,931 kJ/kg and 14,962 kJ/kg. As a general trend, it can be asserted that the conversion coefficients used by EUROSTAT tend to be below those used by the AGEB.

#### *3.1.16.1.2 Analysis of the emission factors used*

One reason for the data discrepancies between EUROSTAT emission inventories and the national emission inventories may lie in the choice of emission factors used. To begin with, we analysed the emission factors used by EUROSTAT for the area of energy-related $CO_2$

emissions. However, as these emission factors were not explicitly available, they had to be identified by way of recalculation from jointly published energy balances and $CO_2$ inventories.

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

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

*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.*

[with; Emission factor for fuel i in energy balance sector j: $CO_2$ emissions for fuel i in energy balance sector j; energy input for fuel i in energy balance sector j; The numerical value consists of the net caloric value of 41.868 kJ per kg of crude-oil equivalents.]

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

Table 28: Results of the recalculation of emission factors, 1991-1998

| | EUROSTAT T $CO_2$/TJ | Remarks |
|---|---|---|
| Hard coal | 94 | UBA uses values from 92 to 94, depending on source category<br>– 92 for power stations and district heat stations<br>– 93 for industrial combustion plants<br>– 94 for households and small consumers |
| Hard-coal coke | 106 | UBA uses values from 100 to 105, depending on source category |
| Hard-coal briquettes | 93 | UBA uses the value 93 throughout |
| Crude lignite | 99 | UBA uses values from 110 to 113, depending on source category and origin<br>– 110 for industry, small consumers and military<br>– 111 for power stations and district heat stations and other transformation<br>– 112 for other industrial power stations<br><br>Where separate energy input data is available for the new German Länder: 113, the value for central German crude lignite, is likely to be about 100 |
| Hard lignite | No emission factor, in crude lignite | UBA uses the value 97 throughout |
| Lignite briquettes | 93 | UBA uses values from 97 to 99, depending on source category and origin<br>– 99 for power stations and district heat stations<br>– 97 for other source categories<br><br>Where separate energy input data is available for the new German Länder: |
| Lignite coke | No emission factor, allocation still unknown | UBA uses values from 96 to 111, depending on source category<br>– 96 for power stations and district heat stations<br>– 107 for industrial combustion plants<br>– 111 for other transformation and small consumers |
| Coal dust and dry coal | No emission factor, allocation still unknown | UBA uses the value 96 throughout |
| Peat | No emission factor, allocation still unknown | UBA uses the value 98 throughout |
| Crude petroleum | No emission factor, allocation still unknown | UBA uses the value 80 throughout |
| Raw gasoline | 73 | UBA uses the value 80 throughout |
| Gasoline | 69 | UBA uses the value 72 throughout |
| Diesel fuel | 73 | UBA uses the value 72 throughout as of 1991 |
| Petroleum and jet kerosine | 71 | UBA uses the value 74 throughout as of 1991 |
| Light heating oil | 73 | UBA uses the value 74 throughout |
| Heavy heating oil | 77 | UBA uses the value 78 throughout |
| Natural gas liquids | 62 | UBA uses values of 64 to 65, depending on source category |
| Refinery gas | 66 | UBA uses the value 60 throughout |
| Petroleum coke | No emission factor, allocation still unknown | UBA uses the value 101 throughout |
| Other petroleum products | 73 | UBA uses values from 78 to 80, depending on |

| | | |
|---|---|---|
| | | source category<br><br>Where separate energy input data is available for the new German Länder: |
| Coke-oven and city gas<br>Blast-furnace gas | Only in aggregated form in the EUROSTAT energy balance | UBA uses the value 44 throughout<br>UBA uses the value 105 throughout; to prevent double-counting with regard to blast-furnace processes and blast-furnace-gas combustion, blast-furnace gas is treated the same as hard-coal coke |
| Natural gas | 56 | For natural gas, UBA uses values from 55 to 56, depending on origin; for petroleum gas, it uses 58; for pit gas, it uses 55<br>Where separate energy input data is available for natural gas in the new German Länder: 55 |
| Industrial wase | Only organic industrial waste is recorded | Apart from values for special sectors, UBA uses the value 20 throughout |
| Household waste | Household waste is completely recorded, but no emission factor can be determined | UBA uses the value 15 throughout |

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

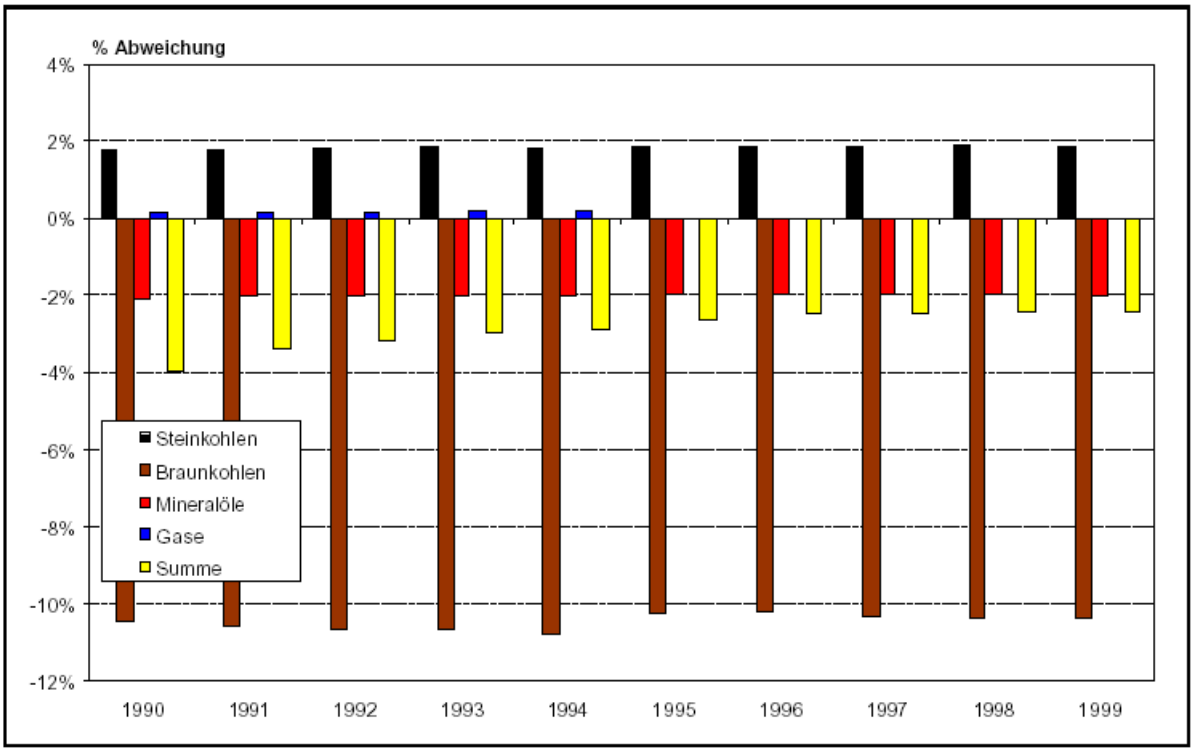
Table 28 lists the results, both in the form of an overview and in comparison to the emission factors used in the Federal Environmental Agency's inventory system.

For the area of *hard coal*, it is evident that the emission factors used by EUROSTAT are always at the top end of the range of values used by the UBA; the spread of fuel consumption (high for power generation, low for 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, the concurrence is good.

In the area of *waste incineration*, an underestimation of emissions is to be assumed, since the non-organic components of household waste are also assigned to biomass, which is listed as having a 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.

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




Quellen: EUROSTAT, UBA, Berechnungen des Öko-Instituts

Figure 23: Discrepancies via differences between UBA and EUROSTAT emission factors, by fuel category, 1990-1999 [% deviation; Hard coal; Lignite; Petroleum; Gases; Total; Sources:]

Divergences arising from differences in emission factors in the period 1990 to 1999 amount to between –39.5 million tonnes of $CO_2$ (1990) and 21.0 million tonnes of $CO_2$ (1999), based on an identical framework of input quantities (according to the German Energy Balance and previous UBA supplementation for crude lignite and natural gas). In EUROSTAT calculations, $CO_2$ emissions in Germany are therefore underestimated by between 4.0 (1990) and 2.5 percent (1999). As illustrated by Figure 23, the deviations in the individual fuel categories are considerably greater than the net balance, however.

The decisive conclusion to be drawn at this point is that harmonisation of data between EUROSTAT and German institutions should not be confined solely to basic energy data – it should be expanded to include the emission factors. There are plans for Germany to provide EUROSTAT with a complete set of emission factors representative of Germany that 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.

#### *3.1.16.1.3 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 the statistical basis for calculating $CO_2$ emissions. This applies not only to the national emissions inventory to be drawn up by the Federal Environmental Agency, but also to relevant efforts of international institutions such as EUROSTAT and IEA, insofar as they make their own calculations of emissions.
2. At present, finalised energy balances for Germany are available only 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 of time. The aim should be to present energy balances no later than 12 months after the end of the year under review.
3. Completion and submission of annual questionnaires should be better co-ordinated, also with regard to timing and content. Measures should be taken to ensure that the arrangements made by all parties for this purpose are consistently implemented. Accordingly, data from individual questionnaires should be compiled, in an initial, provisional energy balance, by the Federal Ministry of Economics and Employment (BMWA), working in close collaboration with the institutions that supply the data (the Federal Statistical Office and the AGEB), and then the data should be forwarded to EUROSTAT/IEA. The "evaluation tables" prepared by the Working Group on Energy Balances (AGEB) constitute a key element of this provisional energy balance. Data which is not yet available at this point in time should be supplemented with appropriate estimates.
4. Corrections made by the Federal Environmental Agency (UBA) to the energy balance with respect to emission-relevant quantities of fuel (lignite drying, waste and others, where applicable), should be included as a memo item in the provisional energy balance referred to in no. 3 once finalised methodological clarification has been achieved.

Emission-related recommendations comprise the following points:

5. In calculating $CO_2$ emissions, as a general principle, EUROSTAT should use the emission factors employed by the Federal Environmental Agency (UBA). To this end, aggregated emission factors should be supplied annually by the UBA – firstly, for the energy resource and sector structure of the provisional energy balance referred to under point 3., and, secondly, for the energy resource and sector structure of the published energy balance.
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 currentness status have not always been used. Any co-ordination that may be needed with EUROSTAT should be carried out as soon as possible in collaboration with the Federal Environmental Agency (and, where necessary, with the AGEB).
7. Within the scope of revision and verification of German inventories of atmospheric pollutants, the Federal Environmental Agency (UBA) should develop, as soon as possible, a methodology for differentiation of bunker fuels for international aviation, by intra-European and extra-European transports, in order to facilitate correct determination of the appropriate memo item at EU level.

As a general principle, agreement should also be reached with EUROSTAT to the effect that energy data and emission factors may be corrected retroactively to take account of changes that are irrefutably confirmed in retrospect (due to new findings). Germany, for its part, must

find a harmonisation procedure for communication of energy data and emission factors, so that a high degree of consistency can always be maintained between both sets of data. For this purpose, procedures must be precisely defined for interaction between the AGEB and the UBA, on the one hand, and between the BMU and the BMWA, on the other.

### 3.1.16.2 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 Germany at present, due to a lack of the necessary further methodological information – particularly on the detailed data used.

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

#### *3.1.16.2.1 Planned improvements*

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

### 3.1.16.3 Comparison with the data obtained for the individual Federal *Länder*

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

The principle task of this Länder Working Group is to co-ordinate 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[42].

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*; these balances are likewise prepared on the

42 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.

basis of the energy balances, according to standardised rules. Two different approaches are adopted:

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

**Consumption balance** – this refers to an account of emissions based on the final energy consumption in a given *Land*. This approach also includes the use of electricity and district heat 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 that up to 70 % of energy consumption in individual *Länder* is based on the import of electricity and district heat from other Federal *Länder*. Only with 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-related $CO_2$ 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; it thus became necessary to use appropriate techniques to close the gaps. As a general rule, these were based on the average Federal statistical trend (percentage changes) or the average values calculated for the year in question.
- 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.

Table 29: Comparison of the results of the $CO_2$ calculations of the individual Federal *Länder* with the national inventories for the year 1998

| Land | CO2 Emissions Gg | Population 1000 | PEC PJ | CO2 Emissi per capita ( |
|---|---|---|---|---|
| Baden-Württemberg | 80073 | 10397 | 1600 | 7,70 |
| Bavaria | 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 |
| Hesse | ***64515*** | 6032 | 1073 | 10,70 |
| Mecklenburg-West Pomerania | ***19336*** | 1808 | 164 | 10,70 |
| Lower Saxony | 81764 | 7845 | 1531 | 10,42 |
| North Rhine - Westphalia | 304375 | 17975 | 4054 | 16,93 |
| Rhineland Palatinate | ***42974*** | 4018 | 770 | 10,70 |
| Saarland | ***11560*** | 1081 | 276 | 10,70 |
| Saxony | 37167 | 4522 | 549 | 8,22 |
| Saxony-Anhalt | 24578 | 2702 | 448 | 9,10 |
| Schleswig-Holstein | 21433 | 2757 | 547 | 7,78 |
| Thuringia | 12729 | 2478 | 227 | 5,14 |
| **Country as a whole,** | **906486** | **82058** | **14804** | **11,05** |
| **for comparison:** | | | | |
| **National result** | 877683 | 82057,5 | 14521 | 10,70 |
| Source: | UNFCCC reporting | Federal Statistical Office | Energy Balance figures | |
| **Deviation from whole-country figure (%):** | **-3,2** | | **-1,9** | |

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 figure 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 29) and 1999 (cf. Table 30) are summarised below.

Table 30: Comparison of the results of the $CO_2$ calculations of the individual Federal *Länder* with the national inventories for the year 1999

| Land | CO2 Emissions Gg | Population 1000 | PEC PJ | CO2 Emis per capita |
|---|---|---|---|---|
| Baden-Württemberg | 80073 | 10476 | 1583 | 7,64 |
| Bavaria | 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 |
| Hesse | ***62761*** | 6052 | 1030 | 10,37 |
| Mecklenburg - West Pomerania | ***18556*** | 1789 | 168 | 10,37 |
| Lower Saxony | 81764 | 7899 | ***1502*** | 10,35 |
| North Rhine - Westphalia | 304375 | 18000 | 3902 | 16,91 |
| Rhineland Palatinate | ***41801*** | 4031 | ***756*** | 10,37 |
| Saarland | ***11112*** | 1072 | 263 | 10,37 |
| Saxony | 37167 | 4460 | 535 | 8,33 |
| Saxaony-Anhalt | 24578 | 2649 | 456 | 9,28 |
| Schleswig-Holstein | 21433 | 2777 | ***536*** | 7,72 |
| Thuringia | 12729 | 2449 | 228 | 5,20 |
| **Country as a whole** | **901775** | **82164** | **14435** | **10,98** |
| **for comparison:** | | | | |
| **National result** | 852066 | 82163,6 | 14324 | 10,37 |
| Source: | UNFCCC reporting | Federal Statistical Office | Energy Balance figures | |
| **Deviation from whole-country figure (%):** | **-5,5** | | **-0,8** | |

In the comparison, an acceptable level of consistency was found between the *Länder* results and the national inventory for the years 1998 and 1999. The consistency is more favourable for the calculated primary energy consumption (deviation less than 2 %). This approach, the only viable one 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.

#### *3.1.16.3.1 Planned improvements*

This year, the approach chosen here will be discussed 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.

## 3.2 Fugitive emissions from fuels (1.B)

During all stages of fuel production and use, from extraction of fossil fuels to their final use, fuel components can escape or be released as fugitive emissions.

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

### *3.2.1 Solid fuels (1.B.1)*

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

#### 3.2.1.1 Coal mining and handling (1.B.1a)

##### *3.2.1.1.1 Source-category description (1.A.1a)*

| CRF 1.B.1a | | | | | |
|---|---|---|---|---|---|
| **Key source** | | **Gas (MSG)** | **1990 – contribution to total emissions** | **2002 – contribution to total emissions** | **Trend** |
| Solid fuels | l / t | $CH_4$ | 1,91 % | 0,53 % | falling |

| **Gas** | **$CO_2$** | **$CH_4$** | **HFCs** | **PFCs** | **$SF_6$** | **$N_2O$** | **$NO_X$** | **CO** | **NMVOC** | **$SO_2$** |
|---|---|---|---|---|---|---|---|---|---|---|
| Emissions factor[43] (EF) | NO | CS | NO | NO | NO | NO | NO | NO | NO | NO |
| EF uncertainties in % | | - | | | | | | | | |
| Distribution of uncertainties [44] | | - | | | | | | | | |
| Method for EF determination[45] | | T2 | | | | | | | | |

In Germany, fugitive methane emissions from coal mines are a key source, in terms of both emissions levels and emissions trend.

During coal production, transport and storage, methane can escape from coal and the rock surrounding it. The amount of methane released depends primarily on the amount of methane stored in the coal. All of the emissions that result from this relationship – but not the greenhouse gases caused by coal combustion – are to be recorded in this source category.

In the mining sector, a distinction is made between open-pit mines, in which raw materials are extracted from pits open to the surface, and underground mines, in which seams are mined underground. In Germany, hard coal is mined in 10 mines (all underground), and lignite is mined in 6 coal fields, primarily using the open-pit method (14 pits). In underground coal mining, ventilation systems are used to keep mine methane concentrations within safe limits for mining. Such systems can emit significant amounts of methane into the atmosphere as they ventilate the air and gas mixtures prevailing in underground mines. Within the framework of this source category, hard-coal mining is thus the largest source of fugitive emissions of $CH_4$. Some methan is suctioned off directly from seams and secondary rocks and used, primarily as pit gas.

As well as active mines, decommissioned hard coal mines (gas releases) represent another relevant source of fugitive $CH_4$ emissions.

In 2002, hard coal production totalled 26.3 million tonnes of usable production, whilst lignite production totalled 177.7 million tonnes (DESTATIS; 2002d). Consequently, hard coal production has fallen by approximately 3.6 % against the previous year, whereas lignite production has increased by approximately 1.4 %.

In recent years, methane emissions from hard coal mining have decreased as a result of significant decreases in production. Following a minimum in 1999, emissions from lignite

mining have increased again as a result of increased production. On 10 November 2003, the Federal Government approved a financial framework for further support of the hard-coal sector, thereby providing support for further adaption of production, from 26 million tonnes in 2005 to 16 million tonnes in 2012 (BMWA 2003). As a result, further decreases in methane emissions from hard-coal mining can be expected.

#### *3.2.1.1.2 Methodological issues (1.B.1a)*

For calculation of $CH_4$ emissions from coal mining, emissions are determined for the areas of underground hard-coal mining, pit-gas use, hard-coal storage, open-pit lignite mining and decommissioned mines.

Emissions from ***underground hard-coal mining*** have been calculated, in keeping with the Tier 2 approach, pursuant to the relevant equation in the IPCC Reference Manual:

Emissions (Gg $CH_4$) = EF ($m^3$ $CH_4$ /t) * hard-coal production * conversion factor ($Gg/10^6 m^3$)

The activity rate (hard-coal mining: total amount extracted) has been taken from the Energy Balance, line 1. Since the Energy Balance currently covers only the period up to 1999, the values for the years 2000 to 2002 were taken, provisionally, from another data source (DESTATIS; 2002d). In the interest of achieving energy-data consistency throughout the entire inventory, this provisional data will be replaced with the relevant data from the Energy Balance, as soon as the updated version is published.

The data basis for the $CH_4$ emission factor used for hard-coal mining, 18.5 kg/t (ca. 27.61 $m^3$/t, cf. Chapter 3.2.1.1.4), is the report on the research project "*Emissions of the greenhouse gases nitrous oxide and methane in Germany: emissions balance, identification of required research and action and development of recommendations for action; Phase 1*" (FHG ISI; 1993). This emission factor lies within the emission-factor ranges given by the IPCC Reference Manual, and is close to the relevant values listed (IPCC et al 1997, Table 1-54, p. 105). Determination of emission factors is based on a source-category-specific "bottom-up" approach that, in addition, to differentiating (sub-) source categories and fuels, also differentiates system technologies in detail. This procedure corresponds to the Tier 2 method of the IPCC Good Practice Guidance (GPG) rules.

Emissions are calculated by multiplying the emission factors by the activity rates, taking pit-gas use into account. Since in ***pit-gas use*** $CH_4$ is used for energy generation, the emissions calculated for pit-gas use must be deducted from the $CH_4$ emissions from hard-coal mining. The amount of pit gas involved is also taken from the Energy Balance, line 1; due to a lack of alternative data sources, until the new Energy Balance is published and relevant data becomes available, pit-gas amounts are assumed to remain constant as of 1999. The emission factor of 320 $kg/10^3 m^3$ is used consistently for the entire time series.

For calculation of $CH_4$ emissions from ***storage of hard coal***, the same activity data is used as was used for hard coal mining. The emission factor of 0.576 kg/t has also been taken from the aforementioned study (FHG ISI; 1993).

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

Emissions from ***open-pit lignite mining*** have been calculated, in keeping with the Tier 2 approach, pursuant to the relevant equation in the IPCC Reference Manual:

Emissions (Gg $CH_4$) = EF ($m^3$ $CH_4$ /t) * lignite production * conversion factor ($Gg/10^6m^3$)

The activity rate (crude lignite) has been taken from the Energy Balance, line 1. Since the Energy Balance currently covers only the period up to 1999, the values for the years 2000 to 2002 were taken, provisionally, from another data source (Federal Statistical Office; FS 4, R 3.1, Meldenr. 10 20 10 330). The emission factor of 0.072 kg/t also is from the aforementioned study (Fraunhofer Institute for System Technology and Innovation Research, 1993).

No ***storage of lignite*** takes place.

Only rough estimates are available on gas releases from decommissioned mines. The value 87 t has been used consistently for the years 1990-2002.

#### *3.2.1.1.3 Uncertainties and time-series consistency (1.B.1a)*

The emission factors remain at the same level in the time series and are thus consistent within the meaning of comparability throughout the time series. Since the Energy Balance currently covers only the period up to 1999, the values for the years 2000 to 2002 were taken, provisionally, from another data source (DESTATIS; 2002e). In the interest of achieving energy-data consistency throughout the entire inventory, this provisional data will be replaced with the relevant data from the Energy Balance, as soon as the updated version is published. As Table 31 shows, there are small differences in the activity rates for 2002.

Table 31: Activity rates for 2002

| | Hard coal [millions of tonnes] | Lignite [millions of tonnes] |
|---|---|---|
| DESTATIS | 26,3 | 177,7 |
| Coal-mining industry statistics | 26,1 | 181,8 |

#### *3.2.1.1.4 Source-specific quality assurance / control and verification (1.B.1a)*

A central review of German emissions reporting for 2003, carried out by independent experts under commission to the Climate Secretariat, critically noted that no data on $CO_2$ and $N_2O$ emissions was provided in this category. Germany plans to take action on this point.

For underground hard coal mining, the IPCC Reference Manual recommends emission factors on the order of 10 to 25 m³/t. Conversion of the German emission factors, using a conversion factor of 0.67 $Gg/10^6m^3$ (pursuant to Reference Manual, at 20° C, 1 atmosphere), produces the individual values given in Table 32. When production, storage and deductable pit-gas use are combined in one emission factor, a value of 23.58 $m^3$ $CH_4$/t coal (marketable production) results, which is within the recommended range, and near the upper limit of the range.

Table 32: Emission factors for $CH_4$, from hard coal mining

| Emission factors | Hard coal | | **Lignite** | |
|---|---|---|---|---|
| | EF $m^3$ $CH_4$/t | **EF kg/t** | EF $m^3$ $CH_4$/t | **EF kg/t** |
| $CH_4$ from extraction | 27,61 | 18,50 | 0,11 | 0,07 |
| $CH_4$ from extraction, minus pit gas | 22,72 | 15,22 | - | - |
| $CH_4$ from storage | 0,86 | 0,58 | - | - |
| $CH_4$ from mining (extraction and storage, minus pit-gas use) | 23,58 | 15,80 | 0,11 | 0,07 |

The IPCC Reference Manual does not recommend any specific emission-factor levels for open-pit lignite mining.

The inventory data is based on the Energy Balance. In addition, figures from the Coal Industry Statistics Association (Verein der Statistik der Kohlenwirtschaft) may also be used. Pursuant to coal-industry statistics, hard-coal production in 2002 amounted to 26.1 million tonnes of marketable production. Lignite production totalled 181.8 million tonnes (Statistik der Kohlenwirtschaft e.V.; 2003a, 2003b). In light of these statistics, hard coal production has fallen by approximately 3.7 % against the previous year, whereas lignite production has increased by approximately 3.6 %. The inventory data needs to be reviewed against this data.

Other source-specific quality assurance / control and verification are being carried out.

#### *3.2.1.1.5 Source-specific recalculations (1.B.1a)*

No source-specific recalculations have been carried out. Efforts will be made to carry out recalculations on the basis of the planned improvements.

#### *3.2.1.1.6 Source-specific planned improvements (1.B.1a)*

Current key-source analysis for methane emissions from coal mining, with regard to emissions levels, has just barely led to the sector's classification as a key source. Consequently, the next step is to consider whether reductions in coal production will soon reduce the sector's emissions to a level that no longer corresponds to that of a key source.

Since methane emissions from coal mining are currently a key source, the IPCC methods require the emissions to be calculated pursuant to Tier 2/3, on the basis of measurements of methane in mine-air/gas mixtures and ventilated pit-gas from individual mines/locations. In this area, the ongoing research project "Methane emissions from coal mining" (FKZ 203 41 253 / 05) will develop the necessary data sources, derive national emission factors, carry out calculations and determine uncertainties. The available relevant data will be compiled from operators, associations and the licensing and monitoring authorities of the Länder. Furthermore, the project is studying estimation ranges and reference formation for use of a combined method, pursuant to Tier 2/3, for the source category. This effort will also include review of currently used emission factors for hard coal, which are relatively high when compared internationally. In addition, the project will consider the issue of what available data can be used as a basis for determining $CO_2$ and $N_2O$ emissions (and, where data is available, also as a basis for determining emissions of CO, $SO_2$, and higher hydrocarbons). All improvements will include consideration of the uncertainties in emission factors.

Since to date German inventories do not list any emissions for lignite transport and storage, and since the available data on hard coal storage is out of date, data/information sources for

determination of these emissions will be developed, and the sources' suitability for inventory preparation will be considered.

The relevance of methane emissions from lignite production will be reviewed, since the two sets of statistics on coal mining (Federal Statistical Office, Association of Coal Industry Statistics - Verein der Statistik der Kohlenwirtschaft) list slightly different data in each case. Efforts are being made to illuminate these discrepancies.

Within the framework of the project, and with the help of other players in the National System, possibilities will be reviewed for improving the inventory calculation of pit-gas use and for taking account of cold and hot gas flaring.

With regard to calculation of emissions from decommissioned mines, feasible, cost-effective ways of quantifying the emissions will be sought.

The IPCC conversion factor of 0.67 Gg/$10^6$m³ at 20°C and 1 atmosphere (IPCC et al; 1997, Reference Manual, p. 1.108) will be reviewed, since the units used by Germany are standard cubic metres at 1.01325 bar and 0°C (DIN No. 1343) (DIN 2004).

The results of the planned NaSE workshop will be noted and applied within the framework of the research project.

### 3.2.1.2 Transformation of coal (1.B.1b)

#### *3.2.1.2.1 Source-category description (1.B.1b)*

| **CRF 1.B.1a** | | | | | |
|---|---|---|---|---|---|
| Key source | | Gas (MSG) | 1990 – contribution to total emissions | 2002 – contribution to total emissions | **Trend** |
| | NO | | | | |

| **Gas** | **$CO_2$** | **$CH_4$** | **HFCs** | **PFCs** | **$SF_6$** | **$N_2O$** | **$NO_X$** | **CO** | **NMVOC** | **$SO_2$** |
|---|---|---|---|---|---|---|---|---|---|---|
| Emissions factor[46] (EF) | NO | CS | NO | NO | NO | NO | NO | CS | CS | CS |
| EF uncertainties in % | | | | | | | | | | |
| Distribution of uncertainties [47] | | | | | | | | | | |
| Method for EF determination[48] | | CS | | | | | | | | |

In 2002, hard-coal coke production amounted to 7.26 million tonnes. Hard-coal coke production comprises production from the country's sole mine-attached byproduct coking plant (about 2 million t) and from four metallurgical byproduct coking plants. As a result, hard-coal coke production has decreased by about 0.5 % over the previous year.

#### *3.2.1.2.2 Methodological issues (1.B.1b)*

The IPCC Reference Manual does not describe any methods for the sub-source-category transformation of coal (IPCC et al, 1997, Reference Manual, p.1.110f). The Länder-specific method that is used is based on activity rates from the Energy Balance and on corresponding emission factors.

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

Production of low-temperature lignite coke took place solely in the new German Länder and, for purposes of the inventory, is of relevance only to the base year. Production was discontinued after 1992.

The activity rate for hard coal coke production was taken from the Energy Balance, line 1. Since the Energy Balance currently covers only the period up to 1999, the values for the years 2000 to 2002 were taken, provisionally, from another data source (DESTATIS; 2002e, Meldenummer 101011300). In the interest of achieving energy-data consistency throughout the entire inventory, this provisional data will be replaced with the relevant data from the Energy Balance, as soon as the updated version is published.

Emissions from hard coal coke production have been calculated pursuant to the Tier 2 approach, in a manner similar to that of the IPCC Reference Manual's equation for $CH_4$ emissions from coal mining:

Emissions (Gg $CH_4$) = EF ($m^3$ $CH_4$ /t) * hard-coal coke production * conversion factor ($Gg/10^6m^3$)

The methane emission factor used for calculation of $CH_4$ emissions from hard-coal coke production (coking plants) is 0.150 kg methane per tonne of hard-coal coke production (LANGE 1988, BATZ 1995), and this value has been used consistently since 1995.

In the CSE, the source category "coal transformation" is covered by the time series for hard-coal coke production (coking plants).

#### *3.2.1.2.3 Uncertainties and time-series consistency (1.B.1b)*

No information about this is available at present.

#### *3.2.1.2.4 Source-specific quality assurance / control and verification (1.B.1b)*

The inventory data are based on the Energy Balance; figures from the Coal Industry Statistics Association (Verein der Statistik der Kohlenwirtschaft) may also be used. Pursuant to these sources, one lignite coking plant, with a capacity of ca. 0.2 million tonnes (Statistik der Kohlenwirtschaft e.V., 2003), was still in operation in Germany in 2002. Other source-specific quality assurance / control and verification are being carried out.

Source-specific quality assurance / control and verification is to be standardised within the framework of a research project.

#### *3.2.1.2.5 Source-specific recalculations (1.B.1b)*

No source-specific recalculations have been carried out.

#### *3.2.1.2.6 Source-specific planned improvements (1.B.1b)*

Methane emissions from coal mining, including coal processing, represent a key source. In a first step, a review will consider whether reductions in coal production will soon bring emissions levels in this area below the level that corresponds to a key source.

The activity rates and emission factors used to date for coal treatment (coal processing) are to be reviewed and updated, and the proper defining limits for the source category (including

those for hard-coal coke production) are to be determined. Current sources of data and information for identifying emissions are to be developed, and the sources' suitability for inventory preparation is to be reviewed.

In light of the requirements from the Guidelines, the data available in Germany for the time series beginning in 1990 is to be reviewed, and a consistent $CH_4$-emissions-calculation procedure is to be developed that permits adequate extrapolation of activity rates and emission factors.

If suitable national emission factors are available, calculations in the area of coal treatment (coal processing) are to be in keeping with the Tier 2 approach.

Results from the planned NaSE workshop are to be noted and applied.

### *3.2.2 Oil and natural gas (1.B.2)*

| CRF 1.B.2 | | | | | |
|---|---|---|---|---|---|
| Key source | | Gas (MSG) | 1990 – contribution to total emissions | 2002 – contribution to total emissions | Trend |
| Natural gas | l | $CH_4$ | 0,63 % | 0,70 % | falling |

| **Gas** | **$CO_2$** | **$CH_4$** | **HFCs** | **PFCs** | **$SF_6$** | **$N_2O$** | **$NO_X$** | **CO** | **NMVOC** | **$SO_2$** |
|---|---|---|---|---|---|---|---|---|---|---|
| Emissions factor[49] (EF) | NO | CS | NO | NO | NO | NO | NO | NO | NO | NO |
| EF uncertainties in % | | 25 | | | | | | | | |
| Distribution of uncertainties [50] | | N | | | | | | | | |
| Method for EF determination[51] | | CS | | | | | | | | |

In terms of natural-gas emissions levels, the oil and natural gas source category is a key source.

Distribution of natural gas constitutes the principal source of fugitive emissions of $CH_4$. $CH_4$ emissions from natural gas extraction and processing, as well as from transfer stations, play a subordinate role in this respect. $CH_4$ emissions from petroleum extraction and from storage of petroleum products only account for approximately 3 % of emissions from natural gas.

#### 3.2.2.1 Source category description: Oil (1.B.2a)

$CH_4$ emissions from petroleum originate primarily from fugitive emissions from extraction, from the refinery process and from 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 4.08 Gg in 2002. Since the emission factor is likely to remain constant, the forecast moderate trend in emissions development is likely to produce only a slight change in 2003.

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

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

In the case of natural gas, the principal source of diffuse $CH_4$ emissions is distribution of natural gas to the end consumer. Even though the distribution network was expanded, during the period covered by the report, from about 150,000 km to 418,065 km (2002), $CH_4$ emissions were slightly reduced. This was accomplished via a reduction of about 40 % in fugitive distribution losses.

The other fugitive emissions arising from extraction, processing and high-pressure distribution of natural gas showed only a slight decrease during the period under review. Overall, $CH_4$ emissions were reduced from 367.20 Gg in 1991 to 343.64 Gg in 2002. Since the overall framework conditions have not changed, only slight changes – if any at all – in emissions for 2003 are to be expected.

#### 3.2.2.3 Methodological issues (1.B.2)

$CH_4$ 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 issued by the petroleum industry association *Mineralölwirtschaftsverband e.V.* (MWV, 2003).

The specific emission factors were derived by the Federal Environmental Agency, on the basis of research in the literature and among relevant companies, and they have been used consistently.

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

The uncertainties, amounting to 25 %, were determined in the framework of an expert judgement, and they are of the same order as the IPCC Good Practice Guidance default value.

#### 3.2.2.5 Source-specific quality assurance / control and verification (1.B.2)

For source category 1.B.2a (oil refining and oil), comparison with the IPCC Guidelines' default values shows good agreement. Table 1.62 on p. 130 of the Guidelines lists summed emission factors for this area ranging from 110 to 1660 kg/PJ. Conversion of the German emission factor for 2002, 0.02 kg/t crude oil, using the lower net calorific value of crude oil (42.7 MJ/kg), produces an emission factor of 468.4 kg/PJ. This value lies within the range for the IPCC default value. Similarly, the emission factor listed by Austria for the year 2000, 0.033 kg/t crude oil, agrees well with the German emission factor determined on a Länder-specific basis.

As to source category 1.B.2b (natural gas production, processing and distribution), Table 1.62 on page 130 of the IPCC Guidelines for National Greenhouse Gas Inventories lists only a default value for the emission factor for the entire source category – 58,000 to 111,000 kg/PJ. A comparison with the summed German emission factors converted using the lower net calorific value of natural gas (35.7 MJ/Nm³) shows good agreement. The Länder-specific calculation produces a total emission factor for this source category of 62,500 kg/PJ, which lies within the lower section of the default-value range.

Measures for standardisation of QC and QA are currently being prepared.

#### 3.2.2.6 Source-specific recalculations (1.B.2)

#### 3.2.2.7 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, an effort is being made to obtain current data. Commissioning a relevant research project in this area seems problematic, since some of the plant operators themselves have no data on fugitive emissions, and since suitable measurements are expensive and thus could be carried out only on a piecemeal basis, which would make the resulting data open to question.

Further aspects of inventory completion have been included in the inventory-improvement plan.

# 4 INDUSTRIAL PROCESSES (CRF SECTOR 2)

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

### *4.1.1 Source category description (2.A.1)*

| CRF 2.A.1 | | | | | |
|---|---|---|---|---|---|
| Key source | | Gas (MSG) | 1990 – contribution to total emissions | 2002 – contribution to total emissions | **Trend** |
| Cement production | I | $CO_2$ | 1,21 % | 1,20 % | |

| Gas | $CO_2$ | $CH_4$ | HFCs | PFCs | $SF_6$ | $N_2O$ | $NO_X$ | CO | NMVOC | $SO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Emissions factor[52] (EF) | CS | NO | NO | NO | NO | NO | NO | NO | NO | CS |
| EF uncertainties in % | ± 20 | - - | - - | - - | - - | - - | | | | |
| Distribution of uncertainties [53] | | - - | - - | - - | - - | - - | | | | |
| Method for EF determination[54] | CS | - - | - - | - - | - - | - - | | | | |

In terms of emissions levels, the source category "Cement production" (2.A.1) under "Mineral products" is a key source.

In 2002, a total of 70 ovens for combustion cement clinkers, with a total capacity of 131820 t/d, were in operation throughout Germany. In a breakdown by oven types, the largest group of these consisted of ovens with cyclonic preheaters (46), followed by ovens with grid preheaters (16) and shaft ovens (8) (BDZ, 2004a, p. 7). A total of 31 companies, with 47 cement plants in Germany, are members of the Association of the German Cement Industry (Bundesverband der Deutschen Zementindustrie - BDZ, 2004b).

The clinker-firing process emits climate-relevant gases. $CO_2$ accounts for the great majority of these emissions. In its monitoring report for 2002, the Association of German Cement Plants (Verein Deutscher Zementwerke - VDZ) reported clinker production of 23,954 kt[55]. The relevant $CO_2$ emissions that depend on the raw materials used can be estimated using a Länder-specific emission factor of 0.53 t $CO_2$/t cement clinkers. Clinker production produced raw-materials-dependent $CO_2$ emissions of 12 695 kt $CO_2$ in 2002.

### *4.1.2 Methodological issues (2.A.1)*

The activity rates data was compiled by the German Cement Works Association, *Verein Deutscher Zementwerke e.V.* (VDZ)/Düsseldorf, by means of surveys amongst German cement factories and via use of BDZ figures. For the most part, the data in question consists of data published in the framework of $CO_2$ monitoring (RWI, 2000). This data differs from the data published in *Environmental data for the German cement industry (Umweltdaten der deutschen Zementindustrie* - VDZ, 2002). The reason for this is that the production figures in the environmental data, and those in the $CO_2$-monitoring data, come from different sources and were compiled using different data-survey criteria. Whereas the environmental data draw on BDZ figures, which cover only the BDZ member plants, the VDZ monitoring data cover all German cement plants. At the same time, some of the data is estimated. In addition, the

52 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
53 N = Normal, L = Log normal, T = Triangular, U = Uniform (even distribution)
54 D = IPCC default, RA = Reference approach, T1= IPPC tier 1, T1a/ T1b/ T1c = IPPC tier 1a/ 1b/ 1c, T2 = IPPC tier 2, T3 = IPPC tier 3, C = CORINAIR, CS = Country-specific, M = Model
55 This figure is provisional, since the 2002 monitoring report of the Rheinisch-Westfälisches Institut für Wirtschaftsforschung (RWI), an economic research institute located in Essen, has not yet been published.

latter source adjusts the activity rates for the German cement industry by deducting imports and exports of cement clinkers, with the result that the $CO_2$ emissions calculated with the adjusted activity rates refer solely to the amount of cement that was ground from cement clinkers manufactured in Germany. For the years 1991 to 1993, the activity rates exhibit a data gap that the association (VDZ) thus cannot close. For the time being, the data for these years has thus been interpolated. For 2002, the VDZ's draft monitoring report lists clinker production of 23,954 kt.

Table 33 summarises the activity rates, and clinker factors determined on the basis of these rates, for the years 1987 to 2002. The clinker factor is calculated as the quotient of clinker production and cement production, and it is expressed in the units *t clinkers / t cement*. This factor is needed for derivation of emission factors for clinker production (see below).

Table 33: Activity rates and resulting clinker factors in the German cement industry, for the years 1987-2002

| **Year** | Brick production [millions of t/a] | Cement production (from German clinkers) [millions of t/a] | Clinker factor [t clinkers/t cement] |
|---|---|---|---|
| 1987 | 29399 | 34171 | 0,860 |
| 1990 | 29054 | 34749 | 0,836 |
| 1991 | 29096 | | |
| 1992 | 29138 | | |
| 1993 | 29180 | | |
| 1994 | 29222 | 35804 | 0,816 |
| 1995 | 29072 | 33649 | 0,864 |
| 1996 | 27668 | 32858 | 0,842 |
| 1997 | 28535 | 33171 | 0,860 |
| 1998 | 29038 | 34681 | 0,837 |
| 1999 | 29462 | 36558 | 0,806 |
| 2000 | 28494 | 34685 | 0,822 |
| 2001 | 25227 | 31481 | 0,801 |
| 2002 | 23954 | 30773 | 0,778 |
| Ø | | | **0,829** |

Emission factors are determined on the basis of a source-category-specific *bottom-up* approach, i.e. the factors are determined via aggregation of plant-specific data. The aggregation was carried out at an early date, at the association level (VDZ, BDZ). The procedure approximately corresponds to the Tier 2 method of the *IPCC-GPG* (IPCC, 2001).

$CO_2$ emissions in the cement industry are both raw-material-related and energy-related. Raw-material-related $CO_2$ emissions occur during deacidification of limestone ($CaCO_3$ → $CaO + CO_2$) and account for around 60 % of total $CO_2$ emissions. Energy-related emissions arise during combustion of fuels and indirectly, via consumption of electrical energy.

Raw-material-related $CO_2$ emissions released through limestone deacidification in the cement industry were determined, pursuant to *IPCC-GPG*, using the following equation, where the emission factor itself was adjusted to take account of Land-specific conditions:

*$CO_2$ emissions = emission factor ($EF_{clinkers}$) x clinker production*

The emission factor $EF_{clinker}$ depends on factors that include the burnt-lime content of the clinkers. In Germany, dust from the exhaust gas purification process is added to the clinker. Also as a result of such dust addition, the lime content in the clinker and, thus, the emission factor $EF_{clinker}$, diverge from the IPPC's default value of 64.6 % or 0.5071 t $CO_2$ / t clinker. With the figures in Table 34, an average raw-material-related emission factor $EF_{clinker}$ of 0.53 t $CO_2$/t clinker was determined for the years 1999-2002. The figures were taken from *Environmental data of the German cement industry for 2002 (Umweltdaten der deutschen Zementindustrie 2002* - VDZ, 2002). The database was collected by BDZ and entered into the environmental data by VDZ.

Conversion of emission factors $EF_{cement}$ (with units t $CO_2$/t cement) to the units t $CO_2$/t clinker requires a recalculation that takes the ratio of clinkers to cement (clinker factor) into account:

$EF_{clinker} = EF_{cement}$ / clinker factor.

Year-specific clinker factors were determined using the activity rates in Table 33.

Table 34: Specific $CO_2$ emissions from the cement industry in Germany (VDZ, 2002)

| **Year** | **Raw-material-related EF** [t $CO_2$/t cement] | **Brick factor** [t clinker/t cement] | **Raw-material-related EF** [t $CO_2$/t clinker] |
|---|---|---|---|
| 1999 | 0,427 | 0,806 | 0,530 |
| 2000 | 0,431 | 0,822 | 0,525 |
| 2001 | 0,415 | 0,801 | 0,518 |
| 2002 | 0,413 | 0,778 | 0,531 |
| Ø | | 0,829 | 0,526 |

Table 35 shows the German cement industry's raw-material-related $CO_2$ emissions, as calculated with the above-described method, for the years 1987 to 2002.

Table 35: Raw material-related $CO_2$ emissions from the German cement industry

Emission factor 0.53 t $CO_2$/t clinker

| **Year** | Clinker production [millions of t/a] | $CO_2$ emissions from raw materials [$10^6$ t/a] |
|---|---|---|
| 1987 | 29399 | 15,6 |
| 1990 | 29054 | 15,4 |
| 1991 | 29096 | 15,4 |
| 1992 | 29138 | 15,4 |
| 1993 | 29180 | 15,5 |
| 1994 | 29222 | 15,5 |
| 1995 | 29072 | 15,4 |
| 1996 | 27668 | 14,7 |
| 1997 | 28535 | 15,1 |
| 1998 | 29038 | 15,4 |
| 1999 | 29462 | 15,6 |
| 2000 | 28494 | 15,1 |
| 2001 | 25227 | 13,4 |
| 2002 | 23954 | 12,7 |

### *4.1.3 Uncertainties and time-series consistency (2.A.1)*

Following conversion of activity data to surveys in the framework of $CO_2$ monitoring, the current status of the discussion on methods now permits near-realistic calculations in the CSE and consistent descriptions in the NIR. Uncertainties still persist in determination of activity rates, since some of the data can only be estimated, using plant data of the VDZ. The clinker factor for conversion of the emission factor $EF_{cement}$ may also be erroneous, as a result of the uncertainties in the activity rates.

With regard to the time-series consistency, cf. also Chapter 4.1.6.

The uncertainties listed for the emission factors were determined via expert assessment pursuant to Tier 1 of the IPCC GPG rules, chapter 6. The following sources of error entered into estimates of the uncertainties for the emission factor for raw-material-related $CO_2$ emissions:

- Uncertainty in collecting and transferring data,
- Uncertainty regarding the average amount of limestone used,
- Uncertainty resulting from use of average values (for example, for the emission factor for raw-material-related emissions).

### *4.1.4 Source-specific quality assurance / control and verification (2.A.1)*

For the cement industry, the calculation procedure was adjusted and the bases for calculation were adapted. Previously, the data published in "Environmental data of the German cement industry" was used. In an additional review, it was found that those statistics covered only the producers registered within the association. The actual figures are higher, however. For this reason, the VDZ data provided for the $CO_2$ monitoring report seems more suitable for the present purposes, since it refers to the amount of cement ground from cement clinkers produced in Germany. In the interest of greater precision and unambiguity, it was decided to change the database – to use the association figures prepared for the $CO_2$ monitoring report, although they have been published only up to the year 2000 (with data up to 1999).

For purposes of quality assurance, all data used, including data from the BDZ, VDZ and from the literature, was checked for plausibility. The determined emission factor for raw-material-related $CO_2$ emissions corresponds approximately to the value that the German cement industry has repeatedly published. Furthermore, the determined emission factor for raw-material-related $CO_2$ emissions has been compared with the relevant figures of other countries. Good agreement was found with figures from Australia, Canada, Denmark, France, Ireland, Spain, the UK and the U.S..

In a quality check carried out by Federal Environmental Agency experts pursuant to IPCC GPG (Chapter 2.2.3 and 8), the Länder-specific emission factors for raw-material-related $CO_2$ emissions were compared with the IPCC Tier 1 default factors from the IPCC Reference Manual. This comparison showed very good agreement.

### *4.1.5 Source-specific recalculations (2.A.1)*

Time-series consistency for the emission factors is being established – using the available data, which remain to be entered into the CSE – for the period 1999 to 2002. Source-specific review, along with any then necessary recalculation of emission factors for the time between 1990 and 1999, has not yet been completed. The year-specific emission factors that would be required for this are still lacking. It may be assumed, however, that during this period raw-material-related $CO_2$ emissions – in contrast to energy-related emissions – either were not significantly higher or were lower, with the result that the relevant emission factor remained about the same.

### *4.1.6 Planned improvements (source-specific) (2.A.1)*

In the interest of better evaluation of the database, in future researchers will attempt to compile their own aggregation from the relevant raw data. To date, pre-aggregated data of the Association of German Cement Plants (Verein Deutscher Zementwerke e.V.) has been used for reporting. Before this procedure can be changed, however, it must be determined whether the data could be provided in such a form.

Plans now call for the data series for the activity rates to be entered into the CSE in the near future. Before this is done, however, the interpolated values for the years 1991-93 are to be replaced, in the near term, with values determined via an engineering approach in keeping with the Good Practice Guidance. Furthermore, the emission factor for $SO_2$ emissions is also to be entered. To this end, relevant calculations must be made and co-ordinated in advance.

In addition, a source-specific review of the specific raw-material-related emissions for the period 1990 to 1999 is to be carried out. This is justified in that only data from the period 1999 to 2002 was used to determine the emission factor for raw-material-related $CO_2$ emissions. On the other hand, it is not likely that a different emission factor will have to be defined for the period 1990 to 1999.

## 4.2 Mineral Products: Lime production (2.A.2)

### *4.2.1 Source category description (2.A.2)*

| **CRF 2.A.2** | | | | |
|---|---|---|---|---|
| Key source | Gas (MSG) | 1990 – contribution to total emissions | 2002 – contribution to total emissions | **Trend** |
| Lime production | $CO_2$ | 0,51 % | 0,54 % | falling |

| **Gas** | **$CO_2$** | **$CH_4$** | **HFCs** | **PFCs** | **$SF_6$** | **$N_2O$** | **$NO_X$** | **CO** | **NMVOC** | **$SO_2$** |
|---|---|---|---|---|---|---|---|---|---|---|
| Emissions factor[56] (EF) | D | NO | NO | NO | NO | NO | NO | NO | NO | NE |
| EF uncertainties in % | +10/-30 | -- | -- | -- | -- | -- | | | | |
| Distribution of uncertainties [57] | L | -- | -- | -- | -- | -- | | | | |
| Method for EF determination[58] | D | -- | -- | -- | -- | -- | | | | |

In terms of its emissions levels in 2002, lime production was a key source.

In 2002 some 130 ovens for burning limestone were in operation in Germany. As Table 36 shows, lime production in 2002 amounted to 6670 kt of burnt lime. With complete deacidification (0.785 t $CO_2$/t burnt lime), this amount corresponds to 5236 kt of raw-material-related $CO_2$ emissions.

Climate-relevant gases are emitted in burning of limestone. $CO_2$ accounts for the great majority of these emissions. In lime production, raw-material-related $CO_2$ emissions occur in deacidification of calcium carbonate ($CaCO_3$) to produce burnt lime (CaO).

$$CaCO_3 + \text{heat} \rightarrow CaO + CO_2$$

Production of burnt dolomite ($CaCO_3$*$MgCO_3$ + heat → CaO*MgO) is also possible, but such production plays an insignificant role in Germany in terms of the amounts involved. These raw-material-related $CO_2$ emissions, therefore, were not included in the estimate.

### *4.2.2 Methodological issues (2.A.2)*

$CO_2$ emissions in the lime industry are both raw-material-related and energy-related. Raw-material-related $CO_2$ emissions, which occur during deacidification of limestone ($CaCO_3$ → CaO + $CO_2$), account for about 67 %[59] of total $CO_2$ emissions. Energy-related emissions, which are not reported here, arise directly, during combustion of fuels, and indirectly, via consumption of electrical energy.

Raw-material-related $CO_2$ emissions in the lime industry, which are released during limestone deacidification, were determined, in keeping with IPCC GPG, pursuant to the following equation:

*$CO_2$ emissions = emission factor (EF) x burnt lime production*

56 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
57 N = Normal, L = Log normal, T = Triangular, U = Uniform (even distribution)
58 D = IPCC default, RA = Reference approach, T1= IPPC tier 1, T1a/ T1b/ T1c = IPPC tier 1a/ 1b/ 1c, T2 = IPPC tier 2, T3 = IPPC tier 3, C = CORINAIR, CS = Country-specific, M = Model
59 This value varies in keeping with the fuels used. Pursuant to the 2000 monitoring report of the Federal Association of the German Lime Industry (Bundesverband der Deutschen Kalkindustrie), the $CO_2$ emission factor for fuel-related emissions averages 0.333 t $CO_2$/t burnt lime. Raw-material-related $CO_2$ emissions thus account for 66.7 % of emissions.

With regard to expulsion of $CO_2$ from the raw material, lime, in the burning process, complete deacidification is assumed. The stoichiometry of the chemical compound calcium carbonate yields a proportion by mass of 44 % $CO_2$ and 56 % calcium oxide. Under complete deacidification, therefore, $CO_2$ is released at a rate of 44/56, which corresponds to a specific emission factor of 0.785 t $CO_2$/t burnt lime.

Emissions are determined using aggregated, plant-specific activity rates and the stoechiometric emission factor. Activity rates are aggregated at the association level (Federal Association of the German Lime Industry; BV Kalk). The emissions data is not differentiated by various products (hard, medium, soft burn), because of a lack of data and because such differentiation is not considered necessary for leached lime. The lime-slaking process itself is not emissions-relevant. Emissions from burning of lime destined for further processing have been taken into account, however.

The above-listed stoichiometric emission factor was used to determine the raw-material-related $CO_2$ emissions, as listed in Table 36, for 1990 and for the period 1995-2002.

Table 36: Raw-material-related $CO_2$ emissions from the German lime industry

| Year of reporting | **1990** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **2001** | **2002** |
|---|---|---|---|---|---|---|---|---|---|
| Production in millions of tonnes | 7,50 | 7,80 | 7,19 | 7,29 | 6,97 | 6,98 | 7,16 | 6,82 | 6,67 |
| $CO_2$ emissions in kt | 5888 | 6123 | 5644 | 5723 | 5471 | 5479 | 5621 | 5354 | 5236 |

The activity rates determined by the BV Kalk lime-producers' association are based only on the association's member lime works. They represent about 95 % of total production, and thus an extrapolation to fictive 100% had to be carried out for the present purpose. The 95 % data was published in monitoring reports of the German lime industry, by Rheinisch-Westfälisch Institut für Wirtschaftsforschung (RWI, 2000), an economic research institute located in Essen; publication up to the reference year 2000 has been completed. Data for 2001 and 2002 was provided by the Federal Association of the German Lime Industry (Bundesverband der Deutschen Kalkindustrie).

### *4.2.3 Uncertainties and time-series consistency (2.A.2)*

With regard to the time-series consistency, cf. Chapter 4.2.6.

As explained above, complete deacidification is assumed for expulsion of $CO_2$ from the raw material, lime, in the burning process,. This procedure does not take into account, however, that partial deacidification can also occur, as a result of various production conditions (oven type, burning temperature, product requirements). What is more, dolomite fractions in the raw material, along with other foreign substances, can distort $CO_2$-emissions data. On the other hand, in light of industry's own quality requirements with regard to its products, such impurities may be neglected with regard to $CO_2$ emissions. Binding of atmospheric $CO_2$, during use of burnt lime – for example, in mortar or filter materials – can also lead to discrepancies in $CO_2$-emissions values. The lime-producing industry is still unable to take account of such $CO_2$ fixing in its relevant balances. Some sources use fixing rates of up to 30 % in calculations. This was not taken into account in estimation of the overall error.

In addition, the raw-material-related $CO_2$ emissions from burning dolomite rock in Germany have not been included. With regard to total emissions, however, these emissions play a rather insignificant role, because the production amounts involved are small.

The uncertainties listed for the emission factors were determined via experts' assessment pursuant to Tier 1 of the IPCC GPG rules, chapter 6 IPCC, 2000). The following error sources entered into estimation of uncertainties for the emission factor for raw-material-related $CO_2$ emissions:

- Uncertainty in collecting and transferring data,
- Uncertainty with regard to the various different degrees of deacidification that were not taken into account
- Uncertainty with regard to dolomite fractions and other impurities in limestone.

Additional uncertainties are present in determination of activity rates, since the BV Kalk association's existing plant data only support estimation of production of lime plants that are not members in BV Kalk, as a percentage of total production in the sector.

The estimates do not take account of re-fixing of $CO_2$ or of $CO_2$ emissions from burning of dolomite. This also leads to errors – errors which, however, have not entered into the estimation of uncertainties.

### *4.2.4 Source-specific quality assurance / control and verification (2.A.2)*

For the lime industry, the calculation procedure was adjusted and the bases for calculation were adapted. The methodological discussion has reached a level that now permits co-ordinated calculations in the CSE and consistent descriptions in the NIR. These two aspects (calculations in the CSE and descriptions in the NIR) now have to be harmonised, however.

For purposes of quality assurance, all data used, including data from the BV Kalk lime industry association and from the literature, was checked for plausibility. The stoichiometric emission factor for raw-material-related $CO_2$ emissions is in keeping with the value used by the German lime industry. Furthermore, the determined emission factor for raw-material-related $CO_2$ emissions has been compared with the relevant figures of other countries. Significantly, other countries' emission factors for raw-material-related $CO_2$ emissions are considerably lower. Presumably, such factors take into account different degrees of product deacidification, and limestone ($CaCO_3$) is used instead of burnt lime (CaO) as the reference element for determining emissions.

### *4.2.5 Source-specific recalculations (2.A.2)*

Source-specific review, along with any then necessary recalculation of emission factors for the time between 1990 and 2002, has not yet been completed.

### *4.2.6 Planned improvements (source-specific) (2.A.2)*

By the NIR 2005, research is again to be carried out to determine the extent to which the calculation procedure needs to be adapted, and can be adapted, to the actual emissions situation (for example, with regard to different product groups or degrees of deacidification). Such adaptation would affect the emission factor. If such a breakdown of product statistics is feasible, it must be determined whether the CSE time series can be retroactively adjusted or whether the calculation procedure must be converted for future reporting.

The activity rates provided by the BV Kalk lime industry association, some of which have not yet been published, have been assessed as plausible with regard to necessary extrapolation

to 100 %. Of course, it would be preferable to be able to rely solely on published data in future. The next steps must be decided within the framework of the National System.

In addition, adapted of the data series in the CSE is planned in the near term. A rough consistency review has already been carried out. This turned up a number of inconsistencies. The emission factor for raw-material-related $CO_2$ emissions needs to be corrected provisionally. Furthermore, the activity rates already entered into the system need to be adjusted[60]. At the same time, the BV Kalk industry association's figures for total share of German lime production need to be re-examined. Not all German lime producers are represented in the Federal Association of the German Lime Industry (Bundesverband der Deutschen Kalkindustrie). The BV Kalk industry association reports that two (rather small) plants are currently not members of the association. For determination of absolute emissions in Germany, the non-included share was estimated and extrapolated to 100 %. In retrospect, it was determined, for 1990 and the 1995-2002 period, that the BV Kalk industry association represents 95 % (instead of 90 %, as reported in the NIR 2003[61]) of German lime production, although this share can vary over a course of years. The amount of fluctuation involved is considered rather low at the moment, however. It must be reviewed whether a year-specific share could be determined in retrospect. The time series in the CSE could then be retroactively adapted. The effects of such a measure are expected to be slight, however.

The quality of the uncertainties estimation is to be improved.

For future reporting, plans call for emissions from burning of dolomite to be estimated as well, even though these emissions are assumed to be less significant.

## 4.3 Chemical industry: Ammonia production (2.B.1)

### *4.3.1 Source category description (2.B.1)*

| **CRF 2.B.1** | | | | | |
|---|---|---|---|---|---|
| Key source | | Gas (MSG) | 1990 – contribution to total emissions | 2002 – contribution to total emissions | **Trend** |
| | NO | | | | |

| **Gas** | **$CO_2$** | **$CH_4$** | **HFCs** | **PFCs** | **$SF_6$** | **$N_2O$** | **$NO_X$** | **CO** | **NMVOC** | **$SO_2$** |
|---|---|---|---|---|---|---|---|---|---|---|
| Emissions factor[62] (EF) | | | | | | | | | | |
| EF uncertainties in % | | | | | | | | | | |
| Distribution of uncertainties [63] | | | | | | | | | | |
| Method for EF determination[64] | | | | | | | | | | |

60 Thus far, data from the Federal Statistical Office has been used. For the following reasons, these figures should not be used:
- They include only lime plants with more than 20 employees.
- The Federal Statistical Office queries the plant operators with regard to products, and not with regard to amounts of burnt lime. This means that burnt lime that is processed into hydraulic lime or slaked lime is not listed separately, and the relevant amounts listed differ from one another.
- Misallocations are possible (for example, it is possible that burnt lime from the sugar industry is being listed with figures for the lime industry.)

On the other hand, the BV Kalk lime industry association separate records amounts of oven-treated lime (i.e. burnt lime).

61 This figure was provided by the BV Kalk lime industry association as a first rough estimate for the NIR 2003. Subsequently, BV Kalk estimated member plants' share of total production to be higher and corrected the share to 95 %. This figure is based on more precise assumptions and broader background information. More precise figures cannot be provided, due to a lack of data on the lime plants that are not members of the association.

62 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model

63 N = Normal, L = Log normal, T = Triangular, U = Uniform (even distribution)

64 D = IPCC default, RA = Reference approach, T1= IPPC tier 1, T1a/ T1b/ T1c = IPPC tier 1a/ 1b/ 1c, T2 = IPPC tier 2, T3 = IPPC tier 3, C = CORINAIR, CS = Country-specific, M = Model

Ammonia is produced on the basis of hydrogen and nitrogen, using the Haber-Bosch procedure. Hydrogen is obtained from synthetic gas. It is generated in a highly integrated procedure within a steam reforming process, generally on the basis of natural gas. Nitrogen is provided by the decomposition of air.

The various plant types for the production of ammonia cannot be divided into individual units and be compared as independent process parts, due to the highly integrated character of the procedure. In steam reforming, a distinction is made between the following processes:

- ACP - Advanced Conventional Process with a fired primary reformer and secondary reforming with excess air (stoichiometric H/N ratio)
- RPR - Reduced Primary Reformer Process under mild conditions in a fired primary reformer and secondary splitting with excess air (sub-stoichiometric H/N ratio)
- HPR - Heat Exchange Primary Reformer Process – autothermic splitting with heat exchange using a steam reformer heated with process gas (heat exchange reformer) and a separate secondary reformer or a combined autothermic reformer using excess air or enriched air (sub-stoichiometric or stoichiometric H/N ratio).

The following procedure is also used:

- Partial oxidation – Gasification of fractions of heavy petroleum or vacuum residues in production of synthetic gas

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

Carbon dioxide emissions may arise in 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 have been taken from the paper "Final BAT Reference Document on Ammonia Production", which was prepared in 1995/96 as a provisional BAT code of practice (EIPPCB). 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 carried out as follows: |
| Emission (kt) = Ammonia production quantity (kt) x emission factor (kt/kt) |

### *4.3.3 Uncertainties and time-series consistency (2.B.1)*

The emission factor is only an average value and, given the various different production conditions involved, it cannot fully and precisely reflect the actual situation.

Because there are only seven ammonia producers in Germany, the data situation could be improved by contacting them directly and requesting them to report their carbon dioxide emissions.

### *4.3.4 Source-specific quality assurance / control and verification (2.B.1)*

Measures for standardisation of QC and QA are currently being prepared.

### *4.3.5 Source-specific planned improvements (2.B.1)*

No improvements are planned at present.

## 4.4 Chemical industry: Nitric acid production (2.B.2)

### *4.4.1 Source category description (2.B.2)*

| **CRF 2.B.2** | | | | | |
|---|---|---|---|---|---|
| Key source | | Gas (MSG) | 1990 – contribution to total emissions | 2002 – contribution to total emissions | **Trend** |
| Nitric acid production | I | $N_2O$ | 0,37 % | 0,39 % | falling |

| **Gas** | **$CO_2$** | **$CH_4$** | **HFCs** | **PFCs** | **$SF_6$** | **$N_2O$** | **$NO_X$** | **CO** | **NMVOC** | **$SO_2$** |
|---|---|---|---|---|---|---|---|---|---|---|
| Emissions factor[65] (EF) | NO | NO | NO | NO | NO | CS | CS | NO | NO | NO |
| EF uncertainties in % | | | | | | | | | | |
| Distribution of uncertainties [66] | | | | | | | | | | |
| Method for EF determination[67] | | | | | | | | | | |

In terms of emissions levels in 2002, $N_2O$ emissions from nitric acid production were a key source.

In production of nitric acid, nitrous oxide occurs in a secondary reaction. In Germany, there are currently only six plants for the production of nitric acid.

$HNO_3$ production occurs in two process stages:

a) **Oxidation** of $NH_3$ to NO and

b) **Conversion** of NO to $NO_2$ and **adsorption** in $H_2O$

Details of the process are outlined below:

**Catalytic oxidation of ammonia**

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

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 undesired secondary reactions:

$$4\ NH_3 + 3\ O_2 \rightarrow 2\ N_2 + 6\ H_2O$$

$$\mathbf{4\ NH_3 + 4\ O_2 \rightarrow 2\ N_2O + 6\ H_2O}$$

All three oxidation reactions are exothermic. Heat may be recovered to produce steam for the process and for export to other plants and/or to preheat the residual gas. The reaction water is condensed in a cooling condenser, during the cooling of the reaction gases, and is then conveyed into the absorption column.

## *4.4.2 Methodological issues (2.B 2)*

### 4.4.2.1 Activity data

The activity data has been taken from the Federal Statistical Office (Manufacturing sector, Fachserie 4, Reihe 3.1: Production in the manufacturing industry). Since there are no consistent time series for the time period involved, a number of adjustments had to be made:

For the old German Länder, production data was available for 1990-1992 (Melde-Nr. (registration number) 4123 10); this data was converted from N to $HNO_3$ (*63/14). For the new German Länder, only an estimate is available for 1990. Production data is available for 1991-1992 (Melde-Nr. 4123 10); this data was converted from N to $HNO_3$ (*63/14).

Beginning in 1993, production figures are no longer listed separately for the new and old German Länder; for this reason, the 1993 and 1994 figures for the new and old German Länder were determined in keeping with the relevant regions' share of total production in 1992.

Since the change in the federal statistics, production figures pursuant to Melde-Nr. 2415 10 503 are used for the years 1995-2001, and the figures are converted from N to $HNO_3$ (*63/14). Since 2002, the Federal Statistical Office no longer lists this statistic, which is required separately, with the result that the combined production figure, under Melde-Nr. (registration no.) 2415 10 500 (nitric acid, nitrating acids) has to be used. This figure is multiplied by nitric acid's share in this combined statistic in 2001 (0.693), and then converted from N to $HNO_3$ (*63/14).

### 4.4.2.2 Emission factors and emissions

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

#### *4.4.2.2.1 Requirements from international reporting guidelines*

Nitrous oxide emissions $E_{N2O}$ [kg] are calculated from the activity rate [t $HNO_3$], a pertinent emission factor [kg $N_2O$/t $HNO_3$] and, if applicable, the efficiency and relative operating time of a system for $N_2O$ emissions reduction, with:

*$E_{N2O}$ = AR x EF x (1 – $N_2O$-reduction factor x rel. operating time of reduction system)*

*AR = Activity rate*

*EF = Emission factor*

The relative operating time of the $N_2O$-reduction system was included so that down time could be taken into account. Alternatively, the entire last term can be included within the EF.

Since EF depend strongly on plant type and on $N_2O$-reduction method used, emissions for key sources should be determined at the plant level. To this end, the activity rate and emission factor must be determined in each case, or emissions must be measured in each plant. If the operator provides the data, it must be ensured that adequate QC/QA measures are carried out.

The EF listed in the guidelines range from less than 2 to 19 kg $N_2O$/t $HNO_3$, and they depend strongly on plant age, plant design and type of $NO_x$-reduction equipment used. If production data, but no emissions measurements, are available for each plant type, adequate default values from the guidelines should be used. Activity rates that have been aggregated across different plant types should be used only if more detailed data cannot be obtained.

In determination of plant-specific EF, regular measurements, carried out at different types, are normally able to prevent systematic errors and to provide the desired degree of precision. Normally, it is a good practice to carry out measurements and analyses whenever significant changes in a plant's processes occur that affect the rate at which $N_2O$ is produced. In addition, such measurements should serve the purpose of ensuring that the operational conditions have remained constant. Plant operators should be queried annually regarding their reduction technologies, and they should confirm that they have indeed used the technologies they have described. For precise determination of emissions rates and efficiencies of $N_2O$-reduction systems, measurements of both controlled and uncontrolled waste-gas flows must be carried out. Where measurement data is available only for controlled waste gases, it is good practice to base emissions figures on this data. In such cases, estimates of the efficiency of $N_2O$-reduction systems should be used only for information purposes and should not be used in emissions calculations.

For European systems ("dual pressure, double absorption"), 8-10 kg $N_2O$/t is proposed as the default value; for older systems dating from before 1975, 10-19 kg $N_2O$/t is proposed. Non-selective catalytic reduction (NSCR) for reducing $NO_x$ emissions also destroys $N_2O$, and the relevant reduction rate is given as 80-90%. Other methods for $NO_x$ reduction either have no impact on $N_2O$ emissions or can even increase them.

#### *4.4.2.2.2 Status of reporting in the Federal Republic of Germany*

Since 1990, the $N_2O$ emission factor has been consistently given as 5.5 kg $N_2O$/t $HNO_3$. In the underlying research project [68] from 1993, it is assumed, however, that 283 kg $NH_3$/t $HNO_3$ are used for production of nitric acid, and that some 1.5 % of this ammonia are converted into $N_2O$. A check calculation using industry figures (3120 $m^3$ waste gas/t $HNO_3$ and 500-1000 ppm $N_2O$) confirmed the above emission factor, in terms of order of magnitude, by yielding 3.1-6.2 kg $N_2O$/t $HNO_3$.

$NO_x$ emissions figures for the entire period are based on UBA-specific emission factors that have decreased strongly over time. This trend is based on a forecast for 2010 pursuant to which in that year the average specific emissions will be on the order of those of state-of-the-art plants in 1997 (0.75 kg/t).

At present, no emission factors from plant data are available.

As of 2010, old plants may no longer exceed the applicable emissions standard, from TA Luft 2002, of 800 mg $N_2O/m^3$.

Table 37: $N_2O$ and $NO_x$ emission factors from nitric acid production

| Year | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $N_2O$ [kg/Mg] | 5,5 | 5,5 | 5,5 | 5,5 | 5,5 | 5,5 | 5,5 | 5,5 | 5,5 | 5,5 | 5,5 | 5,5 | 5,5 |
| $NO_x$ [kg/Mg] | 7,9 | 6,6 | 5,0 | 3,7 | 3,0 | 2,5 | 2,1 | 1,8 | 1,6 | 1,5 | 1,4 | 1,35 | 1,29 |

In light of the objective dependencies between the emission factors for the two gases (cf. Chapter 4.4.2.2.1), consistent use of the same $N_2O$ emission factors is not plausible, and more accurate figures must be used.

Table 38: $N_2O$ and $NO_x$ emissions from nitric acid production

| Year | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $N_2O$ [Gg] | 15,1 | 12,0 | 11,0 | 11,0 | 11,1 | 12,7 | 12,1 | 12,1 | 12,0 | 12,5 | 13,4 | 11,8 | 12,9 |
| $NO_x$ [Gg] | 21,7 | 14,3 | 10,1 | 7,3 | 6,1 | 5,8 | 4,6 | 4,0 | 3,5 | 3,4 | 3,4 | 2,9 | 3,0 |

### *4.4.3 Uncertainties and time-series consistency (2.B.2)*

To date, no uncertainties for activity rates and emission factors have yet been determined. A standardised procedure for quality assurance in emissions calculations is currently being prepared.

The emissions-determination process normally requires not only the produced amount sold; it also requires the entire produced amount, including amounts directly processed further within the plant. On the basis of the supposition that a significant portion of production is not sold, it must be determined whether production statistics include produced amounts that do not enter the market. Furthermore, it must be verified whether the Federal Statistical Office takes all plants into account.

The procedure as of 2002, as described under 4.4.2.1, needs to be reviewed.

[68] M. Schön, R. Walz et al., 1993: Emissionen der Treibhausgase Distickstoffoxid und Methan in Deutschland, Phase 1

### *4.4.4 Source-specific quality assurance / control and verification (2.B.2)*

A standardised procedure for quality assurance in emissions calculations is currently being prepared. In addition, it must be determined what QC/QA measures are already in place for the available data sources, and what such measures could be introduced.

### *4.4.5 Source-specific planned improvements (2.B.2)*

Where no emissions measurements for specific plant types are available, but activity rates are available for emission factors, adequate Länder-specific emission factors should be derived on the basis of the default values from the guidelines. For derivation of emission factors, it is necessary to know whether the activity rates have the same degree of differentiation as the emission factors. Aggregations should be carried out only where detailed activity rates are lacking for the relevant individual types.

In 2010, all existing plants in Germany must meet the requirements of the Clean Air Directive (*TA Luft 2002*). The limit of 800 mg/m$^3$ for $N_2O$ emissions can be met by installing a catalytic reducer. Against this background, it will become possible to obtain more precise emission factors.

## 4.5 Chemical industry: Adipic acid production (2.B.3)

### *4.5.1 Source category description (2.B.3)*

| **CRF 2.B.3** | | | | | |
|---|---|---|---|---|---|
| Key source | | Gas (MSG) | 1990 – contribution to total emissions | 2002 – contribution to total emissions | **Trend** |
| Adipic acid production | t | $N_2O$ | 1,51 % | 0,30 % | falling |

| **Gas** | **$CO_2$** | **$CH_4$** | **HFCs** | **PFCs** | **$SF_6$** | **$N_2O$** | **$NO_X$** | **CO** | **NMVOC** | **$SO_2$** |
|---|---|---|---|---|---|---|---|---|---|---|
| Emissions factor[69] (EF) | | | | | | | | | | |
| EF uncertainties in % | | | | | | | | | | |
| Distribution of uncertainties [70] | | | | | | | | | | |
| Method for EF determination[71] | | | | | | | | | | |

In terms of trends in 2002, adipic acid production represents a key source.

On a plant scale, adipic acid is produced via oxidation of cyclohexanol with nitric acid. In this reaction, considerable amounts of nitrous oxide ($N_2O$) are formed. Until the end of 1993, the two sole German producers emitted all of their nitrous oxide directly into the atmosphere. One producer has since patented, and put into operation, a system for thermal decomposition of nitrous oxide into nitrogen and oxygen. The decomposition is quantitative; i.e., no nitrous oxide is emitted into the atmosphere as long as the system is operating properly. At the end of 1997, the other producer put a catalytic reactor system into operation that, in constant operation, achieves a $N_2O$-decomposition rate of 97-98%. In March 2002, operations were begun with a plant, from another producer, that also uses thermal $N_2O$ decomposition. Following initial technical problems, the system has been in constant operation since 2003.

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

### *4.5.2 Methodological issues (2.B.3)*

Until around the mid-1990s, producers provided data only on amounts produced. For calculation of nitrous oxide emissions for this period, the IPCC's default emission factors were used, and "zero" emission factors were used for quantitatively decomposed production. For the subsequent period, the straightforward emissions figures of the remaining producer with emissions-relevant production were used. At the same time, production data continued to be available for this producer. The figures of the third producer, who appeared later, are of a similar extent.

Variations in emissions figures for the most recent period result from disruption of the reduction systems (fire damage, failure of system components).

### *4.5.3 Uncertainties and time-series consistency (2.B.3)*

As a result of changes in the systems, as described in the previous chapters, and owing to the data provided, consistency is not complete.

The uncertainties relative to the data provided are considered slight. Corresponding uncertainties result from the IPCC emission factor range of +/- 10 % that was used from 1990 until 1996 (in part). Furthermore, it is unknown whether the above-described quantitative decomposition was achieved for all amounts produced.

### *4.5.4 Source-specific quality assurance / control and verification (2.B.3)*

Manufacturers' figures enjoy a high degree of confidentiality protection. The firms in question were assured of this. For this reason, only emissions figures could be listed in the CRF tables. No calculations for verification could be carried out. It should also be noted, however, that the manufacturers provided some of the figures to licensing authorities.

### *4.5.5 Source-specific recalculations (2.B.3)*

No source-specific recalculations have been carried out.

It may be assumed, however, that the improvements described in the following chapter could necessitate at least small corrections for the entire period covered by the present report.

### *4.5.6 Source-specific planned improvements (2.B.3)*

Efforts are being made to have all operators provide all relevant figures, in the near term, for the entire period covered by the present report.

# 4.6 Chemical industry: Methane emissions from other production processes (2.B.5)

## *4.6.1 Source category description (2.B.5)*

| **CRF 2.B.5** | | | | | |
|---|---|---|---|---|---|
| Key source | | Gas (MSG) | 1990 – contribution to total emissions | 2002 – contribution to total emissions | **Trend** |
| | | | | | |

| **Gas** | **$CO_2$** | **$CH_4$** | **HFCs** | **PFCs** | **$SF_6$** | **$N_2O$** | **$NO_X$** | **CO** | **NMVOC** | **$SO_2$** |
|---|---|---|---|---|---|---|---|---|---|---|
| Emissions factor[72] (EF), soot | NO | D | NO | NO | NO | NO | NO | D | NO | D |
| Emissions factor[73] (EF), ethylene, styrene | NO | D | NO | NO | NO | NO | NO | NO | D | NO |
| Emissions factor[74] (EF), methanol, dichloroethylene | NO | D | NO | NO | NO | NO | NO | NO | NO | NO |
| EF uncertainties in % | | | | | | | | | | |
| Distribution of uncertainties [75] | | | | | | | | | | |
| Method for EF determination[76] | | | | | | | | | | |

Various chemical production processes, such as production of soot, ethylene (ethene), dichloroethylene, styrene and methanol, are sources of NMVOC emissions and potential sources of methane emissions. $CH_4$ can occur as a secondary product of industrial processes and then be emitted into the atmosphere. To date, the German greenhouse-gas inventory has not taken such sources into account. It is possible that other greenhouse gases, in addition to methane, are emitted, although no findings in this regard have been obtained to date.

## *4.6.2 Methodological issues (2.B.5)*

The international guidelines give very little attention to this group of emitters. The IPCC Guidelines list as potential sources – without any claim to completeness – production of soot, ethylene, dichloroethylene, styrene and methanol. The guidelines list emission factors for the processes that were identified in studies from 1987 and 1988: These IPCC default EF are listed in Table 39 below.

Table 39: IPCC default emission factors ([kg $CH_4$ / t ]) for $CH_4$ from other chemical industry processes

| **Soot** | **Styrene** | **Ethylene** | Dichloroethylene | Methanol |
|---|---|---|---|---|
| 11 | 4 | 1 | 0,4 | 2 |

The IPCC Good Practice Guidance does not discuss this subject further.

The following figures, from inventory reports of other countries, could provide information relative to the EF that should be used for Germany:

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

- Japan:
  From representative waste-gas measurements, EF were formed that, in some cases, are more than 30-80 times smaller than the IPCC defaults. This is due to reduction measures (methane recovery, flaring) that, presumably, have not yet been taken into account in the IPCC defaults.
- Portugal:
  This country's EF for soot production, which is 25 % below the IPCC default, was obtained from measurements made in 1990-94 at the country's sole producer.

Table 40: Emission factors used in Germany for others of the above-considered pollutants

| | **Soot** [kg CO / t] | **Soot** [kg $SO_2$ / t] | **Ethylene** [kg NMVOC / t] | **Styrene** [kg NMVOC / t] |
|---|---|---|---|---|
| 1990 | 4,8 / 5 | 19,5 / 1) | 5 | 0,25 |
| 1991 | 4,6 / 5 | 19 / 20 | 5 | 0,25 |
| 1992 | 4,4 / 5 | 18,5 / 20 | 5 | 0,25 |
| 1993 | 4,2 | 18 | 5 | 0,25 |
| 1994 | 4 | 17,5 | 5 | 0,25 |
| 1995 | 3,75 | 17 | 5 | 0,25 |
| 1996 | 3,5 | 16 | 5 | 0,25 |
| 1997 | 3,25 | 15 | 5 | 0,25 |
| 1998 | 3 | 14 | 5 | 0,25 |
| 1999 | 2,9 | 13,4 | 5 | 0,25 |
| 2000 | 2,8 | 12,8 | 5 | 0,25 |
| 2001 | 2,7 | 12,54 | 5 | 0,25 |

Remark:

Where two EF are listed, the second figure refers to the new German Länder.

The figures for NMVOC were taken from the European Commission (ed.; 1994). The EF figures for CO and $SO_2$ in soot production are based on assumptions of the responsible expert within the Federal Environmental Agency.

The following activity rates for Germany (Table 42) were taken from the production statistics (Table 41) of the Federal Statistical Office / DESTATIS.

Table 41: Reporting numbers (Meldenummern) from production statistics

| Production | **Soot** | **Ethylene** | **Styrene** |
|---|---|---|---|
| - 1994 | unknown | 422111 | 422460 |
| as of 1995 | 241311300 | 241411300 | 241412500 |

Table 42: Activity rates of soot, ethylene and styrene ([t])

| Production | | **Soot** | **Ethylene** | **Styrene** |
|---|---|---|---|---|
| | Area | | | |
| 1990 | D | 401000 | 3071829 | 1289781 |
| 1990 | ABL | 394000 | 3071829 | 1289781 |
| 1990 | NBL | 7000 | 0 | 0 |
| 1990 | D | 382000 | 3059474 | 1208046 |
| 1991 | ABL | 380000 | 3059474 | 1208046 |
| 1991 | NBL | 2000 | 0 | 0 |
| 1992 | D | 377000 | 3335942 | 1130836 |
| 1992 | ABL | 376000 | 3335942 | 1130836 |
| 1992 | NBL | 1000 | 0 | 0 |
| 1993 | D | 335000 | 3904814 | 1041505 |
| 1993 | ABL | 335000 | 3904814 | 1041505 |
| 1993 | NBL | 0 | 0 | 0 |
| 1994 | D | 299000 | 4182722 | 1150723 |
| 1994 | ABL | 299000 | 4182722 | 1150723 |
| 1994 | NBL | 0 | 0 | 0 |
| 1995 | D | 330799 | 4163377 | 1080531 |
| 1996 | D | 315587 | 3814680 | 1151244 |
| 1997 | D | 337579 | 4186421 | 1099974 |
| 1998 | D | 343319 | 4269586 | 1182697 |
| 1999 | D | 338542 | 4894764 | 1096934 |
| 2000 | D | 345976 | 5119316 | 1089573 |
| 2001 | D | 348371 | 5005029 | 957750 |
| 2002 | D | | | |

D: Germany; ABL: Old German Länder; NBL: New German Länder

The data for ethene production until 1992, and for soot production until 1994, have been taken from the Statistical Yearbook for the Federal Republic of Germany (Statistisches Jahrbuch für die Bundesrepublik Deutschland; soot figures for 1990 in 1992 edition, on p. 234, and soot figures for new German Länder, for 1991 and 1992, estimated).

The data for soot production as of 1995, and for ethene and styrene production as of 1990, were taken from the Federal Statistical Office (Manufacturing sector, Fachserie 4, Reihe 3.1, production in manufacturing sector).

Using methods similar to those used for other source categories, a Tier 1 calculation could be carried out with the following formula:

Emissions = Emission factor x activity rate

If the emissions so determined prove to be low, estimation pursuant to this Tier 1 procedure suffices. If the group, contrary to expectations, proves to be a key source, national emission factors should be determined or, better still, detailed measurements should be carried out in the various relevant plants (so-called "Tier 2/3" calculation).

Non-combustion-related emissions in the new German Länder prior to 1991 are included in the non-disaggregated sum figures up until 1990; as a result, these emissions cannot be listed.

### *4.6.3 Uncertainties and time-series consistency (2.B.5)*

The time series for ethene, styrene and soot, some of which are incomplete, need to be verified. In the process, it must be determined whether suitable activity data for each entire time series can be obtained, by reasonable means, and the likely uncertainties must be identified.

No activity data and no national emission factors are available, for German inventories, for dichloroethylene and methanol. It must be determined whether the existing IPCC default emission factors are representative for Germany or should be replaced with other national emission factors.

Since the IPCC guidelines do not list all chemical industry processes, it should be determined whether other relevant areas emit significant amounts of methane and, if this is the case, the availability of data for these areas should be reviewed. In particular, additional emissions could be present in petrochemical production.

### *4.6.4 Source-specific quality assurance / control and verification (2.B.5)*

No source-specific quality assurance / control and verification has been carried out to date.

### *4.6.5 Source-specific recalculations (2.B.5)*

No source-specific recalculations have been carried out.

### *4.6.6 Source-specific planned improvements (2.B.5)*

This area is to be treated separately at the planned NaSE workshop.

## 4.7 Metal production: Iron and steel production (2.C.1)

### *4.7.1 Source category description (2.C.1)*

| **CRF 2.C.1** | | | | | |
|---|---|---|---|---|---|
| **Key source** | | **Gas (MSG)** | **1990 – contribution to total emissions** | **2002 – contribution to total emissions** | **Trend** |
| | NO | | | | |

| **Gas** | **$CO_2$** | **$CH_4$** | **HFCs** | **PFCs** | **$SF_6$** | **$N_2O$** | **$NO_X$** | **CO** | **NMVOC** | **$SO_2$** |
|---|---|---|---|---|---|---|---|---|---|---|
| Emissions factor[77] (EF) | D | NO | NO | NO | NO | NO | D | D | D | D |
| EF uncertainties in % | | | | | | | | | | |
| Distribution of uncertainties [78] | | | | | | | | | | |
| Method for EF determination[79] | | | | | | | | | | |

In Germany, raw steel is produced from ore in six integrated foundries. The production equipment used includes sintering plants, blast furnaces and oxygen steel plants with downstream continuous casting plants and hot-rolling lines.

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

Raw steel is produced from scrap 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) – waste gas from sintering belt
- **Pig iron** (blast furnace) – blast-furnace charging and tapping. and blast heating apparatus
- **Top-blown steel** (top-blown-steel works) – (waste) gas from converter
- **Electric steel** (electric steel works) – waste gas from flue
- **Hot-rolled steel** (hot-rolling mill) – waste gases from heat-treatment furnaces

Emissions of climate-relevant pollutants, particularly CO, $CO_2$, $NO_x$, $SO_2$ and NMVOC, occur at all process stages.

### *4.7.2 Methodological issues (2.C.1)*

The emission factor used for $CO_2$ is the IPCC default value of 1.6 t/t iron or steel. The activity rate in 2002 was 31,809 kt raw steel (DESTATIS, a). This results in emissions of 50,894.4 kt $CO_2$ for 2002.

The emission factor used for $NO_X$ is the IPCC default value of 76 g/t pig iron (pig-iron production) plus 40 g/t steel (steel processing, rolling mill). The activity rate in 2002 for pig-iron production was 29,427 kt (DESTATIS, b), and for steel processing it was 37,763 kt (hot-rolled steel products) (DESTATIS, c). $NO_X$ emissions in 2002 amounted to 3.747 kt.

The emission factor used for NMVOC is the IPCC default value of 100 g/t pig iron (blast-furnace charging) plus 20 g/t pig iron (tapping off pig iron) plus 30 g/t steel (steel processing, rolling mill). The activity rate in 2002 for pig-iron production was 29,427 kt (DESTATIS, b), and for steel processing it was 37,763 kt (hot-rolled steel products) (DESTATIS, c). This results in NMVOC emissions of 4.664 kt for 2002.

The emission factor used for CO is the IPCC default value of 1,300 g/t pig iron (blast-furnace charging) plus 112 g/t pig iron (tapping for pig iron) plus 1 g/t steel (steel processing, rolling mill). The activity rate in 2002 for pig-iron production was 29,427 kt (DESTATIS, b), and for steel processing it was 37,763 kt (hot-rolled steel products) (DESTATIS, c). This results in 41,589 kt of CO emissions in 2002.

The emission factor used for $SO_2$ is a mean IPCC default value of 2,000 g/t pig iron (blast-furnace charging) plus 30 g/t pig iron (tapping for pig iron) plus 45 g/t steel (steel processing, rolling mill). The activity rate in 2002 for pig-iron production was 29,427 kt (DESTATIS, b), and for steel processing it was 37,763 kt (hot-rolled steel products) (DESTATIS, c). This results in 61.436 kt of $SO_2$ emissions in 2002.

### *4.7.3 Uncertainties and time-series consistency (2.C.1)*

Due to a lack of data, the pertinent uncertainties and time-series consistency have not yet been estimated.

### *4.7.4 Source-specific quality assurance / control and verification (2.C.1)*

Measures for standardisation of QC and QA are currently being prepared.

### *4.7.5 Source-specific recalculations (2.C.1)*

Due to a lack of data, recalculation has not been possible to date in this area.

### *4.7.6 Source-specific planned improvements (2.C.1)*

Plans call for compiling a comprehensive database that will make it possible to determine process-related and energy-related emissions separately.

This data will make it possible to estimate pertinent uncertainties and carry out source-specific recalculations.

## 4.8 Metal production: Primary aluminium production (2.C.3)

### *4.8.1 Source category description (2.C.3)*

| **CRF 2.C.3** | | | | | |
|---|---|---|---|---|---|
| Key source | | Gas (MSG) | 1990 – contribution to total emissions | 2002 – contribution to total emissions | **Trend** |
| Aluminium production | xt | PFCs | 0,20 % | 0,04 % | falling |

| **Gas** | **$CO_2$** | **$CH_4$** | **HFCs** | **PFCs** | **$SF_6$** | **$N_2O$** | **$NO_X$** | **CO** | **NMVOC** | **$SO_2$** |
|---|---|---|---|---|---|---|---|---|---|---|
| Emissions factor[80] (EF) | CS | NE | NO | CS | NO | NO | NE | CS | NO | CS |
| EF uncertainties in % | 15 | | | 15 | | | | | | |
| Distribution of uncertainties [81] | N | | | N | | | | | | |
| Method for EF determination[82] | T3 | | | T3 | | | | | | |

In terms of its trend, primary aluminium production is a key source.

In Germany, aluminium is produced at five foundries, in electrolytic furnaces with pre-burnt anodes. The principal emission sources are the waste gases from the electrolytic furnaces and fugitive emissions via the hall roofs. The principal climate-relevant pollutants emitted are CO, $CO_2$, $SO_2$, $CF_4$ and $C_2F_6$.

Production of primary aluminium continues to be the largest source of PFC emissions in Germany, in spite of the considerable reductions that have been achieved since 1990. In this area, PFCs are produced in the production process as secondary products of electrolytic reduction of aluminium oxide (from alum earth) to aluminium. Thanks to extensive modernisation measures in German aluminium foundries, and to decommissioning of production capacities, absolute emissions from this sector fell by 71 % between 1995 and 2002. As to the future development of PFC emissions, stagnation at a low level can be expected.

### *4.8.2 Methodological issues (2.C.3)*

The production figures for the year 2002 were taken from the monitoring report by the aluminium industry for the year 2002. The average anode consumption is 430 kg of petrol coke per tonne of aluminium. Table 43 shows the process-related emission factors.

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

The total quantity of waste gas incurred per tonne of aluminium during the production of primary aluminium was multiplied by an average concentration value formed from several individual figures, from various different plants, with appropriate weighting. The emission factors also make allowance for diffuse emission sources, such as emissions via hall roofs. The emission figures used for CO are the results of emission measurements within the context of investment projects.

The emission factors for $SO_2$ and $CO_2$ were calculated from the specific anode consumption. The anodes consist of petrol coke; this material has specific sulphur concentrations that can be used to calculate an $SO_2$ emission factor. Theoretically, the $CO_2$ emission factor must be reduced by the proportion resulting from a CO component of 180 kg/t Al, since CO can also form only via consumption of anodes. The $CO_2$ factor listed below does not take this into account.

The emission factors shown in Table 43 were compared with the emission data in Best Available Technology (BAT) data sheets and other sources (such as VDI Guideline 2286 sheet 1).

Table 43: Activity rates and process-related emission factors for primary aluminium production in 2002

| | Production | Emission factors [kg/t] | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **[kt]** | $CO_2$ | $CF_4$ | $C_2F_6$ | $NO_X$ | $SO_2$ | C total | CO |
| Primary aluminium | 654,502 | 1367 | 0,09 | 0,01 | NA | 6,02 | NA | 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. The measurement data is not published, but is made available to the Federal Environmental Agency.

The measurements conducted in all German foundries in the year 2001 form the basis for calculation of $CF_4$ emissions. In this context, specific $CF_4$ emission factors per anode effect[83] were calculated, depending on the technology used. The number of anode effects is recorded and documented in the foundries. The total $CF_4$ emissions in 2002 were calculated by multiplying the total anode effects by the specific $CF_4$ emissions per anode effect determined in 2001. The total emission factor for $CF_4$ is obtained by adding the $CF_4$ emissions of the five foundries and then dividing the sum by the total aluminium production of the foundries. $C_2F_6$ and $CF_4$ occur in a constant ratio of about 1:10. PFC emissions have been determined in accordance with this method since 2001.

### *4.8.3 Uncertainties and time-series consistency (2.C.3)*

The figures for PFC, CO, $CO_2$ and $SO_2$ emissions are in keeping with the Tier 3b approach and are thus considered very accurate.

The time series for CO, $CO_2$ and $SO_2$ are consistent. Data for PFCs (frequency of anode effects) has been collected only since 2001. A time series can be produced until 1990, on the basis of estimates and studies of the aluminium industry. For the period prior to 2001, this

83 „...Organic fluorides occur only under certain conditions, and such conditions occur in the furnace repeatedly, at intervals of hours to severals days. These conditions are referred to as the "anode effect". ... The gas at the anode changes in composition from $CO_2$ to CO and 5 to 20% $CF_4$...." (ÖKO-RECHERCHE 1996)

does not conform to the Tier 3b approach; it has considerably higher uncertainties and can be considered conformal with the Tier 1b approach.

### *4.8.4 Source-specific quality assurance / control and verification (2.C.3)*

Specific PFC emissions during anode effects were determined via industry measurements carried out in 2001 at all plants in Germany that produce primary aluminium. In each case, the amount of PFCs produced depends on the duration of the relevant anode effects. Operators are able to influence and minimise the duration and frequency of anode effects. The German emission factor for $CF_4$ resulting from anode effects is 0.09 kg/t aluminium. This factor is slightly below the average international factor, as reported by the International Aluminium Institute (IAI), of 0.11 kg/t for point-feeder systems. The emission factor thus appears to have been verified.

Industry collects activity data on an annual basis and reports it to the Federal Statistical Office, among other institutions. The relevant time series seems plausible and shows no inconsistencies. It is assumed that collection of this data is subject to quality assurance measures.

### *4.8.5 Source-specific recalculations (2.C.3)*

Up until 1998, emission data was based on surveys amongst the foundries with regard to production capacity and equipment used (number and duration of anode effects); the responses were used in order to calculate emissions. This method (Tier 1 b) should be considered less precise than measurement. A time series can be produced until 1990, on the basis of estimates and studies of the aluminium industry. Recalculation in keeping with the above Tier 3b approach is not possible, however.

### *4.8.6 Source-specific planned improvements (2.C.3)*

No improvements are planned at present.

# 4.9 Metal production: $SF_6$ used in aluminium and magnesium foundries (2.C.4)

## *4.9.1 Source category description (2.C.4)*

| **CRF 2.C.4** | | | | |
|---|---|---|---|---|
| Key source | Gas (MSG) | 1990 – contribution to total emissions | 2002 – contribution to total emissions | **Trend** |
| $SF_6$ in aluminium and magnesium foundries | $SF_6$ | 0,01 % | 0,02 % | rising |

| **Gas** | **$CO_2$** | **$CH_4$** | **HFCs** | **PFCs** | **$SF_6$** | **$N_2O$** | **$NO_X$** | **CO** | **NMVOC** | **$SO_2$** |
|---|---|---|---|---|---|---|---|---|---|---|
| Emissions factor[84] (EF) | | | | | - | | | | | |
| EF uncertainties in % | | | | | - | | | | | |
| Distribution of uncertainties [85] | | | | | - | | | | | |
| Method for EF determination[86] | | | | | - | | | | | |

In terms of trend, use of $SF_6$ in aluminium and magnesium production is a key source.

Prior to casting of molten aluminium, the inert gases nitrogen and/or argon are introduced to remove (degas) hydrogen, as well as alkaline and alkaline earth metals and solids; this prevents porosity in cast pieces. Halogens (chlorine, fluorine, etc.) are introduced for cleansing purposes. Generally speaking, inert gases without additives are sufficient for rinsing secondary molten aluminium. A purification system of inert gases, with added $SF_6$ at a concentration of 1 or 2.5 %, has been used in the past in a few – usually smaller – secondary aluminium foundries and in laboratories. A survey of the market for $SF_6$ in aluminium production revealed that such purification systems are no longer used (no sales in Germany). Pure $SF_6$ is still used as a purification gas in some instances, however.

In magnesium casting, $SF_6$ is used as a protective gas over molten magnesium to prevent its oxidation and ignition. $SF_6$ has been used in this application since the mid-1970s. Use of this gas has competed with use of $SO_2$. Because $SF_6$ is easier to handle than the highly toxic $SO_2$, it became widely used in many new foundries. In Germany, protective gas is only used for the processing of magnesium that has been imported in ingot form.

## *4.9.2 Methodological issues (2.C.4)*

All of the $SF_6$ used in Germany to purify molten aluminium is emitted completely upon use (consumption = emission). The practice of assuming the equivalence between consumption and emissions conforms to the IPCC method (IPCC Guidelines, 1996).

A survey of the two providers of the relevant $SF_6$-containing gas mixture – the only two providers to date – revealed that this mixture has not been sold since 2000.

For the 2002 report year, gas providers' $SF_6$ sales figures were compared, for the first time, with data on amounts consumed by industry. This made it possible to identify $SF_6$ users in the area of aluminium casting. In previous years, the available information made it necessary to assume that only the $SF_6$-containing purification system, and not any pure $SF_6$, was being used. For this reason, no surveys of individual foundries were carried out.

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

The quantity of $SF_6$ used for magnesium production (consumption, activity) is equated with emissions, in accordance with the revised IPCC Guidelines (IPPC et al, 1996). $SF_6$ consumption is determined via direct surveys of foundries aimed at determining annual consumption levels. This is a feasible approach, since there are not a great many foundries. The usage data obtained is cross-checked against gas sellers' sales figures for this sector (these figures are also obtained via surveys).

The method outlined was applied for the reporting years 1995, 1997, 1998, 2000, 2001 and 2002. The missing annual data has been obtained by means of interpolation.

The emission factors listed in the CRF tables are obtained, via recalculation, from metal-production figures and the determined emissions (= consumption).
The factors have not been used for emissions calculations.Table 44 contains an overview of the current status of data reporting (reporting year 2002). For the reporting years 1995 to 2000, certain other factors apply in some cases.

Table 44: Overview of data reporting and emission factors used in TABLE 2(II)s1, C. Metal Production

| | Reported data 2002 | **Substance** |
|---|---|---|
| $SF_6$ in aluminium production | yes [Equ. 3.12] | $SF_6$ |
| $SF_6$ in magnesium foundries | yes [Equ. 3.12] | $SF_6$ |

Equ. = Equation; equation from the IPCC Guidelines

### *4.9.3 Uncertainties and time-series consistency (2.C.4)*

As noted in Chapter 4.9.2, the emission factors listed in the CRF tables result simply through calculation using the amount of metal produced and the determined emissions (= consumption). It is thus of little use to quantify uncertainties.

The uncertainties for the emissions result direct from the uncertainties for the identified usage amounts. The usage amounts determined for Mg foundries are considered sufficiently precise, since they were obtained via direct surveys of purchasing data. The usage amounts determined via the two different procedures (foundries, gas sellers; see above) show good agreement. The relevant uncertainty cannot be quantified.

The usage determined for the Al foundries are currently still considered to be imprecise. The time series for $SF_6$ emissions from aluminium production is inconsistent, due to use of an additional source that was identified for the first time for 2002, in the framework of reporting. The emissions figures determined for the previous report years are considered unreliable, since they do not use this source, and they need to be rechecked. Final verification is required for the emissions figures estimated for the 2002 report year. The relevant uncertainty cannot be quantified.

### *4.9.4 Source-specific quality assurance / control and verification (2.C.4)*

Quality assurance / control for amounts consumed in Mg foundries is carried out by compariing findings from foundry surveys with $SF_6$ sales figures – including both total sales and sales by gas sellers. As to amounts consumed by Al foundries, for the 2002 report year, sales figures were compared for the first time with amounts used by industry, and this comparison revealed a discrepancy. This led to identification of a new source.

The data for the 2002 report year, like the data for most of the previous years, was collected by an external expert working under commission to the Federal Environmental Agency. For the most part, quality assurance was carried out by an external expert. In addition, where possible, the data is checked by the relevant Federal Environmental Agency specialist upon receipt.

A standardised QA/QC method is currently being developed by the Federal Environmental Agency, in co-operation with a research partner.

### *4.9.5 Source-specific recalculations (2.C.4)*

No recalculations have been carried out to date, although recalculations are required for the source $SF_6$ from aluminium production for report years prior to 2002. Recalculation is planned in connection with the data survey for the 2003 report year.

In future, calculations will use better consumption data from magnesium foundries. This may necessitate recalculations in the 2003 report year.

### *4.9.6 Source-specific planned improvements (2.C.4)*

There are plans to review the market development of $SF_6$ in aluminium production regularly over the next few years. Such review will include gas sellers and users of $SF_6$. Plans also call for reaching agreements with users on regular data provision.

There are also plans to carry out future options and improvements for $SF_6$ data collection in magnesium processing in collaboration with the magnesium processors themselves.

## 4.10 Other production (2.D.1): Pulp and paper

### *4.10.1 Source category description (2.D.1)*

| **CRF 2.D.1** | | | | | |
|---|---|---|---|---|---|
| Key source | | Gas (MSG) | 1990 – contribution to total emissions | 2002 – contribution to total emissions | **Trend** |
| | NO | | | | |

| **Gas** | **$CO_2$** | **$CH_4$** | **HFCs** | **PFCs** | **$SF_6$** | **$N_2O$** | **$NO_X$** | **CO** | **NMVOC** | **$SO_2$** |
|---|---|---|---|---|---|---|---|---|---|---|
| Emissions factor[87] (EF) | NO | NO | NO | NO | NO | NO | NO | NO | NO | CS |
| EF uncertainties in % | | | | | | | | | | |
| Distribution of uncertainties [88] | | | | | | | | | | |
| Method for EF determination[89] | | | | | | | | | | |

All emissions of climate-relevant gases from the pulp and paper industry in Germany result from combustion of fuels; for this reason, they are reported in Chapter 3.1 as energy-related emissions. The pulp and paper industry does not produced any process-related emissions of climate-relevant gases within the meaning of the *IPCC Good Practice Guidelines*.

In pulp production with the sulphate procedure (1 of 5 pulp plants in Germany), carbonate is extracted from the circulation of lye via bonding with calcium (causticising) and then, in a

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

separate lime oven, is burned to burnt lime, a process that releases $CO_2$; the burnt lime is then reused for causticising. Fuel-related $CO_2$ emissions from lime ovens are taken into account, via fuel data, as energy-related emissions. Pursuant to the *IPCC Good Practice Guidelines*, $CO_2$ released from $CaCO_3$ is assigned an emission factor of "0", since all of its carbon comes from pulped wood. Calcium loss from the cycle is compensated for solely via addition of burnt lime and thus, for the present purposes, also does not lead to report-relevant $CO_2$ emissions (the $CO_2$ released in production of burnt lime is already included in the figures for the lime industry (CRF 2A2)).

### *4.10.2 Methodological issues (2.D.1)*

These are not relevant, since the pulp, paper and printing industry produces no process-related emissions of climate-relevant gases within the meaning of the *IPCC Good Practice Guidelines*.

### *4.10.3 Uncertainties and time-series consistency (2.D.1)*

These are not relevant, since the pulp, paper and printing industry produces no process-related emissions of climate-relevant gases within the meaning of the *IPCC Good Practice Guidelines*.

### *4.10.4 Source-specific quality assurance / control and verification (2.D.1)*

These are not relevant, since the pulp, paper and printing industry produces no process-related emissions of climate-relevant gases within the meaning of the *IPCC Good Practice Guidelines*.

### *4.10.5 Source-specific recalculations (2.D.1)*

These are not relevant, since the pulp, paper and printing industry produces no process-related emissions of climate-relevant gases within the meaning of the *IPCC Good Practice Guidelines*.

### *4.10.6 Source-specific planned improvements (2.D.1)*

These are not relevant, since the pulp, paper and printing industry produces no process-related emissions of climate-relevant gases within the meaning of the *IPCC Good Practice Guidelines*.

## 4.11 Production of halocarbons and $SF_6$ (2.E)

| CRF 2.E | | | | | |
|---|---|---|---|---|---|
| Key source | | Gas (MSG) | 1990 – contribution to total emissions | 2002 – contribution to total emissions | **Trend** |
| Production of halocarbons and $SF_6$; here: fugitive emissions | t | $SF_6$ | 0,28 % | 0,12 % | falling |

| **Gas** | **$CO_2$** | **$CH_4$** | **HFCs** | **PFCs** | **$SF_6$** | **$N_2O$** | **$NO_X$** | **CO** | **NMVOC** | **$SO_2$** |
|---|---|---|---|---|---|---|---|---|---|---|
| Emissions factor[90] (EF) | | | - | | 0,01 | | | | | |
| EF uncertainties in % | | | - | | | | | | | |
| Distribution of uncertainties [91] | | | - | | | | | | | |
| Method for EF determination[92] | | | - | | | | | | | |

In terms of levels of fugitive emissions, production of halocarbons and $SF_6$ is a key source.

No emission factor for the HFC substance group can be given, since several different sources are involved and since different emission factors are used to calculate the emissions from these sources. The emission factors underlying the emissions figures are shown in the CRF tables.

Table 45 contains an overview of the current status of data reporting (reporting year 2002). For the reporting years 1995 to 2001, certain other factors apply in some cases. Some of the reporting (production-related emissions) is sub-divided, for greater precision, into further sub-source categories. The factors for each sub-source-category are listed individually, whereas only an overview can be given here.

Table 45: Overview of data reporting and emission factors used in TABLE 2(II)s1, E. (a) Production of halogenated hydrocarbons and $SF_6$

| | Reported data 2002 | **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, $SF_6$ |

### *4.11.1 By-product emissions (2.E.1)*

#### 4.11.1.1 Source category description (2.E.1)

HFC-23 is incurred as a by-product of manufactured H-CFC-22. According to the largest producer in Germany (there are two producers), the amount in question is about 3% of the entire H-CFC-22 production; this amount is always incurred in synthesis and is not collected for further processing (for example, for production of refrigerants) or for decomposition for substance recovery. For technical reasons, it is impossible to prevent part of this amount from escaping into the atmosphere.

In 1994, in Frankfurt, a CFC-cracking plant went into operation that cracks, at high temperature, excess HFC-23 produced during production of H-CFC-22 and that recovers hydrofluoric acid; i.e. no emissions are produced. HFC-23 produced at the second German

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

production facility is largely captured at the production system itself; the substance is then sold as HFC-23 refrigerant or – following further distillative purification – as an etching gas for the semiconductor industry. For the past several years, the excess amount that cannot be sold is delivered to the cracking facility in Frankfurt. Since 1995, emissions have been substantially reduced through this measure. At the same time, a considerable portion of the substance is not collected, however; the second H-CFC-22 facility generates by-product emissions on a level now estimated by the operator as about 0.5 % of H-CFC-22 production (1 % in the 2001 reporting year). Possibilities are currently being reviewed for installing equipment that would destroy the substance immediately downstream from production.

#### 4.11.1.2 Methodological issues (2.E.1)

For the 1995 to 2002 reporting years, emissions of the latter producer have been calculated (via mass balance) on the basis of the amount of H-CFC-22 produced, of annual measurements of HFC-23 concentrations in the facility's waste gas, of amounts of HFC-23 sold and of the amounts of HFC-23 delivered to the cracking facility; for the 1995 reporting year, emissions-reduction measures (cracking facility) have been taken into account, as of the middle of the year, for the first production facility. The producer has reported the relevant production amounts of R 22 and of amounts of HFC-23 sold and managed as waste. The emission factor listed in the CRF tables has been obtained via recalculation from the production amount and the relevant emissions determined on the basis of the mass balance. The thus-calculated emission factor is used, in connection with the annual production amount, to determine HFC-23 emissions.

The IPCC default emission factor is not used, since emissions-reduction measures have been taken (cracking facility).

#### 4.11.1.3 Uncertainties and time-series consistency (2.E.1)

The emissions calculation obtained via the aforementioned mass balance is considered to be very accurate. The relevant uncertainties cannot be quantified (pursuant to IPCC, the maximum emissions are 4 % of the amount produced).

In co-operation with the manufacturer of R 22 (this applies only to the second production facility, since the first production facility, as described in Chapter 4.11.1.1, does not produced any emissions), continual efforts are being made to improve data quality (including the emission factor).

The time series reflects the measures that have been taken.

#### 4.11.1.4 Source-specific quality assurance / control and verification (2.E.1)

The plausibility of the data was reviewed on the basis of the amounts produced, the manufacturer's information regarding measures taken and the listed emission factors. The underlying data has not yet been reviewed, but such review is planned in connection with other measures (cf. 0 and 4.11.1.5).

The data for the 2002 report year, like the data for most of the previous years, was collected by an external expert working under commission to the Federal Environmental Agency. For the most part, quality assurance was carried out by an external expert. In addition, where

possible, the data is checked by the relevant Federal Environmental Agency specialist upon receipt.

A standardised QA/QC method is currently being developed by the Federal Environmental Agency, in co-operation with a research partner.

#### 4.11.1.5 Source-specific recalculations (2.E.1)

In co-operation with the second producer, the data for the previous reporting years is being checked further for plausibility and improved as necessary. This can lead to recalculations.

#### 4.11.1.6 Source-specific planned improvements (2.E.1)

The affected manufacturer initially planned to carry out measurements to improve the quality of the data. Since these plans have proved to be technical unfeasible, efforts are now being carried out to improve data calculations.

### *4.11.2 Production-related emissions (2.E.2)*

#### 4.11.2.1 Source category description (2.E.2)

In Germany there is only one company that produces these gases; production take place 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 $SF_6$ in Europe, the company enjoys protected confidentiality. The data is reported to the Federal Environmental Agency, but then disclosed further only in aggregate form.

#### 4.11.2.2 Methodological issues (2.E.2)

For the reporting years 1995 to 2002, emissions have been estimated on the basis of amounts of HFCs and $SF_6$ produced, using substance-specific and plant-specific emission factors provided by the manufacturer (cf. CRF tables). The production quantities were reported by the manufacturer (confidentially).

Some quantities that the manufacturer produces in other countries are sold via Germany, and some quantities (such as HFC-227 for the pharmaceutical industry) are purified in Germany. For reporting purposes, it is necessary to separate, precisely, quantities produced in Germany, quantities only subject to further processes in Germany and quantities sold in Germany; for reporting years until 2001, such separation was not always unambiguous.

#### 4.11.2.3 Uncertainties and time-series consistency (2.E.2)

For calculations, substance-specific EF (= PS) provided by the manufacturer were used. No uncertainty data is available.

As a result of imprecision in assignment of production quantities, until 2001 overly large production quantities – especially for HFC-227 (in Germany) – were assumed, were the result that overly high emissions were reported. For the 2002 reporting year, the required

separation between production / purification / sales was improved. The production figures on which the emissions calculation is based may be considered exact in future.

#### 4.11.2.4 Source-specific quality assurance / control and verification (2.E.2)

The data for the 2002 report year, like the data for most of the previous years, was collected by an external expert working under commission to the Federal Environmental Agency. For the most part, quality assurance was carried out by an external expert. In addition, where possible, the data is checked by the relevant Federal Environmental Agency specialist upon receipt.

A standardised QA/QC method is currently being developed by the Federal Environmental Agency, in co-operation with a research partner.

#### 4.11.2.5 Source-specific recalculations (2.E.2)

No recalculations have been carried out to date, but recalculations will become necessary, for reporting years until 2001, once the quantities actually produced in Germany have been determined.

#### 4.11.2.6 Source-specific planned improvements (2.E.2)

In future, the manufacturer will review production-quantity figures with regard to the production locations actually involved. The data will then be considered sufficiently reliable.

## 4.12 Consumption of halocarbons and $SF_6$ (2.F)

| **CRF 2.F** | | | | | |
|---|---|---|---|---|---|
| Key source | | Gas (MSG) | 1995 – contribution to total emissions | 2002 – contribution to total emissions | **Trend** |
| Consumption of halocarbons and $SF_6$ | l / t | HFCs | 0,01 % | 0,03 % | rising |
| Consumption of halocarbons and $SF_6$ | l / t | $SF_6$ | 0,30 % | 0,36 % | rising |

| **Gas** | **$CO_2$** | **$CH_4$** | **HFCs** | **PFCs** | **$SF_6$** | **$N_2O$** | **$NO_X$** | **CO** | **NMVOC** | **$SO_2$** |
|---|---|---|---|---|---|---|---|---|---|---|
| Emissions factor[93] (EF) | | | - | | | | | | | |
| EF uncertainties in % | | | - | | | | | | | |
| Distribution of uncertainties [94] | | | - | | | | | | | |
| Method for EF determination[95] | | | - | | | | | | | |

In terms of emissions levels and trends, consumption of halocarbons and $SF_6$ is a key source.

Halocarbons and $SF_6$ are used in a number of different applications. Whereas in some, so-called "open" applications consumed quantities are emitted completely, in the same year in question, in other applications large quantities are stored (stocks). The substances then are emitted, either partially or completely, from such "stocks" throughout the entire usage phase

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

and in relevant waste management. It is thus neither possible nor useful to provide a mean emission factor. Most of the EF used are CS; although some are D or M.

The "current emissions (A)", as listed in Table 2(I)s2, consist of the quantities of HFCs, PFCs and $SF_6$ that, during a reporting year, slowly escape from "stocks" and that are emitted in production and waste management. On the other hand, the "stocks" – actually, the average quantities present in the reporting year in question (average annual stocks) – correspond to the potential emissions (P) listed in Table 2(I)s2. The "stocks" do not include quantities from storage only. These amounts vary widely, and thus neither is it possible to determine these quantities nor is it useful to work with an average value. For reasons of confidentiality, potential emissions for the sub-source-categories "solvents" and "semiconductor manufacture" cannot be given. For open applications (aerosols / metered dose inhalers), annual emissions are equated with the quantities sold within the relevant 12-month period (100 % emissions in the relevant year of sales). As a result, this area has no "stocks" that increase annually. The potential emissions thus correspond approximately (the reference periods differ) to the current emissions in the reporting year in question.

Table 46 contains an overview of the current status of data reporting (reporting year 2002). For the reporting years 1995 to 2000, certain other factors apply in some cases. Complete reporting is sub-classified more precisely into further sub-source-categories in many areas. The factors for each sub-source-category are listed individually, whereas only an overview can be given here.

Table 46: Overview of data reporting and emission factors used in TABLE 2(II)s1, F. (a) Consumption of halocarbons and $SF_6$

| | **Reported data 2002** | **Substance** | **Production factor** | Lifetime factor |
|---|---|---|---|---|
| **1. Refrigeration and air-conditioning systems [Tier 2]** | | | | |
| Household refrigeration | **yes [Tier 2]** | HFC | 0,0015 | 0,003 |
| Commercial refrigeration | **yes [Tier 2]** | HFC, PFC | 0,0015 | 0,015-0,15 |
| Transport refrigeration | **yes [Tier 2]** | HFC | 0,0015 | 0,05-0,15 |
| Industrial refrigeration | **yes [Tier 2]** | HFC | 0,0015 | 0,07 |
| Stationary air-conditioning systems | **yes [Tier 2]** | HFC | 0,0001-0,0015 | 0,02-0,06 |
| **Mobile air-conditioning systems** | | | | |
| Mobile air-conditioning, trucks | **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 with 365mfc | **yes [Tier 2]** | HFC | 0,10 | 0,005 |
| 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 | 0,27 | 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** | | | | |
| | **Reported data 2002** | **Substance** | **Production factor** | **Lifetime factor** | **Disposal factor** |
| Switching equipment | **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 |
| NAEWF (formerly, AWACS) maintenance | **yes [national]** | $SF_6$ | 0,00 | 0,05 | |
| Car tyres | **yes [Equ. 3.23]** | $SF_6$ | 0,002 | | 1 |
| Insulating glas panes | **yes [Equ. 3.24ff]** | $SF_6$ | 0,33 | 0,01 | 1 |
| Tracer gas | **yes [Equ. 3.35]** | $SF_6$ | | 1,00 | |

Equ. = Equation; equation from the IPCC Guidelines

### *4.12.1 Refrigeration and air-conditioning equipment (2.F.1)*

Since the early 1990s, companies have been using partially halogenated CFCs (HFCs) on an increasing scale, primarily as substitutes for ozone-depleting and climate-damaging CFCs and H-CFCs. HFC emissions have increased sharply since 1995. This trend continues.

Use of refrigerants in stationary and mobile cooling/refrigeration systems now accounts for 44 % of HFC emissions and is thus one of the primary sources of such emissions. In 2002, stationary refrigeration and air-conditioning systems accounted for nearly 20 % of HFC emissions.

#### 4.12.1.1 Refrigeration and stationary air-conditioning systems (2.F.1)

##### *4.12.1.1.1 Source category description (2.F.1)*

In terms of its emissions levels and trends, the source category "refrigeration and stationary air-conditioning equipment" has been identified as a key source.

This sector can be roughly divided into the source categories household refrigeration, commercial refrigeration, transport refrigeration, industrial refrigeration and stationary air-conditioning systems (cf. Table 46).

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

##### *4.12.1.1.2 Methodological issues (2.F.1)*

The total emissions for each source category / sub-source-category, and for each refrigerant, consist of the sub-emissions in the areas of production, usage and disposal. Emissions in these areas are determined separately.

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

- Scope of source-category-specific HFC stocks.
- Composition of these stocks according to various HFC refrigerants.
- Sector-specific emission factors from on-going operation.
- Rate of refrigerant recovery during disposal.
- Average plant service life (to be seen in connection with the time of the first disposal emissions).

Table 46 shows all the factors (key data) on which emissions data is based, apart from the recovery rate, which, in the absence of an empirical basis, is currently assumed to be the standard value proposed by the IPCC (IPCC 99?) of 70 % of the original refrigerant filling. Because HFC has only been in use since 1993, the recovery rates have thus far been insignificant.

For breakdown of total stocks into source categories, determination of consumption levels in the individual reporting years, determination of absolute sizes and determination of internal refrigerant compositions of stocks, direct national information has been obtained (enquiries

about sales figures, production figures, utilisation figures); in addition, numerous recently published national and international studies have been evaluated.

The emission factors used are the result of literature evaluations and extensive surveys of experts. It should also be noted that emission factors have been adapted in line with technical developments for the various reporting years. However, the method has not been changed.

#### *4.12.1.1.3 Uncertainties and time-series consistency (2.F.1)*

In the area of refrigeration systems and stationary air-conditioning systems, the time-series development (increase) is directly related to the increased use of HFCs as substitutes for CFCs and the resulting increases in potential and current emissions. The increase, which was initially sharp, has been slowing somewhat. Before a reliable interpretation of this development can be provided, the emissions of the coming years will have to be awaited.

Caution is advised, particularly regarding the emission factors. The broad range of emission factors found in the literature for identical applications is only partly a consequence of technical changes in systems' air-tightness or an expression of national differences. For the most part, it reflects real uncertainty, since the solid empirical studies of these factors that have been carried out, among which is a study of supermarket emissions in Germany, have been too few in number.

As a result of the aforementioned uncertainty with regard to emission factors, and to the large number of individual applications (systems) involved, the emissions data is considered too imprecise. In order to improve the reliability of data provided, the data was compared to the sales data (substance-oriented) of the manufacturers.

Until the 2001 reporting year, Germany reported only aggregated emissions, covering all source categories. Within the context of emissions surveys for the years 1999 to 2001, and the emissions survey for the 2002 reporting year, the emissions for the reporting years 1995 to 1998 were reviewed and updated on the basis of new findings on input quantities and emission factors. Such information is often available only after a considerable delay; initially, therefore, it must be estimated. All data is thus being improved on an ongoing basis. For example, the lifetime factor for industrial refrigeration was modified slightly, on the basis of new findings. All other EF remained unchanged from the previous year. The changes implemented are attributable not to a change in the methodological approach, but merely to improved activities and technical information. To date, the relevant uncertainty has not been systematically quantified.

#### *4.12.1.1.4 Source-specific quality assurance / control and verification (2.F.1)*

The data for the 2002 report year, like the data for most of the previous years, was collected by an external expert working under commission to the Federal Environmental Agency. For the most part, quality assurance was carried out by an external expert. In addition, where possible, the data is checked by the relevant Federal Environmental Agency specialist upon receipt.

A standardised QA/QC method is currently being developed by the Federal Environmental Agency, in co-operation with a research partner.

The collected data on the size of source-category-specific HFC stocks, on composition of these stocks with regard to various HFC refrigerants, on EF, etc. are subject to continual quality assurance / control and verification, although this process has not yet been standardised. On a regular basis, various sources (environmental statistics, production and sales figures, etc.) are consulted, and experts (users, refrigerant manufacturers, suppliers, etc.) are consulted to determine the sources' reliability.

#### *4.12.1.1.5 Source-specific recalculations (2.F.1)*

Due to the complexity of this area, and of the large number of facilities involved, constant efforts are made to improve the database (breakdown of types of refrigeration systems, of refrigerants and coolants, of numbers of facilities, etc.). The new findings obtained via annual data surveys are continually applied to emissions calculations. As a result, changes occur in emissions figures for previous reporting years. For 2004 (2003 reporting year), comprehensive recalculation, on the basis of the latest findings, is planned.

#### *4.12.1.1.6 Source-specific planned improvements (2.F 1)*

In future, efforts will be made to improve data by means of prompt enquiries regarding consumption levels (repairs, refill quantities, etc.). In view of the large number of systems involved (several million), however, emissions data is likely to remain subject to uncertainties. Additional possibilities for collecting and improving data are currently being evaluated. Efforts are being made to provide a first evaluation of such possibilities by 2004.

### 4.12.1.2 Mobile air-conditioning systems (2.F.1)

#### *4.12.1.2.1 Source category description (2.F.1)*

In terms of its emissions levels and trends, the source category "mobile air-conditioning systems" has been identified as a key source.

"Mobile air-conditioning systems" comprises vehicle air-conditioning systems in passenger cars, trucks and commercial vehicles, buses, agricultural machinery, rail vehicles and ships. In terms of coolant stocks, consumption and emissions, car systems predominate, accounting for 90% of each category. Car air-conditioning systems account for nearly half of all refrigerant emissions (including those from stationary sources). A total of 22 % of all HFC emissions are attributable to this source alone.

Since about 1993, partially halogenated CFCs (HFCs) have been used as ozone-neutral substitutes for CFCs and H-CFCs. R134a now accounts for nearly 100 % of the HFC coolant used in mobile air-conditioning systems. In conversion of old R12 air-conditioning systems, a drop-in coolant (mixture) was used instead of R134a in a small proportion of cases; this coolant itself consists of 88 % R134a.

#### *4.12.1.2.2 Methodological issues (2.F.1)*

The total emissions for each source category / sub-source-category, and for each refrigerant, consist of the sub-emissions in the areas of production, usage and disposal. Emissions in these areas are determined separately.

In calculation of HFC emissions (only HFC-134a) from mobile air-conditioning systems, the following key data was collected/estimated:

- Scope of source-category-specific HFC stocks.
- Sector-specific emission factors from on-going operation and as a result of accidents.
- Rate of refrigerant recovery during disposal.
- Average plant service life (to be seen in connection with the time of the first disposal emissions).

As a general principle, the above statements on the stationary systems sector also apply here. However, annual levels of HFC consumption may be calculated fairly precisely from statistics that cover the bulk of this sector, including new car registrations, production quantities and imports and exports of cars. In addition, model-specific rates of air-conditioning installation, and the relevant fill quantities, were also determined.

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

For the 2002 reporting year, less relevant sources (such as agricultural machinery) have been included for the first time. In another change, carried out for the first time in this reporting year, only ships sailing under German flags – rather than all German ships – have been taken into account. The resulting changes are marginal, however.

#### *4.12.1.2.3 Uncertainties and time-series consistency (2.F.1)*

The quality of data on emissions from mobile air-conditioning systems is quite good; in fact, it is better than that refrigeration systems and air-conditioning systems.

The time series show a significant increase in emissions since 1995. In the area of mobile air-conditioning systems, this increase is directly related to increased use of air-conditioning systems in vehicles, the resulting increased use of HFC and the resulting increasing potential and current emissions.

The emission factors previously assumed have been confirmed via the results of an expert report by the Federal Environmental Agency (UBA) and an EU study on leakage rates from mobile air-conditioning systems (EU Commission, 2003). Overall, the EF are considered to be good. For precise information on uncertainties, the reader is referred to the aforementioned studies/report. Determination of annual consumption rates and, thus, of total annual stocks, is sufficiently precise. Furthermore, good-quality data is available on rates of installation of air-conditioning systems in vehicles and on relevant fill levels. Only in the area of commercial vehicles is the data subject to major uncertainties. The uncertainties for individual data items have not yet been quantified.

#### *4.12.1.2.4 Source-specific quality assurance / control and verification (2.F.1)*

The data for the 2002 report year, like the data for most of the previous years, was collected by an external expert working under commission to the Federal Environmental Agency. For the most part, quality assurance was carried out by an external expert. In addition, where

possible, the data is checked by the relevant Federal Environmental Agency specialist upon receipt.

A standardised QA/QC method is currently being developed by the Federal Environmental Agency, in co-operation with a research partner.

Since 1993, all data required for calculations (see above) has been collected on an ongoing basis and checked for plausibility; it is not subject to standardised quality assurance / control and verification, however.

#### *4.12.1.2.5 Source-specific recalculations (2.F.1)*

In this area, only a small amount of recalculation (additional sources of rather minor importance, reorganisation of emissions allocation) is required.

#### *4.12.1.2.6 Source-specific planned improvements (2.F 1)*

Further possibilities for improvement are just beginning to be discussed.

### *4.12.2 Foam blowing (2.F.2)*

#### 4.12.2.1 PU foam products (2.F.2)

#### *4.12.2.1.1 Source category description (2.F.2)*

In terms of its emissions levels and trends, the source category "PU foam products" has been identified as a key source.

PU foam products include products made of soft foam, integral foam and hard foam. For soft foam, HFC is not required as a blowing agent. HFCs have been used as blowing agents for hard foams only since 1998. Between 1995 and 1997, HFCs were used only for integral foams.

A new blowing agent now being used, in addition to HFC 134a, 245 and 152a, is HFC-365mfc. This substance can not yet be included in CRF-table reporting, since data for it is not yet available in the specified formats. Pursuant to our surveys in 2003, HFC-365mfc emissions relative to use of 21.5 t of PU foam products must be assigned to the 2002 reporting year. Assuming a $GWP_{100}$ of 890 for this substance, this corresponds to emissions of 0.02 million tonnes of $CO_2$ equivalents.

#### *4.12.2.1.2 Methodological issues (2.F.2)*

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

Table 46 shows all of the determining factors (key data) on which the emissions data is based, apart from the recovery rate, for which source-category-specific standard values

proposed by the IPCC (IPCC 99?) are generally used, in the absence of an empirical basis. Because HFC has only been in use since 1998, the recovery rates have thus far been insignificant.

To classify total stocks into source categories (boards, "sandwich" and integral), to determine sales figures (foam containing HFC) in the individual reporting years and to determine the composition of the blowing agents involved, relevant national information (enquiries relating to sales figures, production figures, utilisation figures) was obtained, and numerous international studies recently published were evaluated.

As in the refrigeration / air-conditioning sector, the emission factors used are the result of evaluations of the literature and extensive surveys of experts. It should also be noted that, for the various reporting years, emission factors have been adapted in line with technical developments, which have included changes in blowing agents.

The EF and other key data used have been determined for reporting purposes and, with the exception of the recovery rate, are, for the most part, CS.

#### *4.12.2.1.3 Uncertainties and time-series consistency (2.F.2)*

The emissions data for prior years is considered fairly accurate, since the quantities of HFCs used are still rather small at present. In future, however, it will become more difficult to obtain a good market overview in view of the anticipated product diversity.

It is not possible to quantify the uncertainties for the EF and the AR. While the EF are considered sufficiently precise, the AR are subject to considerable uncertainties, due to the product diversity involved. Because use of HFCs is still limited, however, the market can still be studied well via surveys and estimates.

The time series, which does not begin until after 1995, shows a small initial increase in emissions. Both of these factors – the time of commencement and the small initial increase – agree with the historical development of HFC use in this application area, an area which arose only slowly, as a result of the long period of utilisation of H-CFC.

#### *4.12.2.1.4 Source-specific quality assurance / control and verification (2.F.2)*

The data for the 2002 report year, like the data for most of the previous years, was collected by an external expert working under commission to the Federal Environmental Agency. For the most part, quality assurance was carried out by an external expert. In addition, where possible, the data is checked by the relevant Federal Environmental Agency specialist upon receipt.

A standardised QA/QC method is currently being developed by the Federal Environmental Agency, in co-operation with a research partner.

Evaluation of special QA/QC measures is just getting underway.

#### *4.12.2.1.5 Source-specific recalculations (2.F.2)*

HFCs have only been in use since 1998, and thus only the data for the reporting years 1998 to 2000 is reviewed within the context of emissions surveys for the 2001 reporting year. In all likelihood, no additional recalculations will be required.

#### *4.12.2.1.6 Source-specific planned improvements (2.F.2)*

New possibilities for data collection are currently being evaluated. Efforts are being made to provide a first evaluation of such possibilities by 2004.

### 4.12.2.2 PUR foam (2.F.2)

#### *4.12.2.2.1 Source category description (2.F.2)*

In terms of its emissions levels and trends, the source category "PU installation foam" products has been identified as a key source.

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 propellants. In Germany and, generally, in central Europe, industry has reduced its HFC use, largely for economic reasons. Increasingly, HFC-152a – which has a lower greenhouse gas potential – is being used instead of HFC-134a. In addition, per-can quantities of HFCs have been reduced by increasing proportions of flammable propellants.

#### *4.12.2.2.2 Methodological issues (2.F.2)*

In computational terms, an average can has a foam weight of 660 g, approximately 18 % of which is propellant. In 1997, propellants were mixtures of which approximately 40 % consisted of the highly flammable gases propane, butane, and dimethyl ether (DME), and approximately 60 % consisted of HFCs, which are low-flammable (152a) or non-flammable (134a). Proportions of HFCs in propellants have been decreasing since 1995: In 1995, the HFC component in a 660-g can weighed 84 grams, while in 1997 it weighed only 75 g. Today, HFCs account for no more than 70 g, or less than 10 % of foam weight. According to manufacturers, the average quantity of HFCs contained in all different types of cans (winter foams, pistol foams, etc.) is 30 g. For purposes of emissions calculation, it is assumed that, after being sold, cans are used promptly by professional craftsmen or by do-it-yourselfers. In keeping with the IPCC Guidelines, the HFC emissions for year n are thus considered equivalent to sales for year n. Fill losses from domestic production for year n must also be considered. Used cans are not completely empty at the time of disposal; they still contain around 8 % of the original amount of foam, including propellant. The bulk of this propellant eventually enters the atmosphere after a certain delay. The same also applies to the 30 % of cans that are brought to the central recovery plant for PU foam cans.

Assumptions regarding losses in production and disposal, and figures for fill quantities and for propellant ratios, are based on repeated surveys of experts (experts' assessments). The total quantities of cans consumed refer to sales figures in Germany.

In keeping with the IPCC method, it is assumed that all HFCs used are emitted. The consumption quantities are based on sales (cans) and on the average quantity of HFCs per can.

#### *4.12.2.2.3 Uncertainties and time-series consistency (2.F.2)*

While good data on the relevant sales quantities is available and is considered sufficiently precise, manufacturers' data regarding the quantities of HFCs contained in products are considered less accurate. Verification was not possible for this reporting year; as a result, given the lack of a better source, manufacturers' figures were used for calculation. The uncertainty factor for the data item "HFC quantity/can" is estimated to be 1.7 (corresponds to a maximum average quantity of 50g/can).

The time series for this application begins before 1995, due to the early discontinuation of CFC use in this area, and it shows a decreasing emissions trend. This is due to continuous reduction of HFC quantities per can (through increased use of halogen-free propellants) (cf. Chapter 4.12.2.2.2).

#### *4.12.2.2.4 Source-specific quality assurance / control and verification (2.F.2)*

The data for the 2002 report year, like the data for most of the previous years, was collected by an external expert working under commission to the Federal Environmental Agency. For the most part, quality assurance was carried out by an external expert. In addition, where possible, the data is checked by the relevant Federal Environmental Agency specialist upon receipt.

A standardised QA/QC method is currently being developed by the Federal Environmental Agency, in co-operation with a research partner.

Evaluation of special QA/QC measures for this sector is just getting underway.

#### *4.12.2.2.5 Source-specific recalculations (2.F.2)*

In the 2001 reporting year, recalculations were carried out, on the basis of discussions with the "Working Group on Polyurethane Foams", concerning the quantities of HFCs in individual cans and the ratio between 152a and 134a in HFC composition. Due to existing uncertainties, recalculations may again be necessary in the next reporting year.

#### *4.12.2.2.6 Source-specific planned improvements (2.F.2)*

The procedure corresponds to the Tier 2 approach. Data is available for domestic production, exports and imports. Additional verification is needed solely with regard to the average HFC quantity. In collaboration with the manufacturers, work is underway to further improve the data situation.

### 4.12.2.3 XPS hard foam (2.F.2)

#### *4.12.2.3.1 Source category description (2.F.2)*

In terms of its emissions levels and trends, the source category "XPS hard foam" has been identified as a key source.

For XPS boards, no consumption or emissions of HFCs occurred prior to 1999, since H-CFCs or $CO_2$ were still being used at that time.

From the year 2000 onwards, a number of domestic producers turned to HFC solutions. Since 2001, 152a and 134a have been used as blowing agents, either alone or mixed together, in addition to $CO_2$.

#### *4.12.2.3.2 Methodological issues (2.F.2)*

Around 3 to 3.5 kg of halogenated blowing agents 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 all of the blowing agent is emitted. Collection and recovery trials have been conducted, but to date no relevant systems have been implemented, for both technical and economic reasons.
Where 152a is used for foam production, remaining blowing agent diffuses almost completely from boards in the factory warehouse. 134a, on the other hand, remains in the product and degases almost as slowly as 142b. In a board 100 mm thick, 134 a has a half-life of 76 years, while 142b has a half-life of 84 years. The annual emission factor of 0.66% for the entire product mix, as 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. Like other key data, they have been determined for purposes of reporting, and they are usually CS.

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

#### *4.12.2.3.3 Uncertainties and time-series consistency (2.F.2)*

It is not possible to quantify the uncertainties for the EF and the AR. Because the German XPS market includes only a small number of manufacturers, it is relatively easy to obtain an overview of this market. Since the EF and AR were prepared in co-operation with manufacturers, they are considered sufficiently precise.

The time series, which does not begin until after 1995, shows a considerable increase in emissions. Both factors – the time of commencement and the increase in emissions – agree with the historical development of HFC use in this application.

#### *4.12.2.3.4 Source-specific quality assurance / control and verification (2.F.2)*

The data for the 2002 report year, like the data for most of the previous years, was collected by an external expert working under commission to the Federal Environmental Agency. For the most part, quality assurance was carried out by an external expert. In addition, where possible, the data is checked by the relevant Federal Environmental Agency specialist upon receipt.

A standardised QA/QC method is currently being developed by the Federal Environmental Agency, in co-operation with a research partner.

Evaluation of special QA/QC measures for this sector is just getting underway.

#### *4.12.2.3.5 Source-specific recalculations (2.F.2)*

No recalculations have been carried out.

#### *4.12.2.3.6 Source-specific planned improvements (2.F.2)*

The option of a monitoring system is currently being discussed with the manufacturers and industry associations. This process is just getting underway.

### *4.12.3 Fire extinguishers (2.F.3)*

#### 4.12.3.1 Source category description (2.F.3)

In terms of its emissions levels and trends, the source category "fire extinguishers" has been identified as a key source.

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

HFC-227, one of the substances proposed by the U.S. as halon substitutes (HFC-23 and 236fa, HFC-227, PFC-218 and PFC-3110), was licensed in Germany in 1997. It is sold under the commercial name "FM-200" – essentially, by one licensed company. A further HFC (HFC-23) was licensed in the year 2002 but has not been used to date. HFC 236fa, which has been certified since 2001 for use in Germany, is used only in the military sector.

#### 4.12.3.2 Methodological issues (2.F.3)

The emission figures for HFC 227 are based on statistical surveys by one company, covering the aspects of input quantities, refill quantities, accidental releases, releases in case of a fire, and trial floodings in Germany (by analogy to Tier 2). As a result, the entire market is not covered, since there is another seller. This seller has a very small market share, however. This seller is taken into account via addition of about 5 % (already included in the data; estimate of the market leader).

The figures for HFC-236 are based on reporting obligations set forth in the relevant license, and they are considered to be very good.

#### 4.12.3.3 Uncertainties and time-series consistency (2.F.3)

The data on HFC-227 and HFC-236 is considered good and very good, respectively. The time series, which do not begin until after 1995, show increasing emissions; this is in agreement with increasing use of HFCs as fire extinguishing agents.

#### 4.12.3.4 Source-specific quality assurance / control and verification (2.F.3)

Where possible, the data are checked by the Federal Environmental Agency.

A standardised QA/QC method is currently being developed by the Federal Environmental Agency, in co-operation with a research partner.

#### 4.12.3.5 Source-specific recalculations (2.F 3)

No recalculations have been carried out.

#### 4.12.3.6 Source-specific planned improvements (2.F.3)

No improvements are required at present.

### *4.12.4 Aerosols/metered dose inhalers (2.F.4)*

#### 4.12.4.1 Aerosols/metered dose inhalers (2.F.4)

##### *4.12.4.1.1 Source category description (2.F.4)*

In terms of its emissions levels and trends, the source category "aerosols / metered dose inhalers" has been identified as a key source.

In Germany, the first metered-dose inhaler containing the propellant 134a was introduced on the market in April 1996; it was followed by two more such inhalers in 1997 and 1998. Enough HFC-powered metered-dose inhalers are now available for almost all active-ingredient groups, and thus use of CFCs in this area is no longer required. In addition to HFC-134a, HFC-227 is also used.

##### *4.12.4.1.2 Methodological issues (2.F.4)*

The emission data is based on figures on sales of metered-dose inhalers in Germany, as obtained via surveys of producers. In keeping with the application in question, 100 % emissions in the year of sale are assumed.

##### *4.12.4.1.3 Uncertainties and time-series consistency (2.F.4)*

The data is considered to be very good. The uncertainties have not been quantified to date.

The time series does not begin until 1996, the year when HFCs were first used in this area, and it shows increasing emissions, which agrees with increasing use of HFCs as substitutes for CFCs.

#### *4.12.4.1.4 Source-specific quality assurance / control and verification (2.F.4)*

The data for the 2002 report year, like the data for most of the previous years, was collected by an external expert working under commission to the Federal Environmental Agency. For the most part, quality assurance was carried out by an external expert. In addition, where possible, the data is checked by the relevant Federal Environmental Agency specialist upon receipt. A standardised QA/QC method is currently being developed by the Federal Environmental Agency, in co-operation with a research partner.

#### *4.12.4.1.5 Source-specific recalculation (2.F.4)*

No recalculations have been carried out.

#### *4.12.4.1.6 Source-specific planned improvements (2.F.4)*

No further improvements are planned at present.

### 4.12.4.2 Other aerosols (2.F.4)

#### *4.12.4.2.1 Source category description (2.F.4)*

In terms of its emissions levels and trends, the source category other aerosols has been identified as a key source.

In Germany, HFCs are 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 and "novelties".

#### *4.12.4.2.2 Methodological issues (2.F.4)*

The emissions data is based on estimates of aerosol sales in Germany, obtained via surveys (producers, association). In keeping with the application in question, 100 % emissions in the year of sale are assumed here as well.

#### *4.12.4.2.3 Uncertainties and time-series consistency (2.F.4)*

In comparison to the emission data on metered-dose inhalers, this data is not considered to be very good, since the large number of products involved makes it difficult to obtain an overview of the market. Large quantities of imports, especially in the area of "novelties", also complicate the situation. At present, the uncertainties cannot be quantified.

#### *4.12.4.2.4 Source-specific quality assurance / control and verification (2.F.4)*

The data for the 2002 report year, like the data for most of the previous years, was collected by an external expert working under commission to the Federal Environmental Agency. For

the most part, quality assurance was carried out by an external expert. In addition, where possible, the data is checked by the relevant Federal Environmental Agency specialist upon receipt.

Collected data is checked for plausibility via comparison with data from the previous year; the reasons for any marked changes are explored.

A standardised QA/QC method is currently being developed by the Federal Environmental Agency, in co-operation with a research partner.

#### *4.12.4.2.5 Source-specific recalculation (2.F.4)*

No recalculations have been carried out.

#### *4.12.4.2.6 Source-specific planned improvements (2.F.4)*

Improvements have been initiated in collaboration with the industry association. In addition, the possibility of using additional data sources (Environmental Statistics Act - Umweltstatistikgesetz) is being reviewed.

### *4.12.5 Solvents (2.F.5)*

#### 4.12.5.1 Source category description (2.F.5)

In terms of its emissions levels and trends, the source category "solvents" has been identified as a key source.

Use HFCs as solvents was banned in Germany up until the year 2001 (2nd Ordinance on the Implementation of the Federal Immission Control Act – 2. BimSchV) and remains heavily restricted to this day, since individual applications must be submitted for each form of use. The applications are examined, and approval is only granted in exceptional cases. Virtually no applications are known to date.

#### 4.12.5.2 Methodological issues (2.F.5)

Emissions result solely from the use of HFC-43-10mee from the year 2001 onwards; the relevant data has been obtained through a survey of manufacturers. Since HFC-43-10mee is sold by only one manufacturer and is used only as a solvent, the selling company enjoys protection of confidence. The data is reported to the Federal Environmental Agency – this has been taking place since 2003 – but it is not published. Data for the 2003 reporting year includes retroactive data (2001 reporting year).

In keeping with the application in question, emissions in year n are considered equivalent to consumption in year n.

#### 4.12.5.3 Uncertainties and time-series consistency (2.F.5)

The data is considered to be of a good quality.

The time series does not begin until 2001, because that was the first year in which HFCs were used. This is in keeping with the amendment of legislation on halogenated solvents (amended 2. BImSchV).

#### 4.12.5.4 Source-specific quality assurance / control and verification (2.F.5)

The data provided has not yet been reviewed, due to this area's low degree of relevance. Attention is called to planned improvements.

A standardised QA/QC method is currently being developed by the Federal Environmental Agency, in co-operation with a research partner.

#### 4.12.5.5 Source-specific recalculation (2.F.5)

No recalculations have been carried out. Recalculation for the 2001 reporting year may be carried out in the next reporting year.

#### 4.12.5.6 Source-specific planned improvements (2.F.5)

If a relevant form of use emerges, plans call for obtaining exemption applications, for HFC use, that have been submitted to, and approved by, the competent Länder authorities.

### *4.12.6 Other (2.F.6)*

#### 4.12.6.1 Semiconductor manufacture (2.F.6)

##### *4.12.6.1.1 Source category description (2.F.6)*

In terms of its emissions levels and trends, the sub-source-category "semiconductor manufacture" has been identified as a key source.

The semiconductor industry uses large amounts of PFCs as etching gases for structural etching and chamber cleansing. In addition, HFCs, $SF_6$ and $NF_3$ are also used in production processes. The relevant emissions cannot be determined solely on the basis of the quantities used (sales by the gas trade). The difference between consumption and emissions results, firstly, in that only partial chemical conversion occurs in plasma reactors and, secondly, from the effects of downstream gas purification systems. Furthermore, a residue of approximately 10 % per gas bottle must be taken into account as non-consumption. The effective emissions depend primarily on the waste-gas-scrubbing technologies used.

##### *4.12.6.1.2 Description of methodology (2.F.6)*

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

#### *4.12.6.1.3 Uncertainties and time-series consistency (2.F.6)*

The data is considered to be of good quality.

The time series shows a continual increase in emissions until the year 2000. Emissions decreased significantly in 2001 and then increased again in 2002. The decrease is due to economic influences (reduction of semiconductor production) and, possibly, to the effects of emissions-reduction measures. Before any differentiated assessment can be carried out, further developments will have to be awaited.

#### *4.12.6.1.4 Source-specific quality assurance / control and verification (2.F.6)*

The data has been checked for plausibility, and the association has subjected it to an internal quality assurance / control and verification process.

A standardised QA/QC method is currently being developed by the Federal Environmental Agency, in co-operation with a research partner.

#### *4.12.6.1.5 Source-specific recalculation (2.F.6)*

Until the reporting year 2000, emissions figures were based on surveys of semiconductor producers with regard to production capacities, quantities of material used and technologies employed. This emissions data is likewise considered to be fairly accurate. No recalculations have been carried out.

#### *4.12.6.1.6 Source-specific planned improvements (2.F.6)*

Efforts are being made, in collaboration with the industry association, to specifiy data-collection and emissions-calculation procedures precisely.

### 4.12.6.2 Electrical equipment (2.F.6)

#### *4.12.6.2.1 Source category description (2.F.6)*

In terms of its emissions levels and trends, the sub-source-category "electrical equipment" has been identified as a key source.

Electrical equipment for power supply is by far the largest single consumer of $SF_6$ in Germany. Given the high export ratio of over 80 %, however, only a small proportion of consumption is added to new equipment and systems in the national inventory.

$SF_6$ is used primarily in switching systems and equipment in high-voltage (110-380 kV) and medium-voltage (10-30 kV) networks. The gas, which is used instead of air, serves as both a fire retardant and insulator. It is not commonly used in the low-voltage segment (< 1 kV).

#### *4.12.6.2.2 Description of methodology (2.F.6)*

Since 1996, emissions have been determined on the basis of a highly detailed concept developed by the Federal Environmental Agency in collaboration with manufacturers and operators. The installed quantity at the end of a given year and the emissions at the relevant

individual sources (manufacturers' factory losses, manufacturers' assembly losses, leakage at operators' facilities (including maintenance), and disposal) are ascertained.

Through the 2001 reporting year, data was collected systematically for only the largest $SF_6$ applications in this area. Via intensive discussion (monitoring, measures), additional relevant $SF_6$ applications (transformers, inlets) were identified; these were included in reporting for the first time in the 2002 reporting year.

#### *4.12.6.2.3 Uncertainties and time-series consistency (2.F.6)*

The data is considered to be of good quality. Nonetheless, there are uncertainties, resulting from unknown applications. The relevant uncertainties cannot be quantified.

As a result of first-time inclusion, in this reporting year, of additional $SF_6$ applications, the time series shows a marked jump in emissions in 2002.

#### *4.12.6.2.4 Source-specific quality assurance / control and verification (2.F.6)*

The data has been checked for plausibility, and the association has subjected it to an internal quality assurance / control and verification process.

A standardised QA/QC method is currently being developed by the Federal Environmental Agency, in co-operation with a research partner.

#### *4.12.6.2.5 Source-specific recalculation (2.F.6)*

Since insufficient information is available about the quantities used, in past years, in the "new" applications, no recalculations have been carried out. Extensive recalculations are planned for the next report.

#### *4.12.6.2.6 Source-specific planned improvements (2.F.6)*

Tentative plans call for the CAPIEL concept, which is used at the European level, to also be used in Germany, in order to standardise 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 provisions on emissions calculation under the UNFCCC reporting instructions (Tier 3b).

The new applications now included in reporting will be taken into account in the new procedures, and the database and ongoing data collection will also be improved for these applications.

### 4.12.6.3 Sports shoes (2.F.6)

#### *4.12.6.3.1 Source category description (2.F.6)*

In terms of its emissions levels and trends, the sub-source-category "sports shoes" has been identified as a key source.

$SF_6$ is used in soles of sports shoes in order to improve shock absorbency.

#### *4.12.6.3.2 Description of methodology (2.F.6)*

The emissions data (relevant sales of such sports shoes in Germany and, hence, the total quantity in Germany) is based on manufacturers' information with regard to the EU. These figures have been broken down, on the basis of Germany's population, to obtain figures for Germany. The data has been available to the Federal Environmental Agency since the 2001 reporting year, but it is published only in aggregate form, for reasons of confidentiality.

#### *4.12.6.3.3 Uncertainties and time-series consistency (2.F.6)*

The quantities used may be equated with emissions, whereby, in a procedure similar to the IPCC method for automobile tyres, a time lag of three years is assumed.

In spite of the good quality of the data for the EU (manufacturers' reports), the breakdown by Member States is subject to not inconsiderable uncertainties.

The relevant uncertainties cannot be quantified.

#### *4.12.6.3.4 Source-specific quality assurance / control and verification (2.F.6)*

The data for the 2002 report year, like the data for most of the previous years, was collected by an external expert working under commission to the Federal Environmental Agency. For the most part, quality assurance was carried out by an external expert. In addition, where possible, the data is checked by the relevant Federal Environmental Agency specialist upon receipt. A standardised QA/QC method is currently being developed by the Federal Environmental Agency, in co-operation with a research partner. At present, it is unclear whether this method should be applied to this source.

#### *4.12.6.3.5 Source-specific recalculation (2.F.6)*

No recalculations have been carried out.

#### *4.12.6.3.6 Source-specific planned improvements (2.F.6)*

No improvements are needed. $SF_6$ was used for the last time in 2003.

### 4.12.6.4 AWACS (airborne warning and control system) maintenance (2.F.6)

#### *4.12.6.4.1 Source category description (2.F.6)*

In terms of its emissions levels and trends, the sub-source-category "AWACS maintenance" has been identified as a key source.

$SF_6$ is used as an insulating medium for radar in NAEWF (formerly, AWACS) aircraft, which are large military surveillance aircraft. It is used to prevent electrical arcing, towards the antenna, in waveguides, in which there are high voltages in excess of 135 kV.

#### *4.12.6.4.2 Description of methodology (2.F.6)*

The emissions data is based on information provided regarding quantities consumed in filling/refilling NATO's NAEWF fleet (formerly known as the "AWACS" fleet). To date, all emissions have been included in reporting, since they occur in Germany. On a formal level, this procedure is to be reviewed for future reporting years.

#### *4.12.6.4.3 Uncertainties and time-series consistency (2.F.6)*

The emissions figures for reporting years until 2001 are based on estimates made via a 1996 survey. The emissions data for the years 1997 to 2001 is thus subject to non-quantifiable uncertainties.

New surveys of consumption quantities were carried out for the 2002 reporting year. This led to a significant increase over the 2001 reporting year. The collected data is considered to be of very good quality.

#### *4.12.6.4.4 Source-specific quality assurance / control and verification (2.F.6)*

The data for the 2002 report year, like the data for most of the previous years, was collected by an external expert working under commission to the Federal Environmental Agency. For the most part, quality assurance was carried out by an external expert. In addition, where possible, the data is checked by the relevant Federal Environmental Agency specialist upon receipt.

The data for the reporting years 1997 to 2001 has not been reviewed to date. The data for the reporting years 1996 and 2002 was obtained through direct surveys. Additional QA/QC is not required for this application.

A standardised QA/QC method is currently being developed by the Federal Environmental Agency, in co-operation with a research partner; the issue of whether it should be applied to this source has not yet been decided.

#### *4.12.6.4.5 Source-specific recalculation (2.F.6)*

No recalculations have been carried out to date.

#### *4.12.6.4.6 Source-specific planned improvements (2.F.6)*

Regular surveys of consumed quantities are to be carried out in future. Furthermore, the method is to be reviewed ("allocation of emissions").

### 4.12.6.5 Automobile tyres (2.F.6)

#### *4.12.6.5.1 Source category description (2.F.6)*

In terms of its emissions levels and trends, the sub-source-category "automobile tyres" has been identified as a key source.

Automobile tyres, which are filled with $SF_6$ for image-related reasons (the improved pressure constancy is not relevant in practice), are another source of $SF_6$ emissions in Germany.

Because of the climate relevance of $SF_6$, tyre manufacturers have stopped advertising this application. This has led to a considerable reduction. The bulk of today's emissions originates from gas in old tyres.

The peak consumption year was 1995, when over 500 of the 3,500 or some tyre-sales outlets in Germany had the option of filling tyres with $SF_6$ gas.

#### *4.12.6.5.2 Description of methodology (2.F.6)*

Emissions are determined on the basis of consumption quantities, which are obtained from gas dealers and manufacturers ($SF_6$). In each case, emissions follow consumption with a time lag of approximately 3 years, when the tyre is dismantled. This assumption is in keeping with the IPCC method.

#### *4.12.6.5.3 Uncertainties and time-series consistency (2.F.6)*

It is not possible to quantify the uncertainties incurred in assuming that sales figures of gas dealers and manufacturers (estimates of the quantities entering this market) are equivalent to the actual quantities used. It must be assumed, however, that not all amounts sold to workshops are passed on directly to customers; as a result, it must be assumed that the relationship "sales in year n = use in year n" does not hold. This only affects the time at which emissions occur; it does not affect emissions levels.

Overall, the uncertainties applying to manufacturers' figures are assumed to be much greater than those appying to gas dealers' figures.

What is more, any other sources of $SF_6$ supply that workshops may be using are not taken into account; it is not feasible to attempt to survey all workshops.

#### *4.12.6.5.4 Source-specific quality assurance / control and verification (2.F.6)*

The data for the 2002 report year, like the data for most of the previous years, was collected by an external expert working under commission to the Federal Environmental Agency. For the most part, quality assurance was carried out by an external expert. In addition, where possible, the data is checked by the relevant Federal Environmental Agency specialist upon receipt.

In past reporting years, quality assurance / control and verification have been carried out by comparing figures of gas dealers with those of manufacturers.

A standardised QA/QC method is currently being developed by the Federal Environmental Agency, in co-operation with a research partner; the issue of whether it should be applied to this source has not yet been decided.

#### *4.12.6.5.5 Source-specific recalculation (2.F.6)*

No recalculations have been carried out.

#### *4.12.6.5.6 Source-specific planned improvements (2.F.6)*

Since the overall importance of this entire application has been decreasing, no efforts are being made to improve data quality.

### 4.12.6.6 Insulating glass windows (2.F.6)

#### *4.12.6.6.1 Source category description (2.F.6)*

In terms of its emissions levels and trends, the sub-source-category "insulating glass windows" has been identified as a key source.

Insulated multiple glazing gained popularity over single-glazing for windows and glass facades in the 1970s, and since 1975 $SF_6$ has been filled into the cavity between the glazing to enhance noise insulation. At present, emissions from sound-proof windows represent the largest source of $SF_6$ emissions. However, the slight improvement in soundproofing obtained by using $SF_6$ tends to have a negative effect on thermal insulation performance. The higher priority given to thermal insulation – e.g. by the Thermal Insulation Ordinance (Wärmeschutzverordnung) – along with awareness of the higher greenhouse potential of $SF_6$, have led to a reduction in use of $SF_6$ in this application since the mid-1990s.

#### *4.12.6.6.2 Description of methodology (2.F.6)*

For determination of emissions, data on total $SF_6$ consumption is first obtained from gas dealers and data on quantities sold is obtained from manufacturers ($SF_6$). Although emissions cannot be equated with this consumption, they do originate from it with a time delay. $SF_6$ emissions from soundproof windows fall into three different categories, the quantitative significance of which changes over time: Filling losses, averaging 33 % of input, are incurred solely in the year of production, and they are directly proportionate to the annual consumption of $SF_6$. "Stock" emissions consist of gas losses from filled panes; they total approximately 1 % per annum throughout panes' entire service lifetimes, which average 25 years. Finally, disposal losses are incurred at the end of panes' service lifetimes (utilisation periods), or 25 years after the filling emissions.

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

#### *4.12.6.6.3 Uncertainties and time-series consistency (2.F.6)*

It is not possible to quantify the uncertainties incurred in assuming that sales figures of gas dealers and manufacturers (estimates of the quantities entering this market) are equivalent to the actual quantities used. In contrast to the situation with use in automobile tyres, however, it may be assumed that the majority of an amount sold in any given year is used right away. Overall, here as well the uncertainties applying to manufacturers' figures are assumed to be much greater than those applying to gas dealers' figures.

Since it is likely other sources of supply of $SF_6$ are not of any major relevance, no data on such sources is collected.

#### *4.12.6.6.4 Source-specific quality assurance / control and verification (2.F.6)*

The data for the 2002 report year, like the data for most of the previous years, was collected by an external expert working under commission to the Federal Environmental Agency. For the most part, quality assurance was carried out by an external expert. In addition, where possible, the data is checked by the relevant Federal Environmental Agency specialist upon receipt.

In past reporting years, quality assurance / control and verification have been carried out by comparing figures of gas dealers with those of manufacturers.

A standardised QA/QC method is currently being developed by the Federal Environmental Agency, in co-operation with a research partner; the issue of whether it should be applied to this source has not yet been decided.

#### *4.12.6.6.5 Source-specific recalculation (2.F.6)*

No recalculations have been carried out.

#### *4.12.6.6.6 Source-specific planned improvements (2.F.6)*

No further improvements are intended at present.

### 4.12.6.7 Trace gas (2.F.6)

#### *4.12.6.7.1 Source category description (2.F.6)*

In terms of its emissions levels and trends, the source category "trace gas" has been identified as a key source.

$SF_6$, 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.

#### *4.12.6.7.2 Description of methodology (2.F.6)*

Emissions may be equated with the quantities used. The quantities used are determined via experts' assessments. Relevant surveys are conducted only around every five years (1996, 2002) since, according to experts, the quantities used vary only minimally.

#### *4.12.6.7.3 Uncertainties and time-series consistency (2.F.6)*

The collected data on quantities is considered relatively imprecise. This applies especially to the years between the surveys. On the other hand, the time series shows that the quantities used (emissions) vary only slightly.

#### *4.12.6.7.4 Source-specific quality assurance / control and verification (2.F.6)*

The data for the 2002 report year, like the data for most of the previous years, was collected by an external expert working under commission to the Federal Environmental Agency. For the most part, quality assurance was carried out by an external expert. In addition, where possible, the data is checked by the relevant Federal Environmental Agency specialist upon receipt.

The data for the reporting years 1997 to 2001 has not been reviewed to date. The data for the reporting years 1996 and 2002 was obtained through direct surveys. Additional QA/QC is not required for this application.

A standardised QA/QC method is currently being developed by the Federal Environmental Agency, in co-operation with a research partner; the issue of whether it should be applied to this source has not yet been decided.

#### *4.12.6.7.5 Source-specific recalculation (2.F.6)*

No recalculations have been carried out.

#### *4.12.6.7.6 Source-specific planned improvements (2.F.6)*

Due to the very minor importance of this application, no improvements are planned at present.

# 5 SOLVENTS AND OTHER PRODUCT USE (CRF SECTOR 3)

## 5.1 Source category description (3)

| CRF 3 | | | | | |
|---|---|---|---|---|---|
| Key source | | Gas (MSG) | 1990 – contribution to total emissions | 2002 – contribution to total emissions | **Trend** |
| | NO | | | | |

| Gas | $CO_2$ | $CH_4$ | HFCs | PFCs | $SF_6$ | $N_2O$ | $NO_X$ | CO | NMVOC | $SO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Emissions factor[96] (EF) | NO | NO | NO | NO | NO | | NO | NO | | NO |
| EF uncertainties in % | | | | | | | | | | |
| Distribution of uncertainties [97] | | | | | | | | | | |
| Method for EF determination[98] | | | | | | | | | | |

This source category comprises emissions from the use of chemical products. At present, it includes a rough calculation of emissions from the use of $N_2O$ for narcotic purposes and data on the release of solvents from their use in industry, commerce and private households.

This source category also includes all NMVOC emissions resulting from use of solvents and of products containing solvents. In the IPCC Guidelines, this source category is (Sector 3) sub-grouped into categories 3A, 3B, 3C and 3D from the IPCC Common Reporting Format (CRF), as shown in Table 47 below.

Table 47: CRF categories in main category 3

| CRF reporting categories | Category name |
|---|---|
| 3A | Paint application |
| 3B | Degreasing & dry cleaning |
| 3C | Chemical products, manufacture & processing |
| 3D | Other |

Since the relevant NMVOC emissions come from a large number of different substances, no detailed reports have been planned to date for this area (no detailed CRF tables for NMVOC emissions).

The four reporting categories vary widely in structure. In keeping with this variation, data surveys for the present report were carried out with the UNECE/EMEP sub-structures based on the CORINAIR97 (CORINAIR: **CO**ordination d' **IN**formation Environmentale; sub-project **AIR**) SNAP system[99] .

The following detailed structure thus results for category 3D, "other":

- Treatment of glass and rock wool
- Printing industry (printing applications)
- Extraction of oils and fats
- Use of glues and adhesives
- Use of wood preservatives
- Undersealing and wax treatments for automobiles
- Household use of solvents (not including paints and lacquers)

96 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model
97 N = Normal, L = Log normal, T = Triangular, U = Uniform (even distribution)
98 D = IPCC default, RA = Reference approach, T1= IPPC tier 1, T1a/ T1b/ T1c = IPPC tier 1a/ 1b/ 1c, T2 = IPPC tier 2, T3 = IPPC tier 3, C = CORINAIR, CS = Country-specific, M = Model
99 In the present area, this involves "SNAP Level 3" detailing.

- Automobile-wax stripping
- Manufacturing of pharmaceutical products
- Household use of pharmaceutical products
- Other

"NMVOC" is defined in keeping with the VOC definition found in the EC solvents directive[100]. For purposes of the definition of solvents, the term "solvent use" is also defined in keeping with the EC solvents directive[101].

It is important to note that some volatile organic compounds are used both as solvents and as chemical reactants – for example, toluene, which is used as a solvent in lacquers and glues and as a reactant for production of toluenediisocyanate (TDI), and methyl ethyl ketone (butanone), which is used as a solvent in printing inks and as a base material for synthesis methyl ethyl ketone peroxide. Consequently, VOC (either substances or fractions of substances or products) used as chemical reaction components are not included in this source category.

Delimitation of this source category as outlined above takes a highly diverse range of emissions sources into account. This applies for:

- Concentrations and volatility of VOC used.
  The relevant spectrum includes use of volatile individual substances as solvents – for example, in cleansing; use of products with solvent mixtures – for example, in paints and lacquers; and applications in which only small parts of mixtures used (also) have solvent properties (as is the case, for example, in polystyrene-foam production.
- The widely different emissions conditions involved – from solvent uses that are completely open to the environment, such as in cosmetic use, to largely closed applications such as extraction of essential oils or dry-cleaning.

## 5.2 Methodological issues (3)

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 had existed in the former GDR. At the time, the plant had not yet been operational for long (it was constructed in 1988). The annual production capacity was approximately 1200 t. Research indicated that there were no exports or imports of this substance, and thus it was assumed that all of the substance was used for domestic consumption. Via the per-capita emission calculated from this for the former GDR, and assuming identical conditions, an $N_2O$ emission of 6200 t for Germany was roughly estimated. Since then, this figure has been constantly updated.

NMVOC emissions are calculated in keeping with a product-consumption-oriented approach. In this approach, the NMVOC quantities introduced into the source categories, via solvents or solvent-containing products, are determined and then NMVOC emissions are calculated via specific emission factors. This method is explicitly listed, under "consumption-based

100 In this definition, volatile organic compounds (VOC) include all organic compounds that are volatile at 293.15 K, at a vapour pressure of at least 0.01 kPa or under the usual conditions for their use.
101 In this definition, an organic solvent is a volatile organic compound that, either by itself or in combination with other raw materials, products or waste substances, and without changing chemically, either dissolves or is used as a cleanser for dissolving dirt accumulations, as a solvent, as a dispersing agent, as an agent for adjusting viscosity or surface tension, or as a softener or preservative.

emissions estimating", as one of two methods that are to be used for emissions calculation for Sector 3.

Use of this method is possible only with valid input figures – differentiated by source categories – in the following areas:

- Quantities of VOC-containing (pre-) products and agents used in the reporting year,
- The VOC concentrations in these products (substances and preparations),
- The relevant application and emission conditions (or the resulting specific emission factor).

To take account of the highly diverse internal structures of the 4 sub-categories 3A – 3D, these input figures are determined on the level of 37 differentiated source areas (in a manner similar to that used for SNAP Level 3), and the calculated NMVOC emissions are then aggregated. The product / substance quantities used are determined at the product-group level with the help of production and foreign-trade statistics. The so-determined domestic-consumption quantities are then further verified via cross-checking with industry statistics, where such statistics are available.

The average VOC concentrations and emission factors used are based on experts' assessments (expert opinions and industry dialog) relative to the various source categories and source-category areas. These efforts lead to the NMVOC emissions from solvent use shown in Table 48.

Table 48: NMVOC emissions from solvent use in 2002

| GREENHOUSE GAS SOURCE AND SINK CATEGORIES | NMVOC [Gg] |
|---|---|
| Total Solvent and Other Product Use | 827.564 |
| A. Paint Application | 291,157 |
| B. Degreasing and Dry Cleaning | 42,958 |
| C. Chemical Products, Manufacture and Processing | 35.429 |
| D. Other (as specified) | 458.021 |

Calculation of NMVOC emissions is possible only with foreign-trade statistics for 2002, of which the final version will not be available until the first quarter of 2004; as a result, the data for 2002 will probably have to be revised later.

## 5.3 Uncertainties and time-series consistency (3)

The data for $N_2O$ emissions from narcotic use is the result of an estimate which was updated over the entire time series. As such, the time series is consistent, but also entails a high level of uncertainty. At the time of the report, errors had been estimated for NMVOC emissions; this was carried out using the error-propagation method and on the basis of experts' assessments for all input figures (in all 37 differentiated source areas). Table 49 shows the thus-determined error ranges for the report categories.

Table 49: Experts' assessment of uncertainties (Tier 1)

| GREENHOUSE GAS SOURCE AND SINK CATEGORIES | Uncertainties | |
|---|---|---|
| Total Solvent and Other Product Use | + 32,4 % | - 31,8 % |
| A. Paint Application | + 32,0 % | - 33,6 % |
| B. Degreasing and Dry Cleaning | + 71,5 % | - 50,6 % |
| C. Chemical Products, Manufacture and Processing | + 9,9 % | - 10,8 % |
| D. Other (please specify) | + 30,1 % | - 30,0 % |

The main source of current uncertainties consists of inadequate precision in separation of basic statistics (production and foreign-trade statistics), with regard to categorisation in VOC-containing and VOC-free products, and with regard to use in different source areas with highly differing emissions conditions.

## 5.4 Source-specific quality assurance / control and verification (3)

The NMVOC-emissions data used in the emissions inventory was obtained via a current research project and was evaluated, in the framework of this project, for methodological and meterial consistency, plausibility and completeness. In the course of this review, the relevant methods were optimised in co-operation with the affected industry sectors.

In comparison to older emissions calculations for the area of solvent use, increases in product-input quantities increase emissions results, while updating of VOC concentrations, and further differentiation of such concentrations in the framework of methods optimisation, tends to decrease emissions.

Comparison with older emissions calculations involve product-based reviews, as well as correction of errors resulting from erroneous production statistics. In the past, relevant quantities (> 100 kT) of base substances for the chemical industry were erroneously reported as "other organic solvents". This correction led to a reduction – also amounting to ca. 100 kT – of total emissions in the Sector 3 source category.

## 5.5 Source-specific recalculations (3)

As a result of repeated changes in the underlying basic statistical systems, it is difficult to carry out consistent source-specific recalculation; with the exception of the calculation listed under Chapter 5.4, such recalculation is not currently planned.

## 5.6 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 $N_20$ in the various relevant potential applications. The project will consider the various pertinent possibilities (including explosives production), specify methods, prepare documentation, carry out relevant recalculations and make pertinent additions to the inventory.

To reduce data uncertainty in the area of NMVOC, for other emissions-relevant source-category areas, plans call for comparing the input figures used (quantities and VOC concentrations) with industry data.

In addition, as part of periodical updates of source-category emissions, additional discussions will have to be carried out with industry associations, aimed at reaching

agreements on regular provision of differentiated industry data. Relevant activities are planned for the 1st half of 2004.

# 6 AGRICULTURE (CRF SECTOR 4)

The German inventories for the gases methane ($CH_4$), non-methane volatile organic compounds (NMVOC), carbon dioxide ($CO_2$), ammonia ($NH_3$), nitrous oxide ($N_2O$) and nitrogen monoxide (NO), from agricultural sources, have been prepared with the help of the relevant manuals of the UN ECE (EMEP, 2003) and the IPCC Guidelines (IPCC, 1996b and IPCC, 2000), as well as on the basis of other documented sources. Relevant emissions of

- Dinitrogen ($N_2$)

are required for calculation of indirect emissions. Relevant surveys were also carried out.

Emissions are categoriesed in accordance with the reporting categories CRF (Common Reporting Format, IPCC) and NFR (Nomenclature for Reporting, UNECE / EMEP), for the relevant emissions sources.

The calculation methods and provision of activity data are described in detail in Dämmgen et al 2004.

German agricultural statistics do not include herd-zise figures for goats, donkeys and mules. Some indications as to the sizes of the relevant herds are available, however. According to these indications, there are some 165,000 goats in Germany, or far fewer than the country's some 2.7 million sheep (Nationales Fachprogramm 2003, a specialised national programme). As a result, the goat herds in question, and their emissions, are considered negligible (NE). As to donkeys and mules, about 6,000 to 8,000 donkeys, and about 500 mules, are kept in Germany (Dämmgen et al., 2004). The pertinent emissions are considered negligible (NE). Official animal censuses do not include all horses, and thus the pertinent figures for horses are likely to be too low.

As to animals raised for fur, the Federal Ministry of Consumer Protection, Food and Agriculture (BMVEL) obtains the pertient figures from the Länder; in some cases, the figures are estimated.

Models have been prepared for important parameters relative to keeping of animals, storage of farm manure and spreading of such manure.

## 6.1 Agricultural sources and quantification of their emissions and depositions for the period 1990-2002

### *6.1.1 Enteric fermentation (4.A)*

In the area of animal husbandry, $CH_4$ emissions from enteric fermentation (4.A) must be reported. Microbial conversion in stomachs of ruminants – especially conversion of cellulose – releases $CH_4$. The quantities released per animal and unit of time depend on the animal species in question, individual-animal efficiency and feed composition.

The relevant source categories (animal species) in 4.A are considered in combination.

### 6.1.1.1 Source category description (4.A)

| **CRF 4A** | | | | | |
|---|---|---|---|---|---|
| Key source | | Gas (MSG) | 1990 – contribution to total emissions | 2002 – contribution to total emissions | **Trend** |
| Enteric Fermentation, Dairy Cattle | l | $CH_4$ | 1,01 % | 1,22 % | falling |
| Enteric Fermentation, Dairy Cattle | l / t | $CH_4$ | 1,60 % | 1,94 % | falling |

| **Gas** | **$CO_2$** | **$CH_4$** | **HFCs** | **PFCs** | **$SF_6$** | **$N_2O$** | **$NO_X$** | **CO** | **NMVOC** | **$SO_2$** |
|---|---|---|---|---|---|---|---|---|---|---|
| Emissions factor102 (EF) | NO | CS/C/ D/T1 | NO | NO | NO | NO | NO | NO | NO | NO |
| EF uncertainties in % | | 30 | | | | | | | | |
| Distribution of uncertainties 103 | | - | | | | | | | | |
| Method for EF determination104 | | CS/C/ D/T1 | | | | | | | | |

In comparison to last year's inventory data, source category 4.A was a key source in 2002, in terms of emissions levels (and, in one area, also in terms of trend).

Germany reports on the emissions of methane ($CH_4$) from enteric fermentation in the stomachs of dairy cows, other cattle (calves, bulls, heifers and mother cows), swine, sheep and horses. There is a lack of methods for treating poultry in this context; in accordance with the IPCC Guidelines (IPCC, 1996b, Chapter 4, Tab. A-4), the relevant quantities are considered negligible and are not calculated (not occurring).

A chronology of total emissions is presented in Table 50, while Figure 24 breaks down the emissions by animal species.

Almost all agricultural $CH_4$ emissions in Germany originate in keeping of cattle (95 %). The relevant proportions for keeping of swine are small (2 %), while those of all other animals are small enough to be neglected. Dairy cows are the most important group within the cattle category. Decreases in emissions since 1990 (with increasing emission factors for dairy cows and constant emission factors for all other animals) are a result of decreases in animal herds. Detailled data on $CH_4$ emissions (national and at the Länder level) are provided by LÜTTICH et al, 2004.

Table 50: $CH_4$ emissions $E_{CH4}$ from animal husbandry (enteric fermentation). Figures for Germany in Tg $a^{-1}$ $CH_4$.

| **Year** | **1990** | **1991** | **1992** | **1993** | **1994** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **2001** | **2002** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $E_{CH4}$ | 1,63 | 1,44 | 1,38 | 1,35 | 1,36 | 1,36 | 1,35 | 1,32 | 1,30 | 1,29 | 1,26 | 1,28 | 1,28 |

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

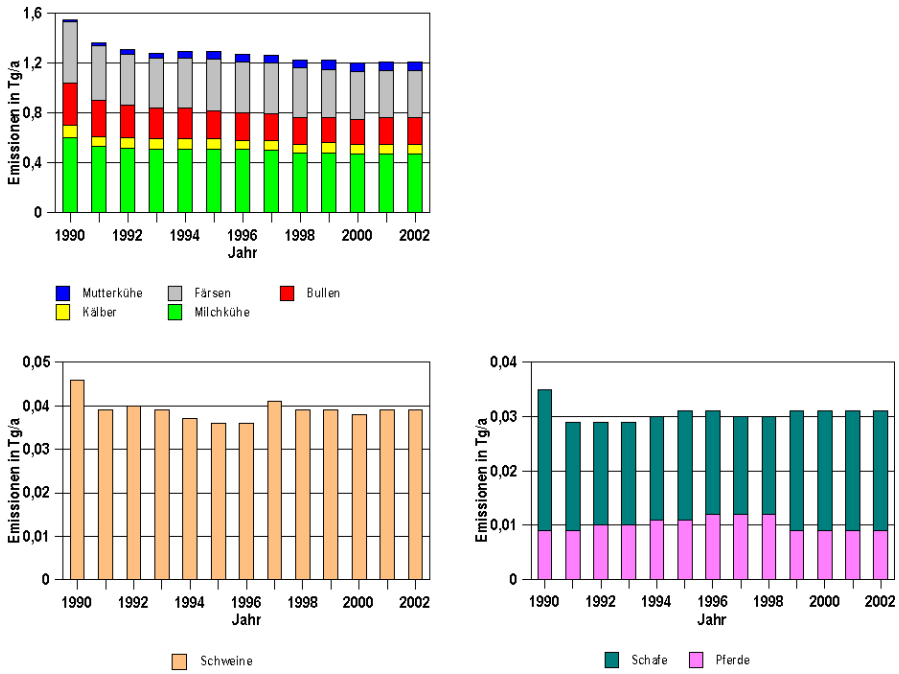



Figure 24: Time series for $CH_4$ emissions $ECH_4$ (enteric fermentation) for the animal categories considered. Above left: cattle; below left: swine; below right: horses and sheep. Figures in Tg $CH_4$ a-1

### 6.1.1.2 Methodological aspects, CRF 4 A (methane, $CH_4$)

Two different methods are available for determining the emissions occurring in fermentation. A simple method, using emission factors based on estimates (Tier 1), and a more detailed method, using Land-specific emission factors (Tier 2).

In principle, Tier 1 and Tier 2 are calculated via the following steps:

1. Animal-herd sizes, for each animal species and category
2. Emission factors for each animal category
3. Calculation of total emissions

In the simpler Tier 1 procedure, the emission factors for the individual animal specific / categories are based on estimates. For determination of methane emissions, the emission factors are multiplied by the number of animals for each category.

IPCC Good Practice Guidance (IPCC, 2000) calls for the more detailed Tier 2 method to be used in cases in which a country has listed methane emissions from animal husbandry as a main source for its inventories.

Tier 2 requires differentiated characterisation of animal herds. Where a sub-category contributes significantly to digestion-related methane emissions, the emissions must be determined pursuant to Tier 2. This means that a country-specific emission factor must be determined for the relevant animals, in accordance with the following equation:

Equation 6-1: Determination of specific emission factors

$EF = (GE*Y*365\ d/a) / (55{,}65\ MJ/kg\ CH_4)$ [%]

with EF emission factor for each sub-category i [%]

GE gross energy requirements [MJ/(animal and day)]

$Y_m$ Methane-conversion rate (percentage of gross energy that is converted to methane)

The gross energy requirement is from the *Detailed characterisation of livestock herds* (*detaillierten Charakterisierung des Viehbestands*) and the methane-conversion rate has been taken from IPCC Good Practice Guidance (Table 4-8) and from national data. Since the methane-conversion factor (MCF) is an important factor in this equation, it should also be differentiated by animal species, age/weight and feed.

Total emissions are then determined as follows:

Equation 6-2: Complete emissions from the enteric fermentation source category

$E = \Sigma EF_i * POP_i / (10^6 kg/Gg)$ [kg/Gg]

with $EF_i$ emission factor for each sub-category i [%]

$POP_i$ population size for each sub-category i [head]

E methane emissions in [kg/Gg]

More detailed population data is required for the Tier 2 approach. Emission factors are determined for the various significant animal categories on the basis of country-specific data, and in several steps.

Where other methods are available, these may be used if they lead to more precise results and if their origin is adequately documented.

In analysis of key sources in agriculture, $CH_4$ emissions from dairy cows and other cattle in category 4 A, enteric fermentation, were identified as key sources. As a result, emissions from enteric fermentation, especially such fermentation in cattle, must be determined on the basis of differentiated characterisation of animal herds. Since adequately differentiated data was not available, it was possible to use only the simple Tier 1 approach, however (cf. Dämmgen et al., 2004, Part 3).

Emissions were calculated on the basis of methods that the CORINAIR manual (EMEP, 2003) describes as "simpler methods" and that were adopted by the IPCC (Tier 1) (IPCC et al., 1996b). The default values for western Europe (IPCC et al., 1996b), and the EF from the CORINAIR manual (EMEP, 2003), were used. In principle, the emission factors reflect the situation in Germany. Calculation was carried out on the rural-district level.

#### *6.1.1.2.1 Characterisation of animal herds*

The total animal population is divided into sub-groups for which activity rates and emission factors are available. Disaggregation is carried out only where emission factors differ significantly, for given uncertainties. The following table provides a comparison of German sub-groups with the IPCC proposals.

Table 51: Detailed characterisation of animal herds pursuant to IPCC, and the breakdown used for Germany

| | IPCC main categories | IPCC sub-categories | Germany |
|---|---|---|---|
| Cattle | Dairy cows | Subdivision into two or more performance classes | Dairy cows, performance-dependent survey for each rural district |
| | Adult cattle, "other" | Male/female<br>Fattening and additions | Mother cows, bulls, heifers |
| | Young animals | Nursing calves<br>Growing young animals<br>Pasture animals | Calves |
| Swine | Sows | Pregnant sows<br>Farrowing sows | Sows (including piglets and boars)<br>Fattening swine |
| | Boars | --- | --- |
| | Young animals | Suckling piglets<br>Growing young animals<br>Slaughter-ready animals | --- |
| **Sheep** | Ewes | Pregnant ewes<br>Dairy sheep | Sheep |
| | Sheep >1 year | --- | |
| | Young animals | Male animals, castrated animals<br>Female animals | |
| **Other** | Horses, poultry, goats, donkeys, mules, camels, fur-bearing animals, etc. | --- | Horses, poultry, fur-bearing animals |

*Sources IPCC GPG (2000)*

In the category of dairy cows, milk yields have been taken from public statistics at the rural-district level, while all other variables have been modelled.

Furthermore, a differentiation is made between calves, male and female fattening animals (referred to as "heifers" and "bulls") and mother and nursing cows. The basic reason for this practical differentiation is that animals listed under "female cows for beef" either may be used to supplement and rejuvenate herds or may be slaughtered. Cattle used to supplement and rejuvenate herds and animals destined for slaughter do not differ in terms of the feed they are given and the conditions under which they are kept. The main basis for the activity data consists of the animal censuses of 1990, 1992, 1994, 1996, 1999 and 2001. The herd figures were not interpolated to permit description of years without herd-size statistics; instead, the herd figures were assumed to remain constant (Lüttich et al., 2004). The gaps in the new German Länder data for the years 1990 to 1993 were closed by means of experts' assessments. The relevant procedure is described in detail in Chapter 2 of the research report of Döhler et al. (UBA, 2002a).

Further sub-grouping is not required for all other animals for which calculations are carried out in accordance with the Tier 1 approach. There are no default emission factors. What is more, it is not useful to use such factors in cases in which the relevant national data is not available. Detailled data on animal herds (national and at the Länder level), as well as additional information, is provided by LÜTTICH et al, 2004.

#### *6.1.1.2.2 Calculation of $CH_4$ emissions from keeping of dairy cows*

For the time being, the emission factor for dairy cows is determined with the help of a regression approach that takes yields and body weight into account. Due to a lack of relevant data, body weight is also calculated from milk yield. Feeding patterns (grass/grass siilage or corn/corn silage) are derived as model variables (here, A and B) from the RAUMIS (Regionalisiertes Agrar- und Umweltinformationssystem für Deutschland – regionalised agricultural and environmental information system for Germany) agricultural sector model (cf. Dämmgen et al., 2002).

$$EF_{CH4} = \alpha \cdot \left(\beta + \gamma \cdot Y + \delta \cdot w^{0.75}\right)$$

with (A) feeding based on grass/grass silage
(B) feeding based on corn / corn silage

| where | | | | |
|---|---|---|---|---|
| | $EF_{CH4}$ | methane emissions | | kg animal$^{-1}$ a$^{-1}$ $CH_4$ |
| | $\alpha$ | constant | | 0.365 kg g$^{-1}$d a$^{-1}$ |
| | $\beta$ | constants | A: | $\beta$ = 55 g animal$^{-1}$ d$^{-1}$ $CH_4$ |
| | | | B: | $\beta$ = 26 g animal$^{-1}$ d$^{-1}$ $CH_4$ |
| | $\gamma$ | Factor | A: | $\gamma$ = 4.5 g kg$^{-1}$ |
| | | | B: | $\gamma$ = 5.1 g kg$^{-1}$ |
| | Y | milk yield | | kg animal$^{-1}$ d$^{-1}$ |
| | $\delta$ | Factor | A: | $\delta$ = 1.2 g animal$^{-0.25}$ d$^{-1}$ $CH_4$ |
| | | | B: | $\delta$ = 1.8 g animal$^{-0.25}$ d$^{-1}$ $CH_4$ |
| | $w$ | live weight | | kg animal$^{-1}$ |

The average milk yield for Germany, weighted by Länder and oriented to the base year 1990, is 12.9 kg animal$^{-1}$d$^{-1}$, which differs slightly from the IPCC Guidelines' suggested value for western Europe, 11.5 kg d$^{-1}$ (IPCC, 1996b, Table A-1). Taking increased yields into account, a value of 17.0 kg animal$^{-1}$d$^{-1}$ is calculated for 2002. Additional information on milk yields, body weight, types of husbandry and VS excretion[105] is provided by LÜTTICH et al. (2004).

The $CH_4$ emission factors in Germany range between 85.4 kg animal$^{-1}$ a$^{-1}$ $CH_4$ (1990) and 131.5 kg animal$^{-1}$ a$^{-1}$ $CH_4$ (2002); the national averages are 94.3 kg animal$^{-1}$ a$^{-1}$ $CH_4$ (1990) and 102.7 kg animal$^{-1}$ a$^{-1}$ $CH_4$ (2002). An overview of the emission factors used is provided in Lüttich et al. (2004).

In light of the poor availability of relevant data, of the regression approach thus used in order to calculate methane emissions (see above) and of the correlation coefficient of $R^2$=0.435 for grass / grass silage and $R^2$=0.387 for corn / corn silage, it is likely that methan emissions are being underestimated (Dämmgen et al., 2004).

#### *6.1.1.2.3 Calculation of $CH_4$ emissions from keeping of all other animals*

For all other mammals, the Tier-1 approach, in keeping with:

$$E_{CH4_A} = EF_A \cdot n_A$$

| with | | | |
|---|---|---|---|
| | $E_{CH4}$ | $CH_4$ emissions | kg a$^{-1}$ $CH_4$ |
| | A | animal class | |
| | $EF$ | emission factor | kg animal$^{-1}$ a$^{-1}$ $CH_4$ |
| | $n$ | number of animals | |

was used. For each animal species, the default values (emission factors) pursuant to IPCC (IPCC, 1996b), Chap. 4, Tab. A4 and Tab. 4-3, were used:

105 Volatile solids; volatile components in the solid substance per day, based on TS intake [kg TS/d]

| | |
|---|---|
| Male and female beef cattle | 84 kg animal$^{-1}$ a$^{-1}$ $CH_4$ |
| Calves | 33 kg animal$^{-1}$ a$^{-1}$ $CH_4$ |
| Mother cows | 100 kg animal$^{-1}$ a$^{-1}$ $CH_4$ |
| Sheep | 8 kg animal$^{-1}$ a$^{-1}$ $CH_4$ |
| Horses | 18 kg animal$^{-1}$ a$^{-1}$ $CH_4$ |
| Swine | 1.5 kg animal$^{-1}$ a$^{-1}$ $CH_4$ |

Germany does not report emissions from donkeys and mules, goats and game in enclosures (NE).

### 6.1.1.3 Uncertainties and time-series consistency (4.A)

#### *6.1.1.3.1 Relevant animal figures*

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, 2000, chapter B1040-6). 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 basically consistent. The Agricultural Statistics Act (Agrarstatistikgesetz) was amended in 1998. This changed the survey bases for determining herd sizes – considerably, in some cases. Impacts were seen especially in numbers of horses. Table 52 shows the impacts of the amendment of the Agricultural Statistics Act, as determined for the state (Land) Thuringia:

Table 52: Percentage changes in herd sizes resulting from the amendment of the Agricultural Statistics Act (Agrarstatistikgesetz) (BML, 1998). Sample results for Thuringia (TMLNU, 2000)

| Category | **Difference** (old - new)/new (%) |
|---|---|
| Cattle | 1,2 |
| Swine | 1,3 |
| Sheep | 10,6 |
| Horses | 40,3 |
| Poultry | 4,3 |

The number of horses actually present in Germany may be assumed to be about twice as large as the relevant figure from the agricultural statistics.

#### *6.1.1.3.2 Emission factors*

The emissions calculated for *keeping of dairy cows*, using the method that takes yield and body weight into account, are probably too low, for systematic reasons (cf. DÄMMGEN et al. Teil 3, 2004, Chap. 6.2 and BERTILSSON, 2002).

By analogy to the CORINAIR manual, Chapter B1040-6 (EMEP, 2003), an error on the order of 30 % is listed for emission factors.

#### 6.1.1.4 Source-specific quality assurance / control and verification (4.A)

The data is reviewed for transcription errors made between the original data and the calculation tables, and it is checked for errors with regard to units and orders of magnitude. For future QA/QC procedures, relevant methods will have to be improved (use of Tier 2) and activity data will have to be broken down more finely (especially district-level data on feeding). In addition, emission factors, except where confidential, will be made publicly available via the German Emission Factor Database (GEREF). This will enable experts to review and comment on the data.

A comparison made with the aid of the "implied emission factors" provided by the UNFCCC Secratariat's *Data Locator*, for individual countries, shows that the method used for Germany – and the resulting factors for methane emissions of dairy cows for 1990 (94.3 kg/(head*a)) and 2002 (102.7 kg/(head*a)) – lie within the middle of the relevant spread.

Table 53: Digestion-related methane emissions of dairy cows of various countries – a comparison of implied emission factors (emission factors calculated from emissions and dairy-cow-herd sizes)

| **Country** | **IEF (calculated EF)** Methane [kg/(head*a)] |
|---|---|
| Denmark | 104 |
| Germany | 100 |
| Finland | 114 |
| France | 103 |
| UK | 117 |
| Ireland | 100 |
| Italy | 111 |
| Sweden | 127 |
| Canada | 80 |
| Netherlands | 81 |
| Austria | 101 |
| Switzerland | 104 |
| Spain | 106 |
| U.S. | 99 |

*Source: CRF data for individual countries*

#### 6.1.1.5 Source-specific recalculations (4.A)

In contrast to the procedure used in earlier calculations, emissions calculation included animals in the city-states of Bremen, Hamburg and Berlin.

Emissions from enteric fermentation were calculated according to the same method for the entire time series (default emission factors). Previously, default emission factors have also been used for calculation of emissions from keeping of dairy cows. The present report uses national emission factors that reflect $CH_4$ emissions' dependence on yields and feeds in use of default values (NIR 2003) and national values (NIR 2004) (cf. Table 54).

Table 54: Comparison of the mean $CH_4$ emission factors used in the NIR 2003 and NIR 2004 for animal husbandry (enteric fermentation). Figures for dairy cows in Germany in kg animal$^{-1}$ a$^{-1}$ $CH_4$ .

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NIR 2003 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | |
| NIR 2004 | 94,3 | 94,6 | 96,3 | 97,1 | 97,2 | 98,2 | 98,7 | 99,1 | 99,8 | 101,0 | 101,9 | 102,7 | 102,7 |

#### 6.1.1.6 Source-specific planned improvements (4.A)

There are plans to calculate enteric fermentation according to the Tier 2 method from 2004 onwards. For it to be possible to use the relevant equations (cf. DÄMMGEN et al.; 2004, Part 3, Chapter 6.3), however, the database for describing frequency distributions in dairy-cow rationing and in yields (weight gains) of beef cattle and fattening swine, must be determined via surveys.

### *6.1.2 Farm-fertiliser management (4.B)*

#### 6.1.2.1 Source category description (4.B)

| **CRF 4B** | | | | |
|---|---|---|---|---|
| Key source | Gas (MSG) | 1990 – contribution to total emissions | 2002 – contribution to total emissions | **Trend** |
| Manure management, dairy cows | $CH_4$ | 1,03 % | 1,25 % | falling |
| Manure management, other cattle | $CH_4$ | 0,67 % | 0,81 % | falling |
| Manure management, swine | $CH_4$ | 0,98 % | 1,19 % | falling |

| **Gas** | **$CO_2$** | **$CH_4$** | **HFCs** | **PFCs** | **$SF_6$** | **$N_2O$** | **$NO_X$** | **CO** | **NMVOC** | **$SO_2$** |
|---|---|---|---|---|---|---|---|---|---|---|
| Emissions factor[106] (EF) | NO | C/D | NO | NO | NO | D | D | - | CS | NO |
| EF uncertainties in % | | 30 | | | | NE | | | | |
| Distribution of uncertainties [107] | | - | | | | NE | | | | |
| Method for EF determination[108] | | C/D/T 1 | | | | CS/C | | | | |

With respect to the previous year's inventory data, source category 4.B (for sub-source-categories 4.B.1.a and b, and 4.B.13) is a key source.

$CH_4$ and NMVOC, and $NH_3$, $N_2O$, NO, and $N_2$, are released in storage of farm manure in stalls, on paved areas outside of stalls and in storage facilities (in the narrower sense), and such emissions are also released when manure is spread. NMVOC emissions can also include sulphur-containing species. Emissions depend on a range of factors, including animal species, animal yield, feed, time spent in specific types of quarters (pasture, stall, paved areas), species-specific behaviour, stall type, use of straw, type and duration of manure storage, time and place of manure spreading, method used to spread manure and ways in which manure is worked into the soil.

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

Germany does not report on donkeys and mules, goats and game kept in enclosures. No time series is available for fur-bearing animals.

#### *6.1.2.1.1 Methane emissions from manure management (4.B)*

Table 55 presents the time series for $CH_4$ emissions from manure management. It shows an emissions decrease that is limited primarily to the years after German reunification and that points to decreases in cattle-herd sizes (Figure 25). Of total emissions, cattle contribute two-thirds (63 % for 1990) and swine contribute one-third (36 % for 1990). As these figures indicate, emissions from keeping of poultry, and from keeping of horses and sheep, are negligible. (cf. Figure 25).

Table 55: $CH_4$ emissions $E_{CH4}$ from animal husbandry (manure management). Figures for Germany in Tg $a^{-1}$ $CH_4$.

| Year | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $E_{CH4}$ | 1,61 | 1,40 | 1,36 | 1,33 | 1,38 | 1,35 | 1,35 | 1,39 | 1,34 | 1,33 | 1,30 | 1,31 | 1,31 |

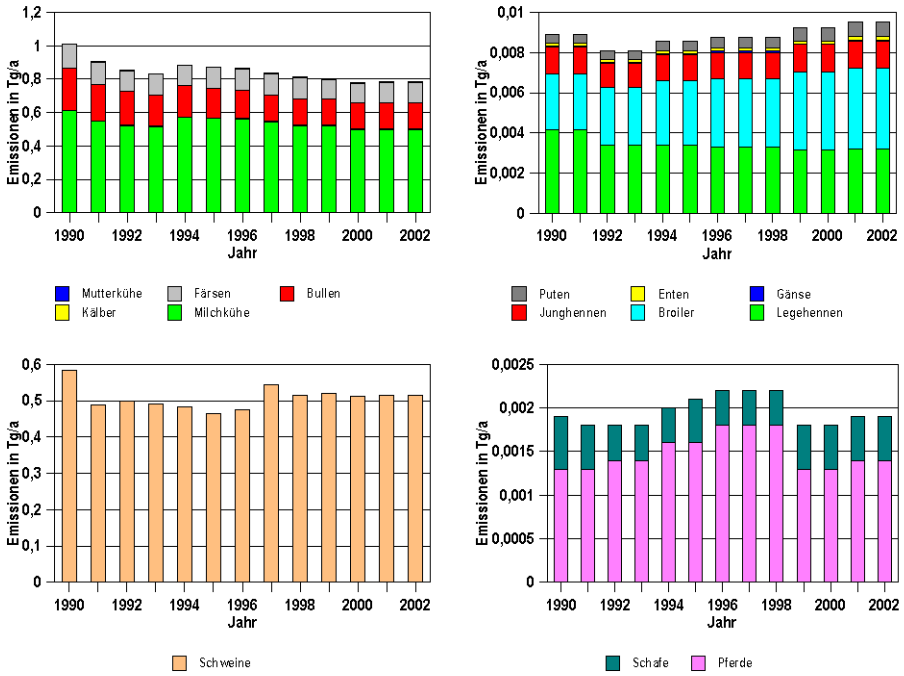



Figure 25: Time series for $CH_4$ emissions $E_{CH4}$ for animal categories considered. Above left: cattle; below left: swine; above right: poultry; below right: horses and sheep. Figures in Tg $a^{-1}$ $CH_4$.

#### *6.1.2.1.2 NMVOC emissions from manure management*

Microbial conversion of proteins in farm manure (about 50 % of the nitrogen contained in excretions is bound in proteins) produces both ammonia ($NH_3$) and non-methane volatile organic compounds (NMVOC). In the UK, the consistent proportionality seen between $NH_3$ emissions and NMVOC emissions from a range of different farm manures was used in preparation of a first NMVOC-emissions inventory. Germany has used that inventory's relative emission factors to prepare a first estimate of NMVOC emissions from animal husbandry (details in Dämmgen et al., 2004, Part 3, Chapter 4.5.1.2.1). The time series for

NMVOC emissions is presented in Table 56, and the emitter composition is shown in Figure 26. Beginning in about 1994, following a decrease in animal-herd sizes, resulting from German reunification, emissions remained constant. Although no figures for horses are available, due to the lack of a relevant calculation procedure, their emissions can be assigned largely to "keeping of cattle", especially "keeping of dairy cows".

Table 56: NMVOC emissions $E_{NMVOC}$ from animal husbandry (manure management); figures for Germany in Tg $a^{-1}$ C

| Year | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $E_{NMVOC}$ | 0,30 | 0,27 | 0,26 | 0,26 | 0,24 | 0,24 | 0,24 | 0,24 | 0,24 | 0,24 | 0,23 | 0,23 | 0,23 |

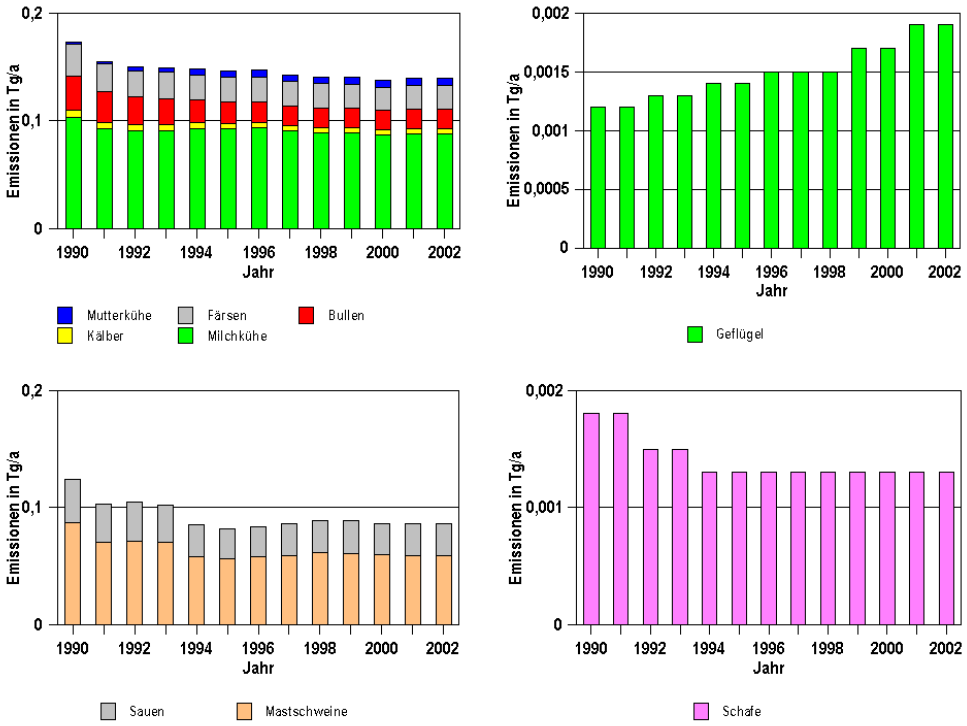



Figure 26: Time series of NMVOC emissions $E_{NMVOC}$ (manure management) for the animal categories considered. Above left: cattle; below left: swine; below right: poultry and sheep. Figures in Tg $a^{-1}$ C

In modelling of NMVOC emissions, it was also found, taking sulphur compounds into account, that considerable amounts of dimethyl sulfide are emitted.

Pursuant to these estimates, the emissions of sulphur bound in NMVOC amount to about 0.03 to 0.04 Tg $a^{-1}$. Additional discussion regarding the possible significance of these emissions for $SO_2$ concentrations and flows, and for ecosystem acidification, is presented in DÄMMGEN et al. (2004, Part 3, Chapter 6.5).

#### *6.1.2.1.3 Nitrous oxide, nitrogen monoxide and dinitrogen emissions from manure management*

The results of calculations of $N_2O$ and NO emissions are shown in Table 57; Figure 27 presents the results with reference to emitters. Since $N_2O$ and NO emissions are

proportional, NO emissions were not considered separately. $N_2O$ and NO emissions have been decreasing considerably with regard to the base year.

Cattle account for the major part of $N_2O$ and NO emissions (66 % in 1990, and a decrease to 63 % in 2000). With regard to 1990, a total of 17 % of $N_2O$ and NO emissions are caused by swine; 10 % are caused by poultry and 6 % are caused by horses and sheep.

Table 57: $N_2O$ and NO emissions $E_{N2O}$ and $E_{NO}$ from animal husbandry (manure management). Figures for Germany in Tg $a^{-1}$ $N_2O$ and NO.

| Year | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $E_{N2O}$ | 14,4 | 12,8 | 12,5 | 12,4 | 10,1 | 10,1 | 10,2 | 10,1 | 10,0 | 9,8 | 9,7 | 9,8 | 9,8 |
| $E_{NO}$ | 19,7 | 17,5 | 17,0 | 16,9 | 13,8 | 13,8 | 14,0 | 13,8 | 13,7 | 13,4 | 13,2 | 13,3 | 13,3 |

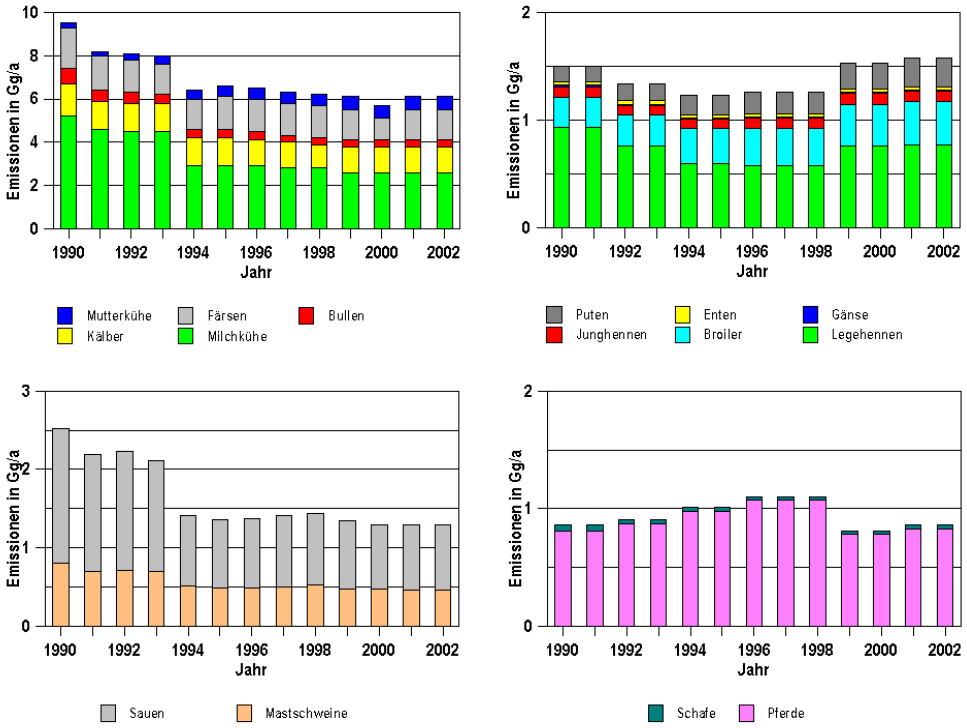



Figure 27: Time series for $N_2O$ emissions $E_{N2O}$ for animal categories considered. Above left: cattle; below left: swine; above right: poultry; below right: horses and sheep. Figures in Tg $a^{-1}$ $N_2O$

### 6.1.2.2 Methodological issues (4.B)

#### *6.1.2.2.1 Methodological issues and requirements CRF 4 B ($CH_4$)*

The IPCC Guidelines specify two methods for determining quantities of $CH_4$ emissions from animal excrement. In emissions calculation pursuant to the Tier 1 procedure, data on animal herds (species and category) and on climate is required, and IPCC Default EF are used. The Tier 2 approach involves detailed determination of methane emissions from manure management. Under good practice guidelines, the procedure is used when a significant portion of a country's methane emissions comes from animal excrement. In Germany, this is the case for at least the categories of cattle, dairy cows and swine.

Country-specific emission factors are determined with the help of detailed data on animal herds and on manure management. The data may be obtained directly, via measurements and model formation, or may be acquired implicitly. The implicit procedure requires data on feed rationing and digestibility, as well as data on the type of manure involved (solid or liquid) and on its storage (duration, temperature records, storage system). Finally, the emission factor is determined via the following equation:

Equation 6-3: Determination of the implicit emission factor for methane from animal excrement, pursuant to Tier 2

$$EF_i = VS_i * 365\ d/a * B_{0i} * 0{,}67\ kg/m^3 * \Sigma_{(jk)}\ MCF_{jk} * MS_{ijk}$$

where:
- $EF_i$ emission factor for each sub-category i [kg]
- VSi volatile solid excretion, in a sub-category, per day, based on TS intake [kg TS/d]
- B0i maximal methane-formation rate of excrement of sub-category i [m³/kg VSi]
- MCFjk Methane-conversion factor for manure, with management j in climate region k
- MSijk Percentage of manure of sub-category i that is treated in keeping with management j in climate region k (in effect, the probability of occurrence in a given state)

As it did with digestion-related emissions, the Tier 2 procedure requires detailed characterisation of animal herds.

In the German inventory report, $CH_4$ emissions from management of manure from dairy cows, cattle and swine are classified as a key source. Since the database is not sufficiently reliable, $CH_4$ emissions are calculated using only the method described by the CORINAIR manual (EMEP 2003) as a "simpler" method. This is in keeping with the IPCC method, pursuant to the Tier 1 approach for treatment of liquid manure (IPCC 2000, Table 4.10). In principle, the emission factors reflect the situation in Germany. For excrement (VS) and maximal methane-formation capacity (Bo), the default values for western Europe are still being used (EMEP 2003, chapter B1040-4 and IPCC 1996b, Table B-2). The calculations are carried out for rural districts (Dämmgen et al. 2004, Part 3, Chap. 4.4).

#### *6.1.2.2.2 Methodological issues and requirements CRF 4 B ($N_2O$, NO and $N_2$)*

Neither the IPCC Guidelines nor the IPCC Good Practice Guidance unambiguously classify the various methods for determining emissions from manure management into separate tiers. The more precise methods use country-specific emission factors for intake, retention (for example, in milk or wool) and excretion of nitrogen and for the various manure-management systems. Pursuant to IPCC Good Practice Guidance, detailed characterisation should be carried out in cases in which emissions represent a key source. Many countries refer to the methods they use as "Tier 1 and Tier 2". And yet Tier 2 always involves calculation with country-specific parameters. In general, $N_2O$ emissions are determined via the following five steps:

Animal-herd sizes, for each animal species and category

- Determination of the annual N excretion per animal of a relevant species / category
- Determination of the distribution of animals of a relevant species / category throughout the various relevant manure-management systems

- Determination of emission factors for each manure-management system
- Calculation of total emissions (addition of emissions of all sub-categories)

Pursuant to IPCC Good Practice Guidance, total emissions are determined via the following equation:

Equation 6-4: Determination of $N_2O$ emissions from manure management

$$(N_2O\text{-}N)_{(mm)} = \Sigma_{(S)}\{[\Sigma_{(T)}{}^{*}{}_{(}N_{(T)}{}^{*}{}_{(}Nex_{(T)}{}^{*}MS_{(T,S)}]{}^{*}EF_{3(S)}\}$$

where $(N_2O\text{-}N)_{(mm)}$ $N_2O$-N emissions from a country's manure management
$N_{(T)}$ animals of a species / category T
$Nex_{(T)}$ Average annual excretions of an animal species / category T
$MS_{(T,S)}$ percentage of the annual excretions of a species / category T that is subject to a certain manure-management system S.
$EF_{3(S)}$ $N_2O$ emission factor for manure-management system S
S manure-management system
T animal species / category for the herd in question

A number of other conditions, such as the ventilation situation, and the manure-storage temperature, must also be taken into account. The entire data-collection, data-review and documentation process is considerably involved. In short, however, three basic types of data are required for determination of $N_2O$ emissions:

- Animal-herd data
- Frequency distribution for the various manure-management systems, by animal species / category
- N excretions, by animal species / category (including adjustment to take account for young animals)

N excretions also enter into calculation of soil-based $N_2O$ emissions. The same calculation method and database should thus be used for both sources.

Pursuant to the key-source analysis, category 4 B $N_2O$ emissions are not a key source. For this reason, a simple method (Tier 1 approach) may be used for calculation. Since 2004, the mass-flow procedure has been used to calculate losses of gaseous N species (cf. Dämmgen et al., 2004, Part 3, Chap. 4.9). The procedure for calculating $N_2O$ and NO emissions, and the relevant standard values for types of storage, were taken from the IPCC Guidelines (IPCC, 1996b). The procedure and standard values were applied to the nitrogen quantities calculated for storage, using the mass-flow procedure.

The procedure traces the flow of all nitrogen deposited in manure and urine – as total N and as total ammoniacal nitrogen (TAN). The substance flow is divided into flows for pasturing and stabling. The flow for stabling takes into account the keeping procedures commonly used in Germany for liquid-manure and straw-based systems and assumes that the relevant quantities occurring with both types are stored in the storage facilities commonly used in Germany. Excrement stored in such facilities is then assumed to be spread with the relevant available equipment. The periods required for working manure into the soil are taken into account.

The quantities of $N_2$ that form simultaneously with formation of $N_2O$ are estimated on the basis of literature data, with a view to calculation of indirect emissions. The emission factors (liquid-manure-based systems: $EF_{N2O}$ = $EF_{NO}$ = 0.001 kg kg$^{-1}$ N, $EF_{N2}$ = 0.007 kg kg$^{-1}$ N; straw-based systems: $EF_{N2O}$ = $EF_{NO}$ = 0.02 kg kg$^{-1}$ N, $EF_{N2}$ = 0.14 kg kg$^{-1}$ N) have either been taken from IPCC or derived from that source (IPCC, 1996b, Table 4-22).

The figures are determined for each rural district, with the help of the RAUMIS agricultural sector model. In principle, a different emission factor results each year for each animal category and each district (DÄMMGEN et al., 2004, Part 3, Chapter 4.4).

#### *6.1.2.2.3 Relevant numbers of animals*

Normally, the emissions for a given animal category are calculated using the numbers of animals in the entire relevant population. In the *swine* category, fattened swine and sows are considered separately in calculation of emissions of N species, however. The emission factors for sows include emissions of piglets and boars. The procedure used to date for calculation of $CH_4$ emissions requires the total number of swine as an activity. In the category *sheep*, emissions of N species are calculated from figures for female sheep for breeding; the relevant emission factor includes lambs and castrated rams. $CH_4$ emissions, on the other hand, are determined from the size of the entire sheep population. Official animal censuses provide only incomplete head counts of horse populations. As to animals raised for fur, the Federal Ministry of Consumer Protection, Food and Agriculture (BMVEL) obtains the pertient figures from the Länder; in some cases, the figures are estimated.

#### *6.1.2.2.4 Excrement*

*C species:* No data on excretion of "volatile solids" is available for Germany . Relevant calculations are based on default values for excretions (IPCC, 1996b, Tables B-1 and B-7):

| | |
|---|---|
| Dairy cows | = 5.08 kg animal$^{-1}$ d$^{-1}$ C |
| Male and female beef cattle | = 2.99 kg animal$^{-1}$ d$^{-1}$ C |
| Calves | = 1.46 kg animal$^{-1}$ d$^{-1}$ C |
| Mother cows | = 5.08 kg animal$^{-1}$ d$^{-1}$ C |
| Swine | = 0.50 kg animal$^{-1}$ d$^{-1}$ C |
| Sheep | = 0.40 kg animal$^{-1}$ d$^{-1}$ C |
| Horses | = 1.72 kg animal$^{-1}$ d$^{-1}$ C |
| Poultry | = 0.10 kg animal$^{-1}$ d$^{-1}$ C |

NMVOC emissions are calculated via use of calculated quantities of $NH_3$ emissions, since the two substance groups are linked via their formation mechanism.

*N species:* N excretions for dairy cows are calculated as a function of milk yields:

$$m_{N_{excr}} = m_0 + a \cdot m_{milk}$$

| | | | |
|---|---|---|---|
| where | $m_{Nexc}$ | Mass of excreted N | kg animal$^{-1}$ · a$^{-1}$ N |
| | $m_0$ | 48.5 kg animal$^{-1}$ a$^{-1}$ N | |
| | $a$ | 0.0095 kg N (kg milk)$^{-1}$ | |
| | $m_{milk}$ | milk yield | kg animal$^{-1}$ a$^{-1}$ milk |

An additional correction factor takes feed (percentage of grass / grass silage) into account. Milk yields are taken from statistics, for each district, and ration compositions are modelled, for each district, with RAUMIS. For details on the method, cf DÄMMGEN et al. (2004, Part 3, Chapter 4.9.1.); regarding chronological and spatial breakdown of N excretions, cf. Lüttich et al. (2004).

For all other animals, N-excretion figures were taken from the German literature (Dämmgen et al., 2004, Part 3, Chapter 4.9.2 to 4.9.9). Specifically, the following figures were used:

| | |
|---|---|
| Male beef cattle | 42 kg animal$^{-1}$ a$^{-1}$ N |
| Female beef cattle | 44 kg animal$^{-1}$ a$^{-1}$ N |
| Calves | 16 kg animal$^{-1}$ a$^{-1}$ N |
| Mother cows | 96 kg animal$^{-1}$ a$^{-1}$ N |
| Fattened swine | 13 kg animal$^{-1}$ a$^{-1}$ N |
| phase-fed | 11 kg animal$^{-1}$ a$^{-1}$ N |
| Sows | 36 kg animal$^{-1}$ a$^{-1}$ N |
| phase-fed | 29 kg animal$^{-1}$ a$^{-1}$ N |
| Sheep | 13 kg animal$^{-1}$ a$^{-1}$ N |
| Horses | 64 kg animal$^{-1}$ a$^{-1}$ N |
| Laying hens | 0.74 kg animal$^{-1}$ a$^{-1}$ N |
| phase-fed | 0.71 kg animal$^{-1}$ a$^{-1}$ N |
| Fattened cocks and chickens | 0.29 kg animal$^{-1}$ a$^{-1}$ N |
| Young hens | 0.28 kg animal$^{-1}$ a$^{-1}$ N |
| Geese | 0.73 kg animal$^{-1}$ a$^{-1}$ N |
| Ducks | 0.60 kg animal$^{-1}$ a$^{-1}$ N |
| Turkeys | 1.50 kg animal$^{-1}$ a$^{-1}$ N |
| phase-fed | 1.41 kg animal$^{-1}$ a$^{-1}$ N |

For animals with lifetimes < 1 a, the figures were calculated for keeping facilities with average rotation periods.

The percentage of total ammoniacal N (TAN) was calculated as follows:

| | | |
|---|---|---|
| Cattle | 0.50 | kg kg$^{-1}$ N |
| Swine | 0.66 | kg kg$^{-1}$ N |
| Sheep | 0.40 | kg kg$^{-1}$ N |
| Horses | 0.40 | kg kg$^{-1}$ N |
| Poultry | 0.70 | kg kg$^{-1}$ N |

#### *6.1.2.2.5 Grazing periods, stable types and stabling periods*

In the cattle category, the duration of grazing (pasture) periods, the average grazing duration per day and the average time spent in milking stalls are used to divide excrement into pasture and stable portions.

All of the stable categories commonly found in Germany are taken into account (Lüttich et al., 2004). The relevant data is compiled in the IPCC-CRF report tables 4 B(a) and 4 B(b) (additional information).

#### *6.1.2.2.6 Processing of liquid and solid manure*

A distinction must be made between processed and unprocessed manure (for example, liquid-manure separation, biogas collection, composting of solid manure). Due to a lack of background information regarding manure processing, as well as to a lack of frequency distributions for liquid manure and to a lack of relevant calculation procedures (solid manure), no figures can be provided in this area.

#### *6.1.2.2.7 Storage*

A distinction is made between solid and liquid manure. The storage forms commonly used in Germany are taken into account. Daily spreading is not commonly practiced in Germany; open lagoons are not used. CRF Table 4 B(b) lists the frequency distributions for the various forms of storage.

#### *6.1.2.2.8 Spreading*

The spreading method used, and the time of subsequent working of manure into the soil, play an important role in calculation of $NH_3$ emissions and in determination of the N quantities added to the soil via manure. For liquid manure, a distinction is made between broad distribution, towed tubes and towed "shoes"; for solid manure, only broad distribution is considered. Farmland (fallow and with vegetation) and grassland are differentiated. A graduated scale of periods required to work manure into the soil is used (< 1 h, < 4 h, < 6 h, < 12 h,< 24 h, no working into the soil).

### 6.1.2.3 Uncertainties and time-series consistency (4.B)

The uncertainties listed in the CORINAIR manual (EMEP, 2003) also apply, for the time being, to Germany; i.e. 10 % for animal head counts and 30 % for emission factors for $CH_4$ and $NH_3$. The errors for the other emission factors are not known.

The time series is inconsistent with regard to animal head counts (for details, cf. 6.1.1.3.1).

The figures on manure management have been modelled on the basis of a database that is considered inadequate (transfer of survey data collected in model districts to other districts; cf. DÖHLER et al, 2002). No information regarding uncertainties is available.

### 6.1.2.4 Source-specific quality assurance / control and verification (4.B)

The data is reviewed for transcription errors made between the original data and the calculation tables, and it is checked for errors with regard to units and orders of magnitude. Future QA/QC procedures pre-suppose the further development of methods and a better breakdown of activity data (cf. Chapter 6.1.1.4). In addition, better data is needed for description of manure management.

In particular, such data would include parameters for feeding, yields (slaughter weight, duration of fattening period, etc.), keeping method (with pasturing, type of stabling), type of storage, spreading methods, etc.. Such data must be obtained via surveys.

At present, Germany has no database for description of data quality and uncertainties. The possibilities for improving the database are currently being reviewed.

#### 6.1.2.5 Source-specific recalculations (4.B)

In contrast to the procedure used in earlier calculations, calculation of all emissions included animals in the city-states of Bremen, Hamburg and Berlin. The IPCC default emission factors (1997) were used for the 2003 submission. The frequency-distribution information in "Additional Information" was not accurate.

For the 2004 submission, calculations will be carried out with the German frequency distributions.

##### *6.1.2.5.1 Source-specific recalculations (4.B, $CH_4$)*

Recalculations had to be carried out due to changes in methane conversion factors (MCF) for liquid-manure storage (IPCC, 2000). The MCF for liquid-manure systems were increased from 10 % (IPCC et al., 1996b, Table B-6) to 39 % (IPCC, 2000, Table 4.10). Furthermore, the recalculations took account (on a district basis) of the frequency distributions for storage options commonly available in Germany. Calculations for the NIR 2003 were carried out with fixed emission factors for each animal species. The differences are considerable (cf. Table 58).

Table 58: Comparison of figures for $CH_4$ emissions $E_{CH4}$ from animal husbandry (manure management) used in the NIR 2003 and NIR 2004 . Figures for Germany in Tg $a^{-1}$ $CH_4$.

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NIR 2003 | 0,27 | 0,24 | 0,23 | 0,22 | 0,22 | 0,22 | 0,22 | 0,22 | 0,22 | 0,22 | 0,21 | 0,21 | |
| NIR 2004 | 1,61 | 1,40 | 1,36 | 1,33 | 1,38 | 1,35 | 1,35 | 1,39 | 1,34 | 1,33 | 1,30 | 1,31 | 1,31 |

##### *6.1.2.5.2 Source-specific recalculations (4.B, NMVOC)*

NMVOC emissions were estimated for the first time. Recalculation is thus not possible.

##### *6.1.2.5.3 Source-specific recalculations (4.B, $N_2O$, NO, $N_2$)*

For the present inventory, nitrous oxide emissions were calculated using the mass-flow approach. In each case, the TAN fraction was considered to be the source for emissions of N species. For the emission factors, the default values were used (DÄMMGEN et al. 2004, Part 3, Chapter 4.9). For the present inventory, the mass-flow approach was used comprehensively for the first time. All relevant emissions were thus recalculated. Table 59 shows the resulting significant changes.

Table 59: Comparison of figures for $N_2O$ emissions $E_{N2O}$ from animal husbandry (manure management) used in the NIR 2003 and NIR 2004 . Figures for Germany in Tg $a^{-1}$ $N_2O$.

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NIR 2003 | 30,9 | 27,0 | 26,0 | 25,6 | 25,4 | 25,1 | 25,1 | 24,7 | 24,7 | 24,5 | 24,0 | 24,1 | |
| NIR 2004 | 14,4 | 12,8 | 12,5 | 12,4 | 10,1 | 10,1 | 10,2 | 10,1 | 10,0 | 9,8 | 9,7 | 9,8 | 9,8 |

#### 6.1.2.6 Source-specific planned improvements (4.B)

The mass-flow model used to calculate emissions of N species needs to be updated in the area of oxidised species. In particular, the emission factors need to be related to TAN.

For it to be possible to use the mass-flow model (cf. Dämmgen et al.; 2004, Part 3, Chapter 4.9), however, the database for describing frequency distributions in dairy-cow rationing and in types of stables, storage procedures and spreading methods must be determined via surveys.

### *6.1.3 Rice cultivation (4.C)*

No rice is cultivated in Germany (not occurring).

### *6.1.4 Agricultural soils (4.D)*

| **CRF 4D** | | | | |
|---|---|---|---|---|
| Key source | | Gas (key source) | 1990 – contribution to total emissions | 2002 – contribution to total emissions | **Trend** |
| Agricultural soil, direct soil emissions | l | $N_2O$ | 1,76 % | 1,77 % | falling |
| Agricultural soil, indirect emissions | l | $N_2O$ | 1,09 % | 1,09 % | falling |

| **Gas** | **$CO_2$** | **$CH_4$** | **HFCs** | **PFCs** | **$SF_6$** | **$N_2O$** | **$NO_X$** | **CO** | **NMVOC** | **$SO_2$** |
|---|---|---|---|---|---|---|---|---|---|---|
| Emissions factor[109] (EF) | IE | CS | NO | NO | NO | C/D | C/D | NO | C | NO |
| EF uncertainties in % | | 50 | | | | 50 | | | | |
| Distribution of uncertainties [110] | | - | | | | - | | | | |
| Method for EF determination[111] | | CS | | | | C/CS | | | | |

#### 6.1.4.1 Source category description (4.D)

In terms of emissions levels, category 4.D is a key source in 2002.

The inventory contains direct $N_2O$, NO and $NH_3$ emissions from nitrogen fertilisation with mineral N fertilisers, farm manure, and from biological N fixing and plant residues in the soil. $N_2O$ emissions from cultivation of organic soils are likewise included as a direct emissions source.

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

Indirect $N_2O$ emissions are calculated from atmospheric deposition of reactive N species ($NH_3$ and NO) from agricultural sources, from leached N and from run-off of spread N. Germany does not report on emissions resulting from use of sewage sludges.

In principle, plant parts are always sources of volatile organic compounds. A first estimate of surch emissions was carried out for important crops.

Agricultural soils are sinks for atmospheric methane that is oxidised by methanotrophic bacteria.

In each case, calculations are carried out for Länder.

$N_2O$ emissions from soils were calculated for use of manure and mineral fertilisers, excretions during grazing on pastures, cultivation of organic soils, harvest residues, legume cultivation and results of depositions (from agricultural sources), as well as for leaching and surface run-off.

NO emissions are determined for use of manure and mineral fertilisers, excretions during grazing on pastures, harvest residues and legume cultivation.

The results of the calculations are shown in Table 60. As the table shows, emissions decreased from 1990-2002.

Table 60: $N_2O$ and NO emissions $E_{N2O}$ and $E_{NO}$ from agricultural soils. Figures for Germany in Gg $a^{-1}$ $N_2O$ and Gg $a^{-1}$ NO.

| Year | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $E_{N2O}$ | 141 | 130 | 125 | 121 | 115 | 120 | 120 | 119 | 121 | 123 | 125 | 121 | 120 |
| $E_{NO}$ | 65 | 59 | 57 | 55 | 51 | 54 | 55 | 54 | 55 | 56 | 57 | 55 | 54 |

The largest share of $N_2O$ emissions (30 %) from soils can be attributed to use of mineral fertilisers in soils. Indirect emissions from leaching account for 24 % of $N_2O$ emissions, while manure accounts for 16 % of $N_2O$ emissions and organic soils account for 13 %. The remaining emissions consist of emissions from grazing, legumes, harvest residues and indirect emissions from deposition.

### 6.1.4.2 Methodological issues (4.D)

In most cases, the calculation methods comply with specifications for the simpler method described in the CORINAIR manual (EMEP, 2003). Specific details are provided in the relevant sections. The data on land under cultivation is taken from the official statistics for each year.

#### *6.1.4.2.1 Methane consumption of agricultural soils (4.D)*

Calculation of $CH_4$ deposition is based on a proposal of Boeckx and Van Cleemput (2001), who summarise the available results of European measurements. The proposal calls for differentiation between grassland ($EF_{CH4}$ = -2.5 kg $ha^{-1}$ $a^{-1}$ $CH_4$) and farmland ($EF_{CH4}$ = - 1.5 kg $ha^{-1}$ $a^{-1}$ $CH_4$).

#### *6.1.4.2.2 Emissions of non-methane volatile organic compounds from agricultural soils and crops (first estimate) (4.D)*

Levels of NMVOC emissions from plants were estimated using the procedure set forth in the CORINAIR manual (EMEP, 2003). This source provides area-dependent emission factors for some of the main crops in question (for details, cf. DÄMMGEN et al, 2004, Part 3, Chapter 4.1.5).

#### *6.1.4.2.3 Nitrous oxide and nitrogen monoxide emissions from agricultural soils (fertiliser use) (4.D)*

For calculation, emissions of the two gases are assumed to be proportional, on the average, to N discharges into the system. N discharges from mineral fertilisers are taken from official statistics, while discharges from manure follow from calculations of N flows in manure management.

#### *6.1.4.2.4 Nitrous oxide, nitrogen monoxide and ammonia emissions from agricultural soils (legumes) (4.D)*

The N quantities fixed via legumes are calculated from the areas under cultivation (DÄMMGEN et al., 2004, Part 3, Chapter 4) and from national averages for area-specific N fixing. The following are differentiated:

| | | |
|---|---|---|
| Legumes | 250 | kg $ha^{-1}$ N |
| Clover, clover/grass, clover/lucerne | 200 | kg $ha^{-1}$ N |
| Lucerne | 300 | kg $ha^{-1}$ N |

The following emission factors are used:

| | | |
|---|---|---|
| $NH_3$ | 1,0 | kg $kg^{-1}$ N |
| $N_2O$ | 0,0125 | kg $kg^{-1}$ N |
| NO | 0,007 | kg $kg^{-1}$ N |

#### *6.1.4.2.5 Nitrous oxide and nitrogen monoxide emissions from agricultural soils (harvest residues) (4.D)*

The N quantities remaining in the soil with harvest residues are calculated from the area under cultivation and the crop-specific N residues:

$$E_{N2O_{Crop}} = EF_{N2O} \cdot m_{N_{Crop}} \cdot A_{Crop}$$

where
$E_{N2O,\ Crop}$ $N_2O$ emissions from cultivation of a crop
$EF_{N2O}$ Emission factor
$m_{N,\ Crop}$ Nitrogen quantity in harvest residues
$A_{Crop}$ Area under cultivation with the relevant crop

The calculations make use of default emission factors for calculation of emissions from use of mineral and manure fertilisers (IPCC et al, 1996b, Table 4-19 and EMEP, 2003, B1010-15): $EF_{N2O}$ = 0.0125 kg $kg^{-1}$ N; $EF_{NO}$ = 0.007 kg $kg^{-1}$ N; $EF_{N2}$ = 0.1 kg $kg^{-1}$ N). The same factors are also applied to the N quantities bound in harvest residues.

The following list indicates what N quantities are found in harvest residues:

| | | |
|---|---|---|
| Wheat | 17 | kg $ha^{-1}$ N |
| Rye | 14 | kg $ha^{-1}$ N |
| Winter barley | 12 | kg $ha^{-1}$ N |
| Summer barley | 9 | kg $ha^{-1}$ N |
| Oats | 14 | kg $ha^{-1}$ N |
| Triticale | 12 | kg $ha^{-1}$ N |
| Grain corn | 60 | kg $ha^{-1}$ N |
| Silo corn | 26,7 | kg $ha^{-1}$ N |
| Rape | 15 | kg $ha^{-1}$ N |
| Sugar beets | 22 | kg $ha^{-1}$ N |
| Fodder beets | 0,11 | kg $ha^{-1}$ N |
| Clover, clover/grass, clover/lucerne | 40 | kg $ha^{-1}$ N |
| Lucerne | 158 | kg $ha^{-1}$ N |
| Grass | 30 | kg $ha^{-1}$ N |
| Potatoes | 10 | kg $ha^{-1}$ N |

A compilation of areas under cultivation is found in DÄMMGEN et al. (2004, Part 1, Chapter 2.3.2.6).

#### *6.1.4.2.6 Nitrous oxide emissions from organic soils (4.D)*

The $N_2O$ quantities released from cultivated organic soils are calculated via the simpler method. They are considered to be area-proportional. The relevant areas were identified via superpositioning of land-use maps and soil maps (for details, cf. DÄMMGEN et al., 2004, Chapter 6.2). The emission factor used was the default factor $EF_{N2O}$ = 8 kg $ha^{-1}$ $a^{-1}$ $N_2O$-N (EMEP, 2003, B1020-22).

#### *6.1.4.2.7 Nitrous oxide emissions from excrement produced during grazing (4.D)*

In treatment of manure via the mass-flow procedure, emissions of N species that result from grazing on pastures are calculated for each species and district, using the relative quantities of excretions occurring on pastures, and then summed for all German Länder (for details, cf. DÄMMGEN et al., 2004, Part 3, Chapter 4.9).

The emission factors used are as follows (EMEP, 2003, B1010-13 und IPCC et al., 1996b, Table 4-22):

| | | |
|---|---|---|
| $NH_3$ | 0.075 | kg $kg^{-1}$ N |
| $N_2O$ | 0.02 | kg $kg^{-1}$ N |
| NO | 0.02 | kg $kg^{-1}$ N |

#### *6.1.4.2.8 Indirect nitrous oxide emissions resulting from atmospheric deposition (4.D)*

Indirect $N_2O$ emissions result from deposition of reactive N species originating in agricultural sources. They include $NH_3$ and NO emissions from manure management, use of mineral

fertilisers, legume cultivation and grazing on pastures. The emissions are considered to be proportional to the emitted quantities. The emission factor used is the default factor $EF_{N2O}$ = 0.01 kg $kg^{-1}$ N (IPCC et al., 1996b, Table 4-23).

#### *6.1.4.2.9 Indirect nitrous oxide emissions resulting from leaching and surface run-off (4.D)*

Leaching and surface run-off of N species lead to formation of $N_2O$. The relevant quantity is considered to be proportional to the amount of N discharged into the soil. The relevant quantities are considered to be the N quantities entering the soil with legumes and harvest residues. In the simpler procedure, 30 % of these are considered to be leachable. The emission factor is $EF_{N2O}$ = 0.025 kg $kg^{-1}$ $N_2O$-N (IPCC et al, 1996b, Table 4-23).

### 6.1.4.3 Uncertainties and time-series consistency (4.D)

The uncertainties are outlined in EMEP/CORINAIR (EMEP, 2003); they apply to Germany as well until further notice. The detailed discussion in this source indicates that the error for relevant areas is on the order of 10 % and that the error for emissions is on the order 50 %. The time series is consistent.

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

The data is reviewed for transcription errors made between the original data and the calculation tables, and it is checked for errors with regard to units and orders of magnitude. Future QA/QC procedures pre-suppose the further development of methods and a better breakdown of activity data (cf. Chapter 6.1.1.4). At present, Germany does not have any database for description of data quality and uncertainties.

### 6.1.4.5 Source-specific recalculations (4.D)

#### *6.1.4.5.1 Methane consumption of agricultural soils (4.D)*

A first estimate of $CH_4$ consumption carried out in the previous year used a factor that was not differentiated by sinks ($EF_{CH4}$ = - 0.5 kg $ha^{-1}$ $a^{-1}$ $CH_4$) and that was considerably smaller than the factor now assumed. Table 61 shows the relevant differences.

Table 61: Comparison of figures, in NIR 2003 and NIR 2004, for $CH_4$ deposition $D_{CH4}$ in agricultural soils. Figures for Germany in Tg $a^{-1}$ $CH_4$.

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NIR 2003 | -0,01 | -0,01 | -0,01 | -0,01 | -0,01 | -0,01 | -0,01 | -0,01 | -0,01 | -0,01 | -0,01 | -0,01 | |
| NIR 2004 | -0,03 | -0,03 | -0,03 | -0,03 | -0,03 | -0,03 | -0,03 | -0,03 | -0,03 | -0,03 | -0,03 | -0,03 | -0,03 |

#### *6.1.4.5.2 Nitrous oxide and nitrogen monoxide emissions from agricultural soils (4.D)*

The previous year's basis for calculating $N_2O$ emissions from legume cultivation was incorrect. The present inventory uses values, for N discharges into soils, calculated via the mass-flow procedure.

The last edition of the CORINAIR manual (EMEP, 2003) contained a considerably larger emission factor for NO than that found in earlier editions (EMEP, 2002): $EF_{NO}$ = 0.007 kg $kg^{-1}$ NO-N, as opposed to the previously used factor $EF_{NO}$ = 0.003 kg $kg^{-1}$ NO-N.

Indirect emissions from leaching were taken into account for the first time.

For this reason, the time series for $N_2O$ and NO were recalculated. The changes are shown in Tables 62 and 63. Inclusion, in calculation, of data on leaching and of national data for N discharges from animal husbandry has increased $N_2O$ emissions figures in comparison to those obtained using the default values pursuant to IPCC et al. (1996b). NO emissions figures also increased, as a result of changes in methods, of inclusion of national data for N discharges into soils from animal husbandry and of additional information on use of manure fertilisers, on legumes, on harvest residues and on grazing.

Table 62: Comparison of figures used in the NIR 2003 and NIR 2004 for $N_2O$ emissions from agricultural soils. Figures for Germany in Tg $a^{-1}$ $N_2O$.

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NIR 2003 | 0,10 | 0,09 | 0,09 | 0,08 | 0,08 | 0,08 | 0,08 | 0,08 | 0,08 | 0,09 | 0,09 | 0,08 | |
| NIR 2004 | 0,14 | 0,13 | 0,13 | 0,12 | 0,11 | 0,12 | 0,12 | 0,12 | 0,12 | 0,12 | 0,12 | 0,12 | 0,12 |

Table 63: Comparison of figures used in the NIR 2003 and NIR 2004 for NO emissions from agricultural soils. Figures for Germany in Tg $a^{-1}$ NO.

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NIR 2003 | 0,015 | 0,014 | 0,013 | 0,012 | 0,011 | 0,012 | 0,012 | 0,012 | 0,012 | 0,013 | 0,013 | 0,012 | |
| NIR 2004 | 0,065 | 0,059 | 0,057 | 0,055 | 0,051 | 0,054 | 0,054 | 0,054 | 0,055 | 0,056 | 0,057 | 0,055 | 0,054 |

### *6.1.5 Clearance of land by prescribed burning (4.E)*

Land clearance by prescribed burning is not practiced in Germany (not occurring).

### *6.1.6 Burning of agricultural residues on farmland (4.F)*

Burning of agricultural residues is prohibited in Germany. It is not possible to collect data on permitted exceptions. Such exemptions are considered to be irrelevant (not occurring).

# 7 LAND-USE CHANGES AND FORESTRY (CRF SECTOR 5)

Generally speaking, calculations of greenhouse gas emissions (GHG) for land-use changes and forestry (LUCF) are based on linking of emission factors with activity data, which characterise the contribution of human activities leading to emissions or to fixations. Lacks of activity data for land use and land use changes (LULUC), and inadequacies in such data, are the most difficult obstacles faced by GHG reporting for agriculture. At present, methods are being developed to ensure that future reporting requirements can be met by compiling pre-existing data series and closing any data gaps. The following chapters outline the current outset situation in this area, and they describe the data available in the areas of wood biomass, land-use changes and organic soil carbon.

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

The data refers to "forest" as defined by the Federal Forest Inventory[112].

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)*

| **CRF 5.A** | | | | | |
|---|---|---|---|---|---|
| Key source | | Gas (key source) | 1990 – contribution to total emissions | 2002 – contribution to total emissions | **Trend** |
| | NO | | | | |

| **Gas** | **$CO_2$** | **$CH_4$** | **HFCs** | **PFCs** | **$SF_6$** | **$N_2O$** | **NOx** | **CO** | **NMVOC** | **$SO_2$** |
|---|---|---|---|---|---|---|---|---|---|---|
| Emissions factor[113] (EF) | CS | | | | | | | | | |
| EF uncertainties in % | | | | | | | | | | |
| Distribution of uncertainties [114] | | | | | | | | | | |
| Method for EF determination[115] | CS/T2 | | | | | | | | | |

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

In respiration, in decomposition of dead plant matter by animals, funguses and micro-organisms and in combustion of biomass, $CO_2$ is once again released. Such processes, therefore, are sources of $CO_2$. The carbon contained in wood removed from the forest during timber harvesting is released into the atmosphere, as $CO_2$, during the (long) periods in which the timber is treated and processed; this process can take decades or even centuries, depending on the duration of wood products' useful lifetimes.

112 "Within the meaning of the Federal Forest Inventory (BWI), irrespective of the data in the cadastre 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, line cuts situated in the forest, other recreational facilities associated with the forest, overgrown heaths and moors, overgrown former pastures, 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, Christmas tree and decorative brushwood cultivations and parkland belonging to residential areas 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)

113 D = IPCC default, C = Corinair, CS = Country-specific, PS = Plant-specific, M = Model

114 N = Normal, L = Log normal, T = Triangular, U = Uniform (even distribution)

115 D = IPCC default, RA = Reference approach, T1= IPPC tier 1, T1a/ T1b/ T1c = IPPC tier 1a/ 1b/ 1c, T2 = IPPC tier 2, T3 = IPPC tier 3, C = CORINAIR, CS = Country-specific, M = Model

The method currently recommended by the IPCC for determining the net source or sink from forest management simplifies the calculation process by assuming that harvested wood is converted completely into $CO_2$ in the year of the wood harvest. This method, which is also employed in Germany, thus makes it possible to determine a forest's source or sink effect by comparing growth with wood harvest. This method underestimates forests' sink effect, because part of the harvested wood is converted into long-lasting products (such as furniture) and therefore is not emitted as $CO_2$ in the same year.

At present, such a comparison of growth and wood harvest for Germany yields an increase in the biomass reserves stored in the forest, i.e. more C is bound in vegetation than is removed (and released) from the forest via wood harvesting. The German forest is currently a net sink for $CO_2$.

Table 64: Annual $CO_2$ removals in the German forest

| Years | Annual $CO_2$ removals [millions of t] |
|---|---|
| 1990-1994 | 33,69 |
| 1995-1999 | 33,40 |
| 2000-2002 | 25,40 |

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. These are taken into account in Chapter 3.1.11.

The activity data required in this chapter of the greenhouse gas inventory includes the forested area, the average annual biomass increase in t of dry mass per hectare, and the annual timber harvest in kilotonnes (kt) of dry mass.

### *7.1.2 Methodological issues (5.A)*

The data on forested area originates from the Federal Forest Inventory for the old Federal *Länder* (BWI I), and from the *Datenspeicher Forestfonds* (Forest Management Database) for the new Federal *Länder*, and refers to the status in 1990. Any area changes that have occurred since then, as a result of conversion of forest to a different utilisations and initial afforestation, have been disregarded. Germany's forested area totals 10.74 million hectares, of which 10.4 million hectares are wooded, i.e. are the portion stocked with forest plants that is used for timber production. The rest is so-called "non-wooded area", which includes, for example, forest paths, forest glades, timber storage areas, line 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 $m^3$/ha; such areas include, for example, mountain pine and green alder fields in mountains, bush areas and other sparsely forested or less-productive forest areas. BWI I found some 180,000 ha of such sites in the old Federal *Länder*; similar data is not available for the new Federal *Länder*.

Some 80,000 ha was 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 28 and Table 65); the growth and timber-harvesting data depicted below are based on this figure.

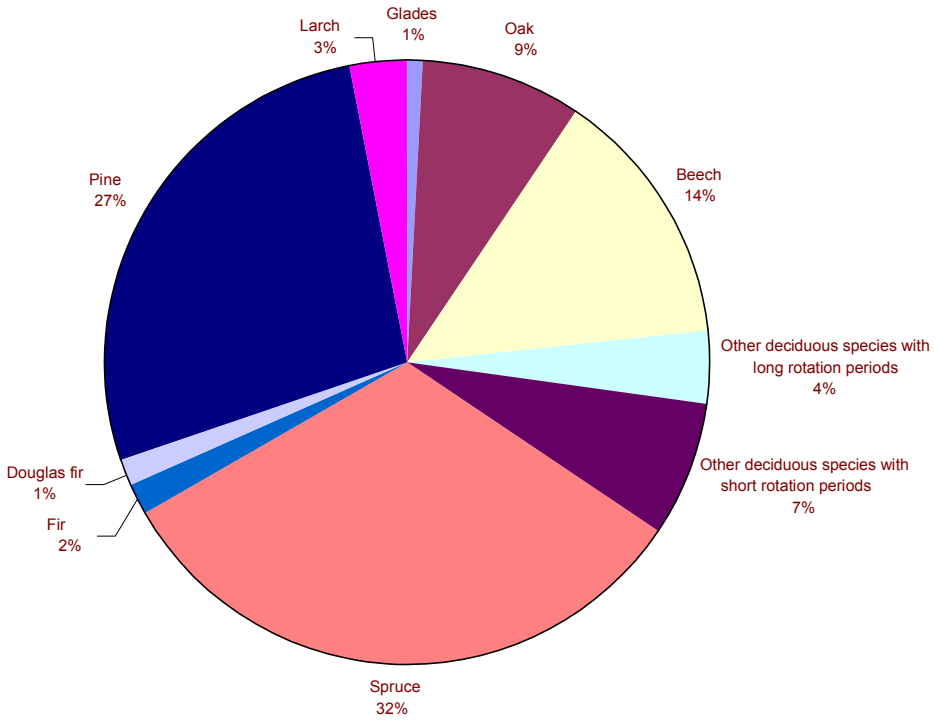



Figure 28: Productive forest area by species

Table 65: Overview of forest area 1990

| Tree species | Area (ha) |
|---|---|
| Oak[116] | 876.476 |
| Beech[117] | 1.424.206 |
| Other types of deciduous trees with a long rotation period[118] | 397.860 |
| Other types of deciduous trees with a short rotation period[119] | 744.835 |
| Spruce[120] | 3.299.281 |
| Fir[121] | 160.277 |
| Douglas fir[122] | 133.683 |
| Pine[123] | 2.807.175 |
| Larch[124] | 300.088 |

116 All species of oak including red oak
117 Fagus sylvatica
118 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)
119 Birch, alder, poplar, balsam poplar, willow, rowan (Betula spec., Alnus, Populus, Salix, Sorbus aucuparia) and other deciduous trees not listed in the tree species catalogue
120 All picea species and all other coniferous tree species not listed separately
121 All species of fir (*Abies spec.)*
122 Pseudotsuga menziesii
123 All species of pine (*Pinus spec.)*
124 All species of larch (*Larix spec.)*

| | |
|---|---|
| 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** |

The areas cited should not be interpreted as pure stocks of the tree species mentioned; instead, they 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 deciduous tree stocks as required by the Common Reporting Format. Instead, the entire forested productive area was summarised under one line, "*deciduous and coniferous*".

In accordance with the IPCC method, calculations were 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 authors for use in Central Europe. Since they are derived from tree-species-specific and Land-specific estimates, the emission factors used correspond largely to a Tier-2 approach; the IPCC estimate, 0.5, was used only for determination of the carbon content of the total biomass, in derivation of growth.

The *Common Reporting Format* (CRF) requires that growth should be specified in tonnes of dry mass per hectare. This figure is derived from other data via a number of conversion steps, as outlined below.

**Step 1: Determination of growth in $Vfm_D$ (cubic metres of standing timber)**
In the forestry industry, growth is generally specified in solid cubic metres per hectare, and in Germany, it is specified in 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 66: 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 deciduous tree species with a high rotation period | 4,6 | WIMMENAUER 1919 | all |
| Other deciduous 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 |

**Step 2: Extrapolation of the growth in solid volume into growth of overground wood volume (saw-timber growth)**

The growth of overground wood volume (saw-timber growth) was derived from the growth in solid volume, via use of expansion factors. These factors were derived from the average emission factor of 1.45 published by BURSCHEL et al. (1993) (cf. Table 67); this was accomplished via deduction of root-wood percentages of 21.2% for deciduous trees and 31.4% for coniferous trees. Root biomass, as well as leaves and needles, were disregarded.

Table 67: Expansion factors for converting solid volume into saw-timber volume

| Tree species | Expansion factor (m3/VfmD) |
|---|---|
| Coniferous trees | 1,14 |
| Deciduous trees | 1,24 |

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

To this end, the bulk density (cf. Table 68) of the principal wood species was used. The bulk density indicates the dry mass in relation to fresh volume. Because timber harvest data is available only for the four wood-species groups oak, beech (including other deciduous trees), spruce (including fir and other conifers) and pine/larch, tree species outside these groups had to be assigned to these species groups for calculation purposes; for reasons of comparability, this was also done with regard to growth.

Table 68: Bulk density (t dry mass/$m^3$ fresh volume)

| **Oak** | Beech, including other deciduous species | Spruce, including fir, douglas fir and other conifers | Pine, including larch |
|---|---|---|---|
| 0,56 | 0,55 | 0,37 | 0,43 |

(pursuant to KNIGGE, SCHULZ, 1966)

**Step 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.

**5. Step 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)/ha) * expansion factor ($m^3$/VfmD) * bulk density (tTM)/$m^3$) * 0.5(tC/tTM) [VfmD = solid cubic metres; 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 is offset with the carbon released from timber harvests.

#### 7.1.2.1 Timber 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 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 2002. The figure for the period 2000 to 2002, which is higher than those for 1990-94 and 1995-99, is the result of a major hurricane in December 1999. Most of the trees uprooted and damaged by the storm were processed in 2000 and thus were included in the felling statistics for that year.

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

Table 69: Timber harvest by timber groups

| | **1990 - 1994** | | 1995 – 1999 | | **2000 - 2002** | |
|---|---|---|---|---|---|---|
| Tree-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 | 1.686.000 | 1.769.014 |
| Beech and other deciduous trees | 6.161.000 | 5.653.515 | 7.452.600 | 6.838.725 | 8.448.000 | 7.752.134 |
| Spruce and other conifers | 25.930.400 | 13.937.702 | 21.048.800 | 11.313.821 | 26.017.333 | 13.984.429 |
| Pine/larch | 6.380.600 | 4.188.978 | 8.412.400 | 5.522.890 | 9.039.000 | 5.934.264 |
| **Total** | **39.558.200** | **24.919.876** | **38.250.000** | **25.077.428** | **45.190.333** | **29.439.842** |

Not only branchwood is left behind in the forest as logging debris; unusable solid volume is also left behind. 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 for 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 these were derived from yield-table estimates, as outlined above.

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

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 no nationwide-aggregated data is available on this.

The **timber harvest data** originates from a range of different sources and was derived using various measurement and estimation methods: Generally speaking, for high-quality rough-sawn timber, volume is measured for each individual log. For industrial timber, random sampling techniques (e.g. surface measurement), and by-weight measurement of lumber (oven-dry and air-seasoned lumber) upon arrival at the factory, are also carried out. Cordwood (firewood and industrial wood in short form) is measured in cubic metres. Quantities of wood harvested in private forests are estimated, in some cases. For statistical purposes, all figures measured or estimated in units other than cubic metres are converted into cubic metres. There is uncertainty with regard to the quantities of wood used by owners of private forests for their own requirements.

### *7.1.4 Source-specific quality assurance / control and verification (5.A)*

Quality assurance / control methods were used in the Federal Forest Inventory I (sampling year: 1987). At least 5 % of forest tracts was checked by control staff (BML 1986). All calculations in the BWI were checked by the Federal *Länder* and by experts. A quality assurance procedure for subsequent calculation stages for derivation of carbon storage has not yet been developed.

Recently, estimates of carbon storage in German forests have been presented (FAO, 2000 and DIETER et al, 2002). Both estimates are considerably higher than the figures given in the greenhouse gas inventory. In the case of FAO, this is primarily attributable to use of the IPCC estimate (1995) for wood density, 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 et al, additional categories, 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 the studies are based on the same growth estimates derived from BWI I that the data in the greenhouse gas inventory is based on. 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)*

No recalculations were carried out in the 2004 greenhouse-gas inventory.

### *7.1.6 Source-specific planned improvements (5.A)*

The Second Federal Forest Inventory (BWI II) (relevant year 2002), which is currently in progress, is expected to 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, obtained via measurements conducted in a systematic random-sampling network, will be available:

- Changes in forested area, and
- Stock changes between 1987 and 2002, including growth and timber harvest data.

For the *new* Federal *Länder,* which joined the Federal Republic of Germany in 1990, BWI II is the first inventory based on this technique. Until the next inventory, growth and stock changes in those *Länder* can only be estimated on the basis of the forest structure determined by BWI II. However, BWI II is expected to produce key findings with regard to improving estimates.

On the occasion of review of Germany's Third National Report pursuant to the Framework Convention on Climate, in September 2003, the review team noted that description of changes in forests as five-year averages did not conform to the specifications of the IPCC Guidelines. Because new inventory calculations are to be carried out, using the results of the

second Federal Forest Inventory, presentation of the old data, which does not yet reflect the BWI-II results, was not modified.

## 7.2 $CO_2$ 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 liming of agricultural soils.

### *7.2.1 Source category description (5.D)*

| **CRF 5.D** | | | | | |
|---|---|---|---|---|---|
| Key source | | Gas (key source) | 1990 – contribution to total emissions | 2002 – contribution to total emissions | **Trend** |
| | NO | | | | |

| **Gas** | **$CO_2$** | **$CH_4$** | **HFCs** | **PFCs** | **$SF_6$** | **$N_2O$** | **$NO_X$** | **CO** | **NMVOC** | **$SO_2$** |
|---|---|---|---|---|---|---|---|---|---|---|
| Emissions factor[125] (EF) | CS | | | | | | | | | |
| EF uncertainties in % | | | | | | | | | | |
| Distribution of uncertainties [126] | | | | | | | | | | |
| Method for EF determination[127] | CS | | | | | | | | | |

Processes of release or removal of $CO_2$ in soils essentially involve changes in the amounts of 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 soils tend to occur primarily in the uppermost soil strata (cultivation horizon, main root space). They take place when a flux equilibrium is established between the addition of organic carbon via photosynthesis in plants, and biological decomposition processes in the soil. In general, agricultural activities are aimed at inducing plants to grow in specific ways. The smallest agricultural unit that is normally cultivated by a single method is the "field" (Schlag = felled area).

A field can contain several different soil types. Pursuant to IPCC (1996), the factors that determine C content include "management factors", such as the crops cultivated, the manner in which the soil is cultivated and the quantity and nature of nutrients added to plants (fertilisation), and climate.

In Germany, such information, differentiated according to soil types, is not recorded throughout all regions. According to CRF, net carbon flows should be determined on the basis of a sliding 20-year difference.

Agricultural use of organic soils (fens and raised bogs) involves profound interventions in their C cycles, resulting in long-lasting, significant losses of C, via release of $CO_2$ into the atmosphere. Drainage leads to fast oxidation of the soils' organic material. This process can continue until the organic horizon (peat bed) completely disappears. When the soil is cultivated, losses in the cultivated layer are replaced via entry of less-oxidised material from below; this process continues until the organic horizon has been completely used up. In contrast to processes with mineral soils, no new usage-intensity-dependent flux balance can

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

become established. The only way of halting the loss process is to re-wet the soil. Where such re-wetting persists, it can lead to new C fixing.

Liming of soils leads to release of $CO_2$ when lime is dissolved. Applied quantities of lime are determined from statistics on domestic sales of mineral fertilisers, which include lime and other nutrients. These are given in tonnes of nutrients or in tonnes of oxides (e.g. CaO), with the following distinctions:

- Type of fertilisation
- For lime: Use for agriculture or forestry
- Federal States (Länder).

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

### *7.2.2 Methodological issues (5.D)*

In order to report on emissions and fixing of $CO_2$ in soils as a result of LUCF, it is necessary to calculate changes in the C content of both forest and agricultural soils. Because insufficient direct $CO_2$ flow measurements are available, the C-balance approach is currently the only option. For this purpose, activity data must be further sub-divided into soil categories or types and must be further categorised by types of management. The climate type, which the IPCC requires, is not relevant apart from the default procedure. In order to describe a change in the stock, two series of activity data, covering different times, are needed. The main problem is to compile the required data (activity data and soil parameters ); in some cases, data of the necessary quality – in keeping with a Tier 3 approach (especially data on natural systems) – is basically available but is kept by different public and private entities, on different administrative levels (Federal Government, Länder, districts, municipalities).

Activity data on management factors within the meaning of the IPCC Guidelines (IPCC et al, 1997) is not collected in Germany and cannot currently be taken into account in estimation of carbon stocks. As a rule, cultivation in Germany involves plowing, and mean-to-high input levels are likely to be common; as a result, factors ranging from 1.0 – 1.2 should be used in the framework of the IPCC default procedure.

### *7.2.3 Data used for provisional estimates of changes in C stocks*

Data on spatial distribution of soil communities in Germany is available in the form of a digital soil map on a scale of 1: 1 000 000 (BGR, 1997). The soil map has been prepared via proportionate allocation of discrete profile data (obtained at individual points in the landscape) on land units (polygons) within the map area. The profiles provide quantitative information on a range of key factors measured. This information provided the basis for estimating the carbon stocks in agricultural soils. Calculation was carried out using the map's/legend's data for the lead profiles of the 72 lead soil units, data that included specific $C_{org}$ content measurements, humus, raw-density and skeleton classes and profile and horizon descriptions. With this data, and under the assumption that the map's values, in each case, are representative of the entire relevant legend unit, $C_{org}$ stocks were calculated. To this end, the $C_{org}$ content figures were multiplied by the relevant raw densities and horizon

depths and the relevant skeleton portions were deducted. The horizon stocks were added to a depth of 30 cm.

The relevant errors were estimated via humus, raw-density and skeleton classes assigned to the various legend units pursuant to KA 4 (ARBEITSGRUPPE BODEN, 1994). In each case, a minimum value (lowest possible $C_{ORG}$ content for the class, lowest possible storage density, maximum skeleton content) and a maximum value (highest possible $C_{ORG}$ content for the class, highest possible storage density, minimum skeleton content) were calculated, and the resulting range was determined.

A geo-information system was used to assign the individual soil units to rural districts and to land-use units. BUEK 1000 (BGR, 1997) was overlaid with polygons of district boundaries and with the CORINE Landcover land-use classes (1997). For each of the resulting polygons, carbon stocks were calculated to a depth of 30 cm and then summed, in keeping with land use (farmland, grassland, heterogeneously structures agricultural land), at the district level. Division by the area sum then produced a weighted carbon-stock figure – relative to soil unit and expressed in t/ha * 30 cm – for each land-use class, at the district level; for the sake of comparison, stocks were summed at both the district and national levels.

Data from the main survey of soil use (Bodennutzungshaupterhebung - BOHE) was used to determine land use and the relevant base year. Complete surveys are conducted every four years; the first full-area survey for reunified Germany was carried out in 1991 (DESTATIS, 1992b). For this reason, the land-use classes determined in connection with BOHE 1991 were assumed to apply for the base year. Since the data for 2003 is not yet available (availability is likely by mid-2004), the land-use classes from the last complete survey evaluated, that of 1999 (DESTATIS, 2000b), were used as the current status. For reasons of data protection, the BOHE data is available only as anonymous data, without geo-referencing and aggregated only for various administrative levels. For the present report, the district level was selected as the aggregation level, since the soil map is too coarse for further spatial disaggregation. Among the BOHE survey parameters, "cropland", "grassland" and "garden land" refer to agriculturally used land; addition of fallow land yields the entire agricultural area. In orientation of BOHE to CORINE, BOHE's "garden land" and "fallow land" categories were assigned to the CORINE classification "heterogeneously structured agricultural land". The areas within the individual land-use classes were assigned to the relevant districts and then multiplied, on that level, with the weighted carbon stocks (and their minima and maxima) determined for the various soil units and land-use classes. This yielded the carbon stocks, and their ranges, at the district level. Data from CORINE-Landcover was used to fill in any data gaps resulting from gaps in individual land-use-form areas.

#### 7.2.3.1 Changes in soil C stocks resulting from changes in use

Originally, a mathematical model, oriented to C stocks (cf. 7.2.3), was to be used to calculate C stocks for 1999, on the basis of the differences in land-use classes between 1991 and 1999. This was not possible in the reporting year, since the BOHE data only supported determination of the absolute differences in land uses; it did not support determination of conversion between the classes. Determination of such conversion would have required at least the data from the area survey (Flächenerhebung - FE) (DESTATIS, 1994, 2002b). At the time of reporting, this data, except for the total-area sums for Germany, was not available to the authors. As a result, 1999 carbon stocks were also calculated with the weighted C

stock figures. Since the agriculturally used area in BOHE is 8.4 % smaller than the agricultural area in the FE, the carbon stocks calculated for the BOHE areas were related to the level of the FE, which reflects the actual land area in question.

#### 7.2.3.2 Mineralisation of organic soils

Organic-soil areas, their percentage sizes with respect to the relevant land-use classes and their carbon stocks (in this context, fens and raised bogs (lead-soil association 6 and 7 from BÜK 1000), were determined via CORINE – Landcover and BÜK 1000 (cf. Chap. 7.4.3). To determine the size ratios between these areas and those with other soil forms, at the district and national levels, the fen/bog areas were described as a percentage of the agricultural areas in BOHE 1991/1999 (DESTATIS, 1992b, 2000); this result was then multiplied by $C_{org}$. stock/ha*30 cm to yield the entire C stocks for fen/bog soils under agricultural cultivation. The carbon loss resulting from absolute area loss is included in the overall calculation. $CO_2$-C mineralisation was estimated on the basis of values from the literature. MUNDEL (1976), AUGUSTIN (2001) and MEYER (1999) report losses in grassland areas ranging from 2.46 – 7.63 t $ha^{-1}a^{-1}$, and HÖPER (2002) reports a range of 4.6 – 16.5 t $ha^{-1}a^{-1}$, with bogs used as cropland reaching 10.6 – 16.5 t $ha^{-1}a^{-1}$. On the basis of experts' assessments drawing on these values, the loss for grassland was placed at 5 t $ha^{-1}a^{-1}$ and that for cropland was placed at 11 t $ha^{-1}a^{-1}$. The uncertainty, and the relevant minimum and maximum values, result from the above value ranges. For emissions calculation, the fen/bog area under agricultural cultivation in 1999 (BOHE) was used, since the carbon stocks for the area difference with respect to 1991 were completely deducted in the overall calculation.

### *7.2.4 Uncertainties and time-series consistency (5.D)*

The provisional $C_{org}$-stock estimates for agriculture are based on the only existing complete-coverage soil map for all of Germany, which is drawn to a scale of 1: 1,000,000 (BUEK 1000). This map integrates soil information over large areas and aggregates indexes within classes. Accordingly, the value-scattering range is very large. For the 72 soil units in the BÜK 1000, the potential range for the organic carbon stocks to a depth of 30 cm is an average of 37 % larger than the layout scale. Time series for $C_{org}$. stocks in soils are available only for a few small long-term-monitoring sites; they are not available on a complete-coverage basis.

The relative areas for cropland and grassland, and for heterogeneously structured agricultural land, were taken from the CORINE Landcover data. The area values differ, in absolute terms, from those of the area survey (Flächenerhebung) and of the main survey of soil use (Bodennutzungshaupterhebung). With respect to the 1993 area survey, the agricultural area is estimated to be about 11 % larger; with regard to the 1991 main survey of soil use, it is estimated to be about 21 % larger. The ratio of grassland to cropland, with regard to that shown by the main survey of soil use, has remained relatively constant in the various rural districts, however. The mean deviation is 6.6 %; this means that the relative cropland area, with respect to the agricultural area, is overestimated, while the grassland area is underestimated. This does not affect calculation of the weighted carbon stocks, however.

The absolute difference between the agricultural area in the 1993 area survey and the agricultural area in the 1991 main survey of soil use is 8.4 %. The reasons for this difference include:

- The survey principle (farm-based principle (BOHE), use-based principle (FE))
- The time difference between the surveys (2 years)
- Differences in definitions
- The intervals at which the cadastre areas are updated and, especially
- The cut-off boundaries[128].

Studies of ERHARD et al. (2002) have shown that the main survey of soil use misses some 10 % of the relevant area as a result. For purposes of compensation, and for comparison of results, the area values calculated on the basis of BOHE were adjusted to the actual values in the area survey, under the assumption that distribution of land-use classes and soil units on the missing area (amounting to some 10 %) corresponds to the relevant distribution on the remaining area and is responsible for the absolute area differences between the relevant years. The thusly corrected values are the values used in reporting.

No absolute area figures for all uses, at the district level, were available, and the BOHE data, as a result of its anonymisation, supports no conclusions on land-use changes – apart from summarising, general conclusions. On the basis of absolute increases and decreases in agricultural area, it was possible to calculate only the differences in carbon stocks. Furthermore, the BOHE parameters provide no information about the nature and intensity of cultivation (e.g. tillage, no tillage) within the meaning of the IPCC Revised Guidelines (IPCC et al, 1997), and such data is not collected in Germany (cf. Chap. 7.4.2). Consequently, it was not possible to determine the impacts of land-cultivation methods and intensity on carbon stocks in Germany's agriculturally used lands. For this reason, it was not possible to carry out any complete calculations with regard to LUC for this report. Therefore, it was not possible to provide a complete report pursuant to CRF.

In compilation of land-use data, problems arose that are due to the political development in Germany after 1989. Since German reunification did not take place until October 1990, the first standardised statistical survey of agricultural area and land use for all of Germany was not carried out until 1991; this is why land use in 1991 served as the basis for calculations.

Other difficulties arose in preparations for comparison of the BOHE 1991 data with the BOHE 1999 data. The administrative divisions between districts were redrawn in the new German Länder following reunification – i.e. the district system in the new German Länder was reorganised between the two BOHE. As a result, "old" districts had to be aggregated or divided and then reassigned. Since the BOHE agricultural-area data is not geo-referenced, division was carried out proportionally, leading to errors at the district level. While these errors cannot be quantified, they are small, however. In the national sum, they tend to cancel each other out.

#### 7.2.4.1 Agriculture

Tables 71 and 71 show the sums of areas and $C_{org}$ stocks for the various land-use classes, as they result when only the BOHE data is used and when they are quantitatively corrected and improved through incorporation of the FE data. For comparison, Table 70 includes the values that result from use of only the CORINE data.

128 Pursuant to the amended Agricultural Statistics Act (Agrarstatistikgesetz – Federal Law Gazette 1992), farms are exempted from BOHE if they have fewer than a certain minimum number of animals or if they have less than 2 ha of land.

Table 70: Areas ($km^2$) and carbon stocks (Mt), at depths of 0- 30 cm, of Germany's agricultural lands, based on the CORINE Land Cover data

| **All soils** (CORINE) | | | | |
|---|---|---|---|---|
| **Use** | **Area ($km^2$)** | **$C_{org}$ stock (Mt)** | | |
| | Total | Total | min. | max. |
| **Cropland** | 145382 | 1142 | 749 | 2191 |
| **Grassland** | 43103 | 452 | 247 | 921 |
| **Garden land / fallow land** | 28036 | 251 | 166 | 491 |
| **Total agricultural area** | 216522 | 1845 | 1162 | 3603 |

Table 71: Areas ($km^2$), Carbon stocks and stock changes, 1991 to 1999 (Mt), at depths of 0- 30 cm, of/on Germany's agricultural lands, based on data from the main survey on soil use (Bodennutzungshaupterhebung), 1991 and 1999, BÜK 1000

| **All soils** (BOHE 91) | | | | |
|---|---|---|---|---|
| **Use** | **Area ($km^2$)** | **$C_{org}$ stock (Mt)** | | |
| | Total | Total | min. | max. |
| **Cropland** | 115784 | 915 | 600 | 1760 |
| **Grassland** | 53436 | 551 | 310 | 1116 |
| **Garden land / fallow land** | 10222 | 95 | 56 | 187 |
| **Total agricultural area** | 179442 | 1562 | 966 | 3063 |
| **All soils** (BOHE 99) | | | | |
| **Use** | **Area ($km^2$)** | **$C_{org}$ stock (Mt)** | | |
| | Total | Total | min. | max. |
| **Cropland** | 118546 | 935 | 614 | 1797 |
| **Grassland** | 51251 | 529 | 298 | 1068 |
| **Garden land / fallow land** | 10813 | 102 | 61 | 199 |
| **Total agricultural area** | 180610 | 1565 | 973 | 3064 |
| **All soils** (BOHE 99 – BOHE 91) | | | | |
| **Use** | **Area ($km^2$)** | | **Change in $C_{org}$ stock (Mt)** | |
| | Total | % (91) | Total | Range |
| **Cropland** | 2762 | 2,4 | 19,59 | 1196,7 |
| **Grassland** | -2185 | -4,1 | -22,51 | 818,3 |
| **Garden land / fallow land** | 591 | 5,8 | 6,35 | 143,3 |
| **Total agricultural area** | 1166 | 0,6 | 3,44 | 2097,9 |

As the tables show, when only BOHE is used, the total agricultural area increased slightly (0.6 %) from 1991 to 1999, with cropland (2.4 %) and fallow land (8.6 %) increasing, and grassland (-4.1 %) and garden land (-8.8 %) decreasing; in sum, this leads to a slight increase 3,44 Mt in the $C_{org}$ stock, with a range of 2098 Mt (Tab. 3). In contrast to these values, the overall results of the area survey (Flächenerhebung) show a decrease, for

Germany, of –2.1 % in the agricultural area, from 195,112 km² in 1993 to 191,028 km² in 2001. Since these figures reflect the area actually used, with respect to the land registry cadastre (Liegenschaftskataster), the BOHE figures were adjusted to them. Table 72 shows the result.

Table 72: Areas (km²), Carbon stocks and stock changes, 1991 to 1999 (Mt), at depths of 0- 30 cm, of/on Germany's agricultural lands, based on data from the main survey on soil use (Bodennutzungshaupterhebung), 1991 and 1999, with respect to the absolute area of the 1993 area survey (Flächenerhebung), BÜK 1000

**All soils** (BOHE 91 corrected in accordance with FE 93)

| | **Area (km²)** | **$C_{org}$ stock (Mt)** | | |
|---|---|---|---|---|
| | Total | Total | min. | max. |
| **Cropland** | 125893 | 995 | 653 | 1913 |
| **Grassland** | 58101 | 599 | 337 | 1213 |
| **Garden land / fallow land** | 11115 | 104 | 61 | 204 |
| **Total agricultural area** | 195112 | 1698 | 1051 | 3331 |

**All soils** (BOHE 99 corrected in accordance with FE 01)

| | **Area (km²)** | **$C_{org}$ stock (Mt)** | | |
|---|---|---|---|---|
| | Total | Total | min. | max. |
| **Cropland** | 125384 | 989 | 649 | 1901 |
| **Grassland** | 54207 | 559 | 315 | 1129 |
| **Garden land / fallow land** | 11437 | 108 | 65 | 211 |
| **Total agricultural area** | 191028 | 1655 | 1029 | 3241 |

**All soils** (BOHE 99 corrected in accordance with FE 01 – BOHE 91 corrected in accordance with FE 93 and 01)

| **Use** | **Area (km²)** | | **Change in $C_{org}$ stock (Mt)** | |
|---|---|---|---|---|
| | Total | % (91) | Total | Range |
| **Cropland** | -511 | -0,4 | -6,40 | 1263,9 |
| **Grassland** | -3895 | -11,2 | -40,13 | 898,5 |
| **Garden land / fallow land** | 322 | 2,9 | 3,90 | 149,2 |
| **Total agricultural area** | -4084 | -2,1 | -42,63 | 2311,6 |

While cropland (-0.4 %) shows practically no change between 1991 and 1999, grassland (-11.2 %) and garden land (-6.5 %) underwent a considerable decrease; fallow land (5.8 %), on the other hand, increased. This calculation approach leads to a change in $C_{org}$ stocks of –42.6 Mt, with a range of 2312 Mt (Tab. 3). The stock changes are due only to the increases and decreases in the agricultural area, however. At present, it is not possible to determine whether these changes entail a net $CO_2$ release or storage for Germany. Only when it becomes possible to learn where area increases originate, and where area decreases "go", will it be possible to provide at least a qualified assessment on this question. The differences shown in Table 71 and 72, with respect to carbon stocks for Germany's agricultural land, result from the differences between the total areas on which the calculations are based (cf. Chap. 7.4.4); the relevant figures for reporting purposes are shown in Tab. 4.

The determined figures show the importance of land use with respect to soils' organic carbon content. Although 64% of Germany's agricultural land is used for crop cultivation, and 29% is used as grassland, cropland holds only 59% of carbon stocks to a depth of 30 cm, while grassland holds 35% of such stocks. This is due to the smaller stocks in cropland, as Table 73 illustrates.

Table 73: $C_{org}$ stocks (0-30 cm in t C $ha^{-1}$) in individual compartments of Germany's agricultural land.

| **Use** | **$C_{org}$ (t $ha^{-1}$)** | |
|---|---|---|
| | Median | Range |
| **Cropland** | 74 | 132 |
| **Grassland** | 89 | 204 |
| **$Lw_{heterog.}$** | 81 | 208 |

Pursuant to CRF, figures must be expressed in $CO_2$ mass units, and not in C mass units, which are used in the above tables. The following Table 74 summarises the results of conversion of $C_{org}$ to $CO_2$ using the factor 3.664 (44.0098/12.011).

Table 74: Carbon stocks in the upper cm[1)] of Germany's agriculturally used soils, based on the data of BOHE 1991 and 1999, and based on the BOHE 1991 and 1999 data, but adjusted in each case to the results of the 1993 and 2001 area surveys (Flächenerhebung).

| **Carbon stocks** (BOHE 91, BOHE 99) | | | |
|---|---|---|---|
| | **Area ($km^2$)** | **$CO_2$ Eq. (Tg)** | **Range** |
| 1991 | 179442 | 5722 | 7683 |
| 1999 | 180611 | 5735 | 7662 |
| **Carbon stocks** (BOHE 91, corr. with FE 93; BOHE 99, corr. with FE 01) | | | |
| | **Area ($km^2$)** | **$CO_2$ Eq. (Tg)** | **Range** |
| 1991 | 195112 | 6222 | 8353 |
| 1999 | 191028 | 6066 | 8104 |

1) Although the included organic soils suffered considerable annual losses, between 1991 and 1999, via peat mineralisation (cf. Table 75 and Table 76), these losses should be disregarded here, since the organic horizons, as a rule, have not been completely used up. Carbon lost at the surface of the 30 cm under consideration is replaced with carbon from below. While total stocks of organic soils are decreasing, the stocks in the upper 30 cm have not (yet) decreased. These stocks are the subject of reporting in the present context, since, pursuant to the relevant soil-scientific map instructions (Bodenkundliche Kartieranleitung - ARBEITSGRUPPE BODEN, 1994), soils must have a peat horizon of at least 30 cm in thickness in order to be mapped as fens or raised bogs.

The following section presents the results of calculations of carbon stocks (Table 75/Table 76) and mineralisation (Table 77) of agriculturally used organic soils in Germany.

Table 75: Area ($km^2$) and $C_{org}$ stocks (Mt) of Germany's agriculturally used organic soils, pursuant to BOHE 1991 and 1999 and BÜK 1000, and differences in results between the relevant survey years

| **Organic soils 1991** (BOHE 91) | | | | |
|---|---|---|---|---|
| **Use** | **Area ($km^2$)** Total | **$C_{org}$ stock (Mt)** Total | min. | max. |
| **Cropland** | 4662 | 121,4 | 35,0 | 273,1 |
| **Grassland** | 8621 | 217,2 | 62,0 | 488,7 |
| **Garden land / fallow land** | 479 | 11,5 | 3,2 | 25,9 |
| **Total agricultural area** | 13762 | 350,1 | 100,2 | 787,7 |
| **Organic soils 1999** (BOHE 99) | | | | |
| **Use** | **Area ($km^2$)** Total | **$C_{org}$ stock (Mt)** Total | min. | max. |
| | 4773 | 124,3 | 35,9 | 279,6 |
| **Grassland** | 8269 | 208,3 | 59,5 | 468,7 |
| **Garden land / fallow land** | 507 | 12,2 | 3,4 | 27,4 |
| **Total agricultural area** | 13549 | 344,8 | 98,8 | 775,7 |
| **Difference 1999-1991** (BOHE 99-BOHE 91) | | | | |
| | **Area ($km^2$)** Total | **$C_{org}$ stock (Mt)** Total | Range | |
| **Cropland** | 111 | 2,9 | 244,6 | |
| **Grassland** | -353 | -8,9 | 429,2 | |
| **Garden land / fallow land** | +8 | +0,7 | 24,1 | |
| **Total agricultural area** | -214 | -5,3 | 688,9 | |

Table 76: Area ($km^2$) and $C_{org}$ stocks (Mt) of Germany's organic soils, pursuant to BOHE 1991 and 1999 and BÜK 1000, and the differences between the survey years with regard to the actual agricultural area pursuant to FE 1993 and 2001

| **Organic soils 1991** (BOHE 91 corrected in accordance with FE 93) | | | | |
|---|---|---|---|---|
| | **Area ($km^2$)** Total | **$C_{org}$ stock (Mt)** Total | min. | max. |
| **Cropland** | 5069 | 131,9 | 38,1 | 296,9 |
| **Grassland** | 9374 | 236,1 | 67,5 | 531,3 |
| **Garden land / fallow land** | 521 | 12,5 | 3,5 | 28,1 |
| **Total agricultural area** | 14964 | 38,05 | 109,1 | 856,4 |
| **Organic soils 1999** (BOHE 99 corrected in accordance with FE 01) | | | | |
| | **Area ($km^2$)** Total | **$C_{org}$ stock (Mt)** Total | min. | max. |
| **Cropland** | 5049 | 131,4 | 37,9 | 295,7 |
| **Grassland** | 8746 | 220,3 | 62,9 | 495,7 |
| **Garden land / fallow land** | 536 | 12,9 | 3,6 | 28,9 |
| **Total agricultural area** | 14331 | 364,6 | 104,4 | 82,03 |
| **Difference 1999-1991** (BOHE 99 corr. with FE 01 – BOHE 91 corr. with FE 93) | | | | |
| | **Area ($km^2$)** Total | **$C_{org}$ stock (Mt)** Total | Range | |
| **Cropland** | -21 | -0,5 | 259,0 | |
| **Grassland** | -628 | -15,8 | 468,4 | |
| **Garden land / fallow land** | 15 | 0,4 | 25,4 | |
| **Total agricultural area** | -634 | -15,9 | 751,9 | |

Table 77: Area ($km^2$) of Germany's organic soils, mineralisation rates and $CO_2$-C losses (Mt) via peat mineralisation as a result of agricultural use, with regard to the actual agricultural area in 1991 and 1999

| **Mineralisation losses 1991** (BOHE 91 corrected in accordance with FE 93) | | | | | |
|---|---|---|---|---|---|
| | **Area ($km^2$)** **Total** | **Rate** **(t $ha^{-1}a^{-1}$)** | **$CO_2$ – C losses (Mt)** | min. | max. |
| **Cropland** | 5069 | 11 | 5,576 | 5,373 | 8,364 |
| **Grassland** | 9374 | 5 | 4,687 | 2,306 | 7,153 |
| **Garden land / fallow land** | 521 | 5 | 0,2605 | 0,128 | 0,398 |
| **Total agricultural area** | 14964 | | 10,524 | 7,807 | 15,915 |
| **Mineralisation losses 1999** (BOHE 99 corrected in accordance with FE 01) | | | | | |
| | **Area ($km^2$)** **Total** | **Rate** **(t $ha^{-1}a^{-1}$)** | **$CO_2$ – C losses (Mt)** | min. | max. |
| **Cropland** | 5049 | 11 | 5,554 | 5,352 | 8,330 |

| | | | | | |
|---|---|---|---|---|---|
| **Grassland** | 8746 | 5 | 4,373 | 2,151 | 6,673 |
| **Garden land / fallow land** | 536 | 5 | 0,268 | 0,132 | 0,409 |
| **Total agricultural area** | 14331 | | 10,195 | 7,635 | 15,413 |

#### 7.2.4.2 Forest

The available $C_{org}$ stocks data for forest soils originates from the first soil status survey in the forest (sampling period 1987-1993); this data is used for the CRF. The total C stocks amount to 0.858 Pg. The average content per ha, to a depth of 30 cm and including the humus layer, is 80.2 t C (BML, 1997). Both values are significantly higher than those calculated pursuant to BUEK 1000. For example, the profiles in BUEK 1000 typically contain lower $C_{org}$ stocks under forest than profiles of the same soil type under cropland or pasture land. This result is inconsistent with the general finding that forest soils have larger $C_{org}$ stocks than croplands do, and it results from the fact that this survey disregarded the overlying humus. This indicates that great care must be taken in using soil maps as a source for calculations of soil carbon stocks.

#### 7.2.4.3 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. It does not provide direct information on the annual use of fertilizers in agriculture and forestry. Differences are possible

- due to changes in commercial stocks
- due to use of fertiliser outside of agriculture and forestry, e.g. on private land, gardens, sports facilities

Until 1992/93, the results published by the Federal Statistical Office referred to the territorial status of the former Federal Republic of Germany. For the territory of the former GDR, the Federal Ministry of Consumer Protection, Food and Agriculture (BMVEL) adapted data for the years 1950 to 1989, based on GDR statistics, to the fertiliser-statistics categories of the Federal Republic of Germany, to facilitate comparison. 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 have been collected and published for unified Germany.

Table 78: $CO_2$ emissions in Gg $a^{-1}$, for the Länder of the Federal Republic of Germany, from fertiliser-lime use in agriculture and forestry (from DÄMMGEN et al, 2003, Emissions from German Agriculture, National Emission Inventory Report (NIR) 2004)

**Tabelle 100600.2:** **CO2-Emissionen in Gg a-1 CO2 für die Länder der Bundesrepublik Deutschland.**
**CO2-Emissionen aus Düngekalkanwendung in der Landwirtschaft**

Bericht:
Rechenverfahren:
Stand: September 2003

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Baden-Württemberg | 60,1 | 62,1 | 64,2 | 49,7 | 46,6 | 55,9 | 54,3 | 67,7 | 76,3 | 72,0 | 74,0 | 76,1 | 89,5 |
| Bayern | 371,6 | 346,0 | 257,3 | 270,3 | 259,6 | 260,1 | 291,5 | 290,3 | 355,0 | 302,4 | 346,3 | 306,0 | 335,0 |
| Brandenburg | 352,0 | 178,4 | 82,8 | 81,7 | 89,6 | 132,9 | 71,8 | 67,2 | 100,6 | 93,8 | 161,2 | 81,3 | 121,9 |
| Hessen | 81,8 | 77,7 | 81,8 | 80,5 | 71,1 | 77,6 | 73,7 | 71,0 | 81,0 | 71,8 | 86,2 | 73,6 | 82,5 |
| Mecklenburg-Vorpommern | 246,7 | 130,4 | 65,4 | 63,9 | 52,8 | 64,3 | 66,5 | 85,1 | 102,2 | 271,6 | 226,2 | 189,2 | 160,5 |
| Niedersachsen | 362,1 | 357,2 | 271,6 | 272,8 | 212,4 | 236,7 | 263,4 | 323,9 | 328,7 | 299,6 | 352,0 | 315,1 | 340,4 |
| Nordrhein-Westfalen | 236,3 | 257,6 | 244,5 | 274,8 | 221,7 | 241,9 | 287,0 | 242,9 | 266,5 | 233,0 | 267,7 | 235,9 | 263,4 |
| Rheinland-Pfalz | 61,4 | 48,5 | 43,5 | 45,5 | 40,1 | 41,0 | 41,2 | 43,7 | 49,4 | 38,1 | 40,4 | 37,2 | 43,2 |
| Saarland | 5,1 | 5,5 | 4,4 | 4,9 | 4,9 | 4,8 | 6,9 | 3,8 | 3,1 | 1,7 | 1,8 | 1,9 | 3,5 |
| Sachsen | 291,8 | 147,2 | 67,6 | 66,9 | 60,2 | 135,7 | 120,2 | 124,5 | 162,2 | 147,4 | 153,1 | 118,9 | 104,0 |
| Sachsen-Anhalt | 182,3 | 95,2 | 46,7 | 45,7 | 37,7 | 43,6 | 40,7 | 69,2 | 67,8 | 66,1 | 95,1 | 84,6 | 67,8 |
| Schleswig-Holstein | 105,8 | 108,9 | 134,8 | 123,9 | 96,1 | 126,7 | 145,4 | 142,2 | 136,3 | 163,6 | 173,3 | 175,8 | 167,2 |
| Thüringen | 122,9 | 64,7 | 32,3 | 31,5 | 18,8 | 33,5 | 24,7 | 20,3 | 32,0 | 30,9 | 32,2 | 26,7 | 26,5 |
| Stadtstaaten | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| Deutschland | 2479,9 | 1879,4 | 1397,0 | 1412,1 | 1211,7 | 1454,7 | 1487,2 | 1551,8 | 1761,2 | 1792,0 | 2009,5 | 1722,3 | 1805,4 |
| Deutschland in Tg a-1 (gerundet) | 2,48 | 1,88 | 1,40 | 1,41 | 1,21 | 1,45 | 1,49 | 1,55 | 1,76 | 1,79 | 2,01 | 1,72 | 1,81 |

**Tabelle 100600.3:** **CO2-Emissionen in Gg a-1 CO2 für die Länder der Bundesrepublik Deutschland.**
CO2-Emissionen aus Düngekalkanwendung in der Forstwirtschaft

Bericht:
Rechenverfahren:
Stand: September 2003

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Baden-Württemberg | 11,8 | 7,7 | 10,4 | 10,6 | 5,1 | 3,3 | 10,9 | 6,2 | 10,4 | 8,8 | 11,8 | 17,6 | 31,8 |
| Bayern | 0,9 | 1,2 | 3,2 | 3,6 | 0,3 | 7,0 | 5,6 | 0,8 | 0,1 | 2,2 | 4,2 | 0,3 | 0,7 |
| Brandenburg | 0,0 | 0,0 | 0,0 | 0,0 | 0,9 | 0,1 | 0,1 | 0,0 | 0,0 | 0,1 | 0,0 | 0,0 | 0,0 |
| Hessen | 17,9 | 32,7 | 53,6 | 24,5 | 21,6 | 23,5 | 33,0 | 25,4 | 17,8 | 23,4 | 23,8 | 10,1 | 14,5 |
| Mecklenburg-Vorpommern | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| Niedersachsen | 42,4 | 37,6 | 43,4 | 30,2 | 37,0 | 20,8 | 24,5 | 31,5 | 21,6 | 27,9 | 23,4 | 21,6 | 27,1 |
| Nordrhein-Westfalen | 37,3 | 17,0 | 35,7 | 25,0 | 31,7 | 29,6 | 16,1 | 26,6 | 19,9 | 9,1 | 10,2 | 39,5 | 29,4 |
| Rheinland-Pfalz | 49,2 | 54,4 | 60,8 | 62,9 | 54,5 | 56,3 | 50,6 | 30,6 | 53,5 | 33,4 | 39,1 | 24,6 | 25,6 |
| Saarland | 0,0 | 0,0 | 0,1 | 0,0 | 0,0 | 1,5 | 0,0 | 0,0 | 0,0 | 0,2 | 0,0 | 0,0 | 3,3 |
| Sachsen | 0,0 | 0,0 | 0,0 | 0,0 | 3,3 | 6,5 | 19,4 | 40,8 | 45,3 | 39,7 | 15,0 | 10,7 | 15,8 |
| Sachsen-Anhalt | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| Schleswig-Holstein | 3,5 | 2,1 | 1,0 | 0,7 | 0,1 | 1,2 | 0,0 | 0,0 | 0,0 | 1,4 | 0,0 | 1,0 | 0,0 |
| Thüringen | 0,0 | 0,0 | 0,0 | 0,0 | 26,9 | 18,9 | 9,9 | 7,7 | 3,5 | 8,0 | 7,7 | 8,6 | 0,7 |
| Stadtstaaten | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| Deutschland | 163,0 | 152,7 | 208,1 | 157,5 | 181,2 | 168,8 | 170,4 | 169,6 | 172,1 | 154,4 | 135,3 | 134,0 | 148,8 |
| Deutschland in Tg a-1 (gerundet) | 0,16 | 0,15 | 0,21 | 0,16 | 0,18 | 0,17 | 0,17 | 0,17 | 0,17 | 0,15 | 0,14 | 0,13 | 0,15 |

### 7.2.4.4 Summary

The following section summarises the described net emissions from Germany's agricultural land for comparison (Chapter 7.4.4.1 and 7.4.4.3). These emissions result from the loss of agricultural land to other land-use classes, as well as from peat mineralisation in organic soils and liming of agricultural soils. Since it was not possible to determine whether the loss of agricultural land to other land-use classes has led to real $CO_2$ emissions, these figures represent only an estimate, under a worst-case assumption (total loss of all organic carbon from the upper 30 cm of the soil). On the other hand, the data presented in Tables 79 and 80, on $CO_2$ emissions from peat mineralisation and liming for the period 1991 to 1999 and for 1990 and 2002, represents a well-founded estimate. Owing to the differences in the quality of the data, these sources were not presented in a joint table.

Table 58 shows that the loss of agricultural land to other land-use classes, in a worst-case scenario, may have caused emissions of up to 156 Tg $CO_2$ equivalents over nine years, or up to 17,356 Gg per year (complete loss of the organic substance in the area in question). Pursuant to Tab. 59, a total of 39160 Gg $CO_2$ emissions may have occurred through peat mineralisation and liming. In light of the very small total area of organic soils, compared to the total agricultural area involved, peat mineralisation is clearly a "hot spot" for $CO_2$

emissions from agricultural lands, and its emissions amount to over twice the potential maximum emissions from loss of agricultural land to other land-use classes.

Table 79: Overview of $C_{org}$-stock differences in Germany's agriculturally used soils, between 1991 and 1999, as a result of the loss of agricultural land to other land-use classes.

| **$C_{org}$-stock change** (BOHE 91, BOHE 99) | | |
|---|---|---|
| **Use** | **$CO_2$ Eq. (Tg)** | |
| | Total | Range |
| **Cropland** | -71,78 | 3986,2 |
| **Grassland** | 82,48 | 2725,7 |
| **Garden land / fallow land** | -23,27 | 477,4 |
| **Total agricultural area** | **-12,60** | 6961,6 |
| **$C_{org}$-stock change** (BOHE 91 corr. with FE 93, BOHE 99 corr. with FE 01) | | |
| **Use** | **$CO_2$ Eq. (Tg)** | |
| | Total | Range |
| **Cropland** | 23,45 | 4210,2 |
| **Grassland** | 1147,04 | 2993,1 |
| **Garden land / fallow land** | -14,29 | 499,4 |
| **Total agricultural area** | **156,20** | 7665,6 |

Table 80: Compilation of data on $CO_2$ emissions for 1990 (area pursuant to BOHE 1991, corr. with FE 93) and 2002 (area pursuant to BOHE 1999, corr. with FE 01), from Germany's agriculturally used soils, as a result of mineralisation of organic soils and liming (lime figures for 1990 and 2002)

| Area pursuant to BOHE 1991, corr. with FE 93 | | | | |
|---|---|---|---|---|
| **Use** | **Mineralisation (Gg $CO_2$ Eq)** | | **Liming (Gg)** | **Total (Gg)** |
| | Total | Range | | |
| **Cropland** | 20432,05 | 10959,01 | | |
| **Grassland** | 17174,42 | 17758,35 | | |
| **Garden land / fallow land** | 954,58 | 987,03 | | |
| **Total agricultural area** | **38561,05** | **29704,39** | **2479,9** | **41040,95** |
| Area pursuant to BOHE 1999, corr. with FE 01 | | | | |
| **Use** | **Mineralisation (Gg $CO_2$ Eq)** | | **Liming (Gg)** | **Total (Gg)** |
| | Total | Range | | |
| **Cropland** | 20349,16 | 10914,55 | | |
| **Grassland** | 16023,02 | 16567,80 | | |
| **Garden land / fallow land** | 982,23 | 1015,63 | | |
| **Total agricultural area** | **37354,41** | **28497,98** | **1805,4** | **39159,81** |

The emissions data for 1990 and 2002 shown in Table 80 was transferred, as such, to the CRF tables. Since no data on distribution of agricultural land in reunified Germany is available for 1990, the 1991/93 result for $CO_2$ emissions from organic soils was transferred to the base year, 1990, and then entered into the CRF tables. The chronologically nearest data was also used for 2002 (1999/2001). The values for 1994 –1998 were calculated in the manner shown above, using the results of BOHE 1995 and FE 1997.

Emissions from liming are listed in Table 78.

### *7.2.5 Source-specific quality assurance / control and verification (5D)*

At the present time, no source-specific QA/QC and reviews for $C_{org}$ stocks are available. The activity and liming data were taken from official statistics based on federal laws that, as a rule, feature high-quality specification. The general relevant principles include neutrality, objectivity and scientific independence. The affected parties are required by law to provide truthful, complete information.

### *7.2.6 Source-specific planned improvements (5D)*

#### 7.2.6.1 Agriculture

Not all of the data required for reporting for the Framework Convention on Climate is available, and existing data cannot always be accessed in the manner required (regularly, within a proper legal framework). What is more, the data varies in quality, and conversion of data into a common format, for compatibility, can be a laborious process. In addition, staffing levels and IT systems are inadequate for the task of proper, regular reporting in the manner

described below. Efforts are currently being made to find solutions to the resulting legal and administrative problems.

In particular, the following are lacking:

1. Complete-coverage activity data on area management (geo-referenced and on an annual basis),
    - for determining management factors and input factors for the default procedure
    - as input parameters for the model for calculating C content.
2. Legally and financially (cost-free) assured access to various data sources, due to
    - data-protection issues. (for example, data is available only in aggregated form; aggregated data is still being blacked out in some cases (including BoHe); InVeKoS).
    - federal issues (such as InVeKoS, surveying data, property data, geological data under the authority of Länder, municipalities or Land-owned companies)
3. periodic inventories that precisely determine the carbon stocks in Germany's agriculturally used soils,
    - for creation of a chronologically precise map of C stocks, and their changes, in Germany's agricultural soils
    - for a standard definition of the baseline
    - as input parameters for the mathematical C model
    - for regular validation of calculated C stocks

Intensive efforts are currently being made, in a research project and in interministerial committees and working groups, to achieve the following, urgently required steps toward lasting improvements:

1. Implementation of a system for collecting management data on an annual basis
2. Review of the legal and administrative possibilities and options – and creation of same, if necessary – for eliminating hindrances to access to required, existing data.
3. Carbon inventory of agriculturally used soils (planning is underway, funding proposed for inclusion in the 2006 federal budget)

In addition, the following specific steps will be taken to improve carbon inventories in the coming year:

1. In 2004, all data from the area survey (Flächenerhebung) and the main survey on soil use (Bodennutzungshaupterhebung) will be used as a calculation basis at the municipal level, for
    - Categorisation of land use
    - Determination of changes in area use

2. Where possible, BÜK 1000 will be replaced by BÜK 200, or similar maps with relevant information, or by geo-referenced soil information from other data sources (long-term soil monitoring, meta-databases, etc.).

3. Data from CORINE 2000 is to be used as a basis for area distribution and as a basis for map overlays

4. Calibration and validation of the carbon model (Roth-C) on the basis of data from long-term soil-monitoring sites

5. Modelling of carbon stocks for the base and reporting years

6. Incorporation of InVeKoS (Integriertes Verwaltungs- und Kontrollsystem – integrated administration and control system) data (recording of all relevant information for all EU-supported areas (currently > 80 – 95 % of German agricultural land). As of 1 January 2005, reports must be GIS-based; this will require the affected agricultural area to be geo-referenced. Review is currently being carried out to determine if InVeKoS data can be used in the context of climate reporting. Geo-referenced reports on land use and land-use changes could then be obtained on an annual basis).

#### 7.2.6.2 Forests

At present, the second soil status survey is under preparation. It 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 $C_{org}$ stock changes in forest soils.

# 8 WASTE AND WASTEWATER (CRF SECTOR 6)

## 8.1 Solid waste disposal on land (6.A)

| CRF 6.A | | | | | |
|---|---|---|---|---|---|
| **Key source** | | **Gas (key source)** | **1990 – contribution to total emissions** | **2002 – contribution to total emissions** | **Trend** |
| Solid waste disposal on land | l / t | $CH_4$ | 2,52 % | 1,16 % | falling |

| Gas | $CO_2$ | $CH_4$ | HFCs | PFCs | $SF_6$ | $N_2O$ | $NO_X$ | CO | NMVOC | $SO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Emissions factor[129] (EF) | | CS | | | | | | | | |
| EF uncertainties in % | | | | | | | | | | |
| Distribution of uncertainties [130] | | | | | | | | | | |
| Method for EF determination[131] | | T2 | | | | | | | | |

In terms of its emissions levels and trend, the source category "solid waste disposal on land" (6.A) is a key source for 2002.

Only managed waste disposal in landfills (6.A.1) is relevant for purposes of German emissions reporting under CRF 6.A. "Wild" or illegal dumping of solid waste (CRF 6.A.2) is prohibited by law in Germany. In the framework of reporting, "other sources" (6.A.3) are included in reporting under CRF 6.A.1 (cf. Chapter 8.1.2).

### *8.1.1 Managed disposal in landfills – landfilling of municipal waste (6.A.1)*

#### 8.1.1.1 Source category description (6.A.1)

At present, some 330 landfills for municipal waste (household-waste landfills) are operated in the Federal Republic of Germany. Strict legal regulations are in place that require such landfills to have equipment for collecting and treating landfill gas; these regulations have extensively reduced methane emissions from such facilities. As a result of new, more extensive requirements imposed by the Ordinance on waste disposal and on landfills (Abfallablagerungs- und der Deponieverordnung), about 2/3 of these landfills will close by June 2005. As of that time, landfills that remain in operation may store only waste that conforms to strict categorisation criteria, and they must reduce landfill-gas formation from such waste by much more than 90 % with respect to gas from untreated waste. As landfill-gas formation from older waste-storage sites diminishes, methane emissions from landfills will thus have been extensively reduced.

#### 8.1.1.2 Methodological issues (6.A.1)

The *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC et al, 1997) specify two methods for determining methane emissions from landfills, a default method (Tier 1) and the "first-order decay method" (short name: "FOD method" or "Tier 2"). Whereas the default method functions under the assumption that methane from waste forms completely in the year in which the waste is placed in a landfill, the FOD method uses a

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

kinetic approach that describes methane formation, more realistically, as taking place over several years.

To date, the default method has been used to determine landfill methane emissions in Germany. There are several reasons why this method is inadequate for determining emissions in Germany:

- IPCC *Good Practice Guidance* specifies that the first-order decay method should be used when source category 6A is a key source. At present, this source category is a key source in German in terms of emissions levels and trend.
- The default method tends to underestimate emissions especially when quantities of waste being placed in landfills are decreasing, and this is occurring in Germany. This problem is going to worsen in Germany, especially as of 1 June 2005, when the the waste-storage ordinance's transition periods expire. As of that date, no waste may be landfilled that has a loss due to burning of greater than 5 % by weight.[132] In other words, landfilling of waste that forms significant amounts of methane will no longer be possible. As a result, as of 2005, the default method would identify virtually no methane emissions; if it were used, virtually no emissions would be reported. And yet a close look at the actual course of methane formation over time shows that landfills tend to emit methane for years. The FOD method's kinetic approach takes such behaviour into account.

For this reason, in the following section, $CH_4$ emissions were calculated with the FOD method (Tier 2).

The following section describes the FOD method, and the relevant parameters used, for determining methane formation in landfills. The FOD method calculates in accordance with Equation 1:[133]

$$CH_4\ generated\ \ in\ year\ t\ (Gg/year) = \sum_x [(A * k * MSW_T(x) * MSW_F(x) * L_0(x) * e^{-k(t-x)}]$$

$$with: L_0(GgCH_4/kg\ waste) = MCF * DOC * DOC_F * F * 16/12$$

$$for\ x = first\ year\ until\ t$$

where

*t = inventory year*

*x = year in which consideration begins and quantity data is collected*
*$MSW_T$ (x) = total amount of municipal waste*
*$MSW_F$ (x) = percentage of municipal waste that is landfilled*
*$A = (1\text{-}e^{-k})/k$ = normalisation factor for sum correction*
*k = constant methane-formation rate (1/year)*
*$L_0$ = potential methane formation*
*MCF (x) = methane-correction factor for year x*
*DOC (x) = degradable organic carbon in year x (percentage)*
*$DOC_F$ = Proportion of DOC converted into landfill gas*

*F = proportion of $CH_4$ in landfill gas*
*16/12 = factor for conversion from C to $CH_4$*

No individual measurements of k are available; for this reason, the IPCC default value of 0.05 (corresponds to a half-life of about 14 years) was used for k in calculation.

To obtain the final $CH_4$-emissions result, methane that is collected and used for energy recovery is deducted, and a correction factor is applied that accounts for methane oxidation in landfill covering layers, as shown by Equation 2:

*$CH_4$ emitted in year t (Gg/year) = ($CH_4$ produced in year t – R(t)) • (1- OX)*

Where

R(t) = $CH_4$ collection in year t
OX = oxidation factor (proportion)

For both Tier 1 and Tier 2, the relevant quantities of municipal waste ($MSW_T$), and the proportion of municipal waste that is landfilled ($MSW_F$), must be determined; for Tier 2, production of municipal waste over the previous decades must also be determined. Pursuant to IPCC Good Practice Guidance, landfilled municipal waste should be broken down – via estimation – into waste types, since the further procedure takes account of the fact that different waste types have different DOCs.

Produced quantities of municipal waste (household and commercial waste), and the relevant landfilled proportions, are taken from relevant statistics of the Federal Statistical Office (DESTATIS), which are based on annual surveys of waste types, origins and final destinations, as well as on surveys taken of waste-storage facilities, every two years, that focus on specific equipment of the facilities (cf. Chapter 14.6.1). The surveys of waste quantities commenced in 1975, on the basis of the Environmental Statistics Act of 1975. Waste quantities for the period from 1970 to 1975 were extrapolated on the basis of population data. The most recent year for which suitably differentiated data is available is 2000. For 2001 and 2002, quantities were assumed to remain constant in comparison to 2000. This data will be recalculated as soon as the relevant specialised series of the Federal Statistical Office become available.

For the period 1970 to 1990, there was no standardised statistical basis for waste-production and waste-disposal data throughout all of Germany, and this creates a problem with regard to data on waste quantities and landfilled proportions of waste during that period. Data for the former GDR cannot simply be derived from average data of the old German Länder, since marked differences applied: The average per-capita waste production (municipal waste), at about 175 kg/a, was considerably lower than that of the Federal Republic of Germany, where the corresponding figure was about 365 kg/a of household waste (BMU, 1990, p. 27). From the former GDR's Ministry for Nature Conservation, Environmental Protection and Water-Resources Management (MNUW), statistical data on settlement-waste production for the

132 As of 2005: Landfill class I: little or no gas formation; landfill class II: moderate gas formation, except for formation in mechanical-biological landfill facilities, of which only a few are in operation to date (sub-report waste / waste water F+ E 299 42 245).
133 A detailed description of the FOD method and its parameters is presented in the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, in the Greenhouse Gas Inventory Reference Manual, known as the "IPCC Guidelines" (IPCC et al 1997), and in the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, known as the "Good Practice Guidance" (IPCC 2001).

territory of the former GDR is available for four different years in the period leading up to reunification (1983, 1985, 1988, 1989) (MNUW, 1990); from this data, in connection with population data, the applicable settlement-waste quantities for the former GDR were derived for the period 1970-1990. Another reason why it is difficult to compare the data is that in the former GDR most sources recorded waste-quantity data in $m^3$, and the waste-composition information necessary for conversion into tonnes is lacking.

For the years 1990 and 1993, and for the period since 1996, differentiated data is available on landfilled quantities of individual fractions of municipal waste (such as household waste, bulky waste, compostable waste, garden and park waste). For the years prior to 1990, the landfilled proportions from 1990 were used, with no changes. For years after 1990 for which data was lacking, data from framing years with data was interpolated. In general, all waste was landfilled in the former GDR, and thus 100% landfilling of municipal waste was assumed for the period 1970-1990.

#### *8.1.1.2.1 MCF (methane-correction factor)*

Until 1972, when the first Waste Act was introduced, waste was usually stored in uncontrolled landfills; such landfills were closed after 1972. After 1972, waste was stored in managed landfills. In keeping with this history, a default MCF value of 0.6 was used for "unclassified landfills" ("nicht zugeordnete Deponien"), while an MCF of 1 was used after 1972.

Data is available from a 1989 survey of the territory of the former GDR that covered 120 managed landfills, some 1000 controlled storage sites and some 10,000 uncontrolled dump sites (MNUW, 1990). Of the some 13,000 waste-storage sites, a total of 11,000 were for household waste and 2,000 were for industrial waste; most of the latter were plant-owned facilities (BMU, 1990, p. 28). Consequently, an MCF of 0.6 (default value for unclassified landfills) was assumed for the territory of the former GDR for the period 1970 to 1990. Upon German reunification, the Federal Republic of Germany's waste laws were extended to the territory of the new German Länder, and transitional regulations were introduced to ensure that facilities – including both decommissioned facilities and still-operational facilities in which waste was (or is) produced or disposed of – were accounted for and that suitable clean-up measures were initiated (BMU, 1990, p. 46). Uncontrolled landfills were closed in 1990, facilities permitted to remain open were secured, cleaned up and modernised/expanded in keeping with the standards of Federal German waste law, and sites for new facilities were sought. As of 1990, the Federal Statistical Office has collected statistics on both parts of Germany. For purposes of calculation for the period after 1990, an MCF of 1 is used for all of Germany's territory.

#### *8.1.1.2.2 DOC*

Both national data and IPCC default factors were used for DOC, the proportion of degradable organic carbon in waste. Table 81 provides an overview of the DOC values used. The fractions in Table 81 are based on the waste fractions for which data on landfilled waste quantities is available via the 1990–2002 time series. While national studies of individual DOC fractions of household waste (paper, glass, textiles, etc.) are available, no reliable data on landfilled quantities of these waste fractions is available, and thus DOC values from a more highly aggregated level had to be used.

Table 81: DOC values used

| Fraction | DOC | Source |
|---|---|---|
| Household waste, commercial waste similar to household waste | 18% | WALLMANN, 1999, p.118/119 |
| Municipal waste of former GDR | 15% | Assumption: smaller DOC than for household waste of old German Länder; larger mineral component |
| Compostable waste from "bio" bins (Biotonnen) | 15% | IPCC default for food |
| Bulky waste | 31% | ÖKO-INSTITUT 2002, p. 12ff |
| Road sweepings | 18% | WALLMANN, 1999, p.118/119 |
| Market waste | 15% | IPCC default for food |
| Garden and park waste | 17% | IPCC default |
| Sewage sludge | 30% | MUNLV 2001, p. 205ff |

For the fractions shown in Table 81, time series are available or can be derived from existing data. For the listed fractions, constant DOC values were assumed for all years, since no data is available for chronological adaptation of DOC values for household waste or bulky waste. Overall, waste-management measures carried out in the 1990s (including increasing separate collection of biological waste, paper and packaging waste) had various, often opposing effects, and experts consider it realistic to assume constancy in the aformentioned terms in the final result.

#### *8.1.1.2.3 $DOC_F$*

$DOC_F$, the DOC proportion that can be converted into landfill gas, is put at 50% for municipal waste, on the basis of a national study (RETTENBERGER et al, 1997, p. 277). This value lies within the IPCC default range of 0.5-0.6.

The proportion of carbon that is actually converted into gas is likely to be significantly lower for sewage sludge than for municipal waste, since sewage sludge is generally an extensively putrefied product resulting from sludge treatment in sewage plants. Consequently, the level of biological activity is likely to be comparatively low. Furthermore, sewage sludge is often limed prior to landfilling. In such cases, the resultant pH value is significantly above the neutral range favoured by methanogens. In the absence of sewage-sludge-specific data, the 10 % carbon-decomposition rate cited in the literature, based on output of mechanical-biological waste treatment, is used as an approximation (WALLMANN, 1999).

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 methane-emissions potential of methane would be assumed even during the landfilling process. In (UBA, 1993) a factor $DOC_F$ = 40% is assumed, i.e. a higher portion of organic carbon in the portion converted into landfill gas. This factor is also consistent with the data in (ATV 1996) and, in the time series, is used on the portion of sewage sludge generated in east Germany until 1994.

#### *8.1.1.2.4 F = proportion of $CH_4$ in landfill gas*

A value of 50%, the mean value in the IPCC default-value range, is assumed for F. This value was confirmed by a national research project (UBA, 1993).

#### *8.1.1.2.5 Half-life*

A half-life of 5 years was assumed; this yields a value of 0.14 for k (constant for the methane-formation rate). The half-life is considerably less than the IPCC default value of 14 years. The small national half-life figure was derived from various literature sources and from information of national experts. For example, EHRIG (1997) gives a half-life of 3.5 to 6 years, while RETTENBERGER (1998) gives a half-life of 4 to 6 years for domestic landfills. The lower half-life could have to do with the composition of landfilled waste, as well as with specific technologies for placing waste in landfills, technologies that were specially developed early on in Germany and that are designed to create optimal conditions for decomposition.

#### *8.1.1.2.6 Landfill-gas use*

At present, a total of 75% of the filled landfill capacity in Germany, by volume, is connected to a system for collecting landfill gas (FHG ISI, 2003, p. 3). Gas-collection systems collect some 50% of the landfill gas produced. In 1993, only 35% of landfills were connected to gas-collection systems (UBA, 1994), and collection, basically, did not begin until the 1980s. These basic figures were used as a basis for calculating the amounts of $CH_4$ that must be deducted as a result of use of generated methane gas. In 2002, such calculation showed that some 63% of the generated methane is actually emitted.

Use of landfill gas for energy recovery is recorded and reported by the energy sector. Rough conversion, into energy data, of the assumptions made in this area, and comparison with other sources of data on use of landfill gas for energy recovery, show that the selected method leads to conservative results and tends to underestimate landfill-gas use and is thus a conservative procedure.

#### *8.1.1.2.7 Oxidation factor*

As to the factor determining the proportion of $CH_4$ that is oxidised in landfill covering layers, the IPCC default value of 0.1 was accepted for the entire time series. On the one hand, a larger proportion of uncontrolled landfills can be expected in the former GDR in the early 1990s; on the other hand, a research project found only a low $CH_4$-formation potential for landfills of the former GDR, and thus the factor 0.1 was also used for this period (BMBF, 1997).

### 8.1.1.3 Uncertainties and time-series consistency (6.A.1)

The method's uncertainties have not yet been estimated.

Over the long activity-data period involved, thirty years, time-series inconsistencies have to be expected. In Germany, such inconsistencies must be expected primarily as a result of German reunification and its fusion of two different economic and statistical systems; furthermore, they must be expected as a result of improvements of laws and statistics for the waste sector.

Since 1996, procedures for recording quantities of waste produced, and quantities of waste disposed of by the manufacturing sector, have been considerably modified, and statistics have taken greater account of waste recycling. Pursuant to the new Environmental Statistics Act (Umweltstatistikgesetz), waste production and waste origins are determined soley via the

waste actually delivered to waste-management facilities. As a result, findings from statistical waste surveys carried out as of 1996 are only partly comparable with published figures for 1993 and earlier (especially with regard to listed waste fractions). These changes were taken into account in the structure of the calculation model.

Section 1.1.2 explained the methods that were used to achieve consistent time series, in spite of these difficulties.

#### 8.1.1.4 Source-specific quality assurance / control and verification (6.A.1)

The selected parameters were compared with relevant data for other countries. In particular, the Länder-specific DOC figures for municipal waste tend to be high compared to those for other European countries, which indicates that the underlying estimates tend to be conservative.

In the area of landfill-gas use, various data sources were compared and a consistent, conservative approach was selected.

In entry of data, the correctness of entries was checked via sum values – various waste categories were recorded solely for the purpose of checking correctness of data entry.

#### 8.1.1.5 Source-specific recalculations (6.A.1)

The entire time series for $CH_4$ emissions from landfilling of municipal waste, for the period 1990-2002, was recalculated using a Tier 2 method.

#### 8.1.1.6 Planned improvements (6.A.1)

Statistics and reporting on use of renewable energies are being improved within the framework of promotion of use of renewable energies. At the same time, efforts are being made in this context to improve the data on landfill-gas use. At present, the various available data sources exhibit considerable disagreement. A conservative estimate was used for $CH_4$ emissions from waste landfilling. Further efforts should be carried out in this area, aimed at improving the precision of inventory calculations and at enhancing comparability of data from statistics on renewable energies (biomass use).

Commercial waste is included in the estimates for municipal waste. At present, emissions from industrial waste are not calculated. Data is available on the waste quantities produced by various sectors, but no data is available on the composition of such waste (paper, wood or biological waste fractions); consequently, no default DOC values can be used in this area, and no data on DOC values for waste of various sectors is available. No further calculations can be carried out on this basis.

### *8.1.2 Other sources – landfilling of residues from mechanical-biological waste treatment (MBA) (6.A.3)*

MBA landfills are landfills on which residual waste is deposited following mechanical/biological treatment. Use of mechanical/biological treatment technology has been growing since the mid-1990s. From the year 2005 onwards, a growing volume of MB waste residues is anticipated due to the obligation for compulsory pre-treatment of municipal wastes prior to landfilling. The criteria applying to MB-waste residue are outlined in the Ordinance on Environmentally Compatible Storage of Waste from Human Settlements and

on Biological Waste Treatment Facilities (AbfAblV). Future requirements for MB-waste landfilling of waste stipulate that this must be done in such a way as to eliminate the need for after-care. This is defined more precisely, *inter alia*, with the formulation "virtually no landfill gas". On the whole, because residual wastes will be extensively stabilised via pre-treatment, and since regulations require that TOC content not exceed 18% of the dry mass in MB-waste residue, MB-waste landfills can be expected to have only minimal $CH_4$ formation. Currently, statistics record what quantities of waste are treated in facilities for mechanical/biological treatment, but they do not show what quantities of MB-waste residues are landfilled. For this reason, waste treated in MB-waste facilities is still reported as part of the entire quantity of municipal waste, under category 6.A "Solid waste disposal on land", and methane emissions are calculated without regard for the very low rates of $CH_4$ formation in this sub-category of municipal waste; as a result, calculation of $CH_4$ emissions in category 6.A is conservative. Plans call for $CH_4$ emissions from landfilling of MB-waste residues to be calculated separately as soon as more reliable activity data is available for this sub-category.

## 8.2 Wastewater treatment (6.B)

| **CRF 6.B** | | | | | |
|---|---|---|---|---|---|
| Key source | | Gas (key source) | 1990 – contribution to total emissions | 2002 – contribution to total emissions | **Trend** |
| Wastewater treatment, industrial wastewater | t | $CH_4$ | 0,18 % | 0,01 % | falling |

| **Gas** | **$CO_2$** | **$CH_4$** | **HFCs** | **PFCs** | **$SF_6$** | **$N_2O$** | **$NO_X$** | **CO** | **NMVOC** | **$SO_2$** |
|---|---|---|---|---|---|---|---|---|---|---|
| Emissions factor[134] (EF) | NE | D/CS | NO | NO | NO | D | NO | NO | NO | NO |
| EF uncertainties in % | | | | | | | | | | |
| Distribution of uncertainties [135] | | | | | | | | | | |
| Method for EF determination[136] | | | | | | | | | | |

In terms of trend, methane emissions from industrial wastewater and sludge treatment are a key source for 2002.

### *8.2.1 Methane emissions from industrial wastewater and sludge treatment (6.B.1)*

#### 8.2.1.1 Source category description (6.B.1)

The composition of industrial wastewater, in contrast to that of household wastewater, varies greatly, by industrial sector. In Germany, the biological stage of industrial wastewater treatment is partly aerobic and partly anaerobic. Anaerobic wastewater treatment is especially useful for industries whose wastewater has high levels of organic loads. This treatment method has the advantages that it does not require large amounts of oxygen, produces considerably smaller amounts of sludge requiring disposal and generates methane that can be used for energy recovery. As in treatment of municipal wastewater, treatment of industrial wastewater releases no methane emissions into the environment. The procedures used include aerobic treatment and anaerobic putrification; gas formed in the latter procedure is either used for energy recovery or is flared off.

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

Industrial sludge treatment and stabilisation, like industrial wastewater treatment, is carried out either aerobically or anaerobically with methane-gas use.

## *8.2.2 Municipal wastewater treatment (6.B.2)*

### 8.2.2.1 Methane emissions from municipal wastewater treatment (6.B.2)

#### *8.2.2.1.1 Source category description (6.B.2)*

Municipal *wastewater treatment* in Deutschland – like that in Sweden and Denmark – uses aerobic procedures (municipal wastewater-treatment facilities, small wastewater-treatment facilities), i.e. it produces no methane emissions (default value for MCF = 0), since such emissions occur only under anaerobic conditions.

Treatment of human sewage from persons not connected to sewage networks or small wastewater-treatment facilities represents an exception: in cesspools and septic tanks, uncontrolled processes (partly aerobic, partly anaerobic) can occur that lead to methane formation. Since 1990, organic loads discharged into cesspools and septic tanks have been drastically reduced; the percentage of inhabitants connected to small wastewater-treatment facilities has continually increased, especially in eastern Germany.

#### *8.2.2.1.2 Methodological issues (6.B.2)*

Organic loads from cesspools and septic tanks are calculated pursuant to the IPCC method, in which the relevant population is multiplied by the average organic load per person; cf. Table 82. The average organic load is assumed as 60 g $BOD_5$ per inhabitant. This value, the IPCC default value, is used for Germany.

Table 82: Organic wastewater load in cesspools and septic tanks (1990-2001)

| Organic load in | $BOD_5$ in t/a | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1990** | **1991** | **1992** | **1993** | **1994** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **2001** | **2002** |
| Cesspools and septic tanks | *180.334* | 172.452 | *164.569* | *156.687* | *148.804* | 140.922 | *105.409* | *69.896* | 34.383 | *31.062* | *27.740* | 24.419 | 21.097 |
| of these, in western Germany | *91.686* | 87.449 | *83.212* | *78.975* | *74.738* | 70.500 | | | | | | | |
| of these, in eastern Germany | *88.653* | 85.009 | *81.366* | *77.722* | *74.078* | 70.435 | | | | | | | |

numbers in italics: interpolated and extrapolated values

(DESTATIS, e; calculations ÖKO-INSTITUT, 2004b)

Methane emissions from cesspools and septic tanks are determined in keeping with the IPCC method. The IPCC default value for potential methane formation, and an MCF of 0.5 for cesspools and septic tanks, are assumed. The MCF for cesspools and septic tanks has been estimated on the basis of experience gained other in countries (septic tanks in the U.S., anaerobically treated municipal wastewater in the Czech Republic (cf. Chapter 14.6.2). Emissions for 2001 are determined as follows:

$$CH_4(cesspools\ and\ septic\ tks) = 24\,419\,000\ kg\ BOD_5\ x\ 0.6\ kg\ CH_4\ /\ kg\ BOD_5\ x\ 0.5$$

Table 83: Methane emissions from cesspools and septic tanks (1990-2001)

| Methane emissions from | in t $CH_4$ | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1990** | **1991** | **1992** | **1993** | **1994** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **2001** | **2002** |
| cesspools and septic tanks | 54.100 | 51.735 | 49.371 | 47.006 | 44.641 | 42.277 | 31.623 | 20.969 | 10.315 | 9.318 | 8.322 | 7.326 | 6.329 |

(DESTATIS, e; IPCC default value; calculations ÖKO-INSTITUT 2004b)

#### *8.2.2.1.3 Uncertainties and time-series consistency (6.B.2)*

The method's uncertainties have not yet been estimated.

The activity rates for organic loads in cesspools and septic tanks are based on data from the Federal Statistical Office's Fachserie 19 Reihe 2.1, which was published in 1991, 1995, 1998 and 2001. For production of a consistent time series, the activity rates were linearly interpolated between 1991 and 1995, between 1995 and 1998 and between 1998 and 2001. The activity rates for 1990, on the other hand, were extrapolated from the 1991 to 1995 time series.

Until 1995, data for the old and new Federal Länder was determined separately; since then, a single value for all of Germany has been determined in each case. This does not affect time-series consistency, however.

#### *8.2.2.1.4 Source-specific quality assurance / control and verification*

The MCF for cesspools and septic tanks in Germany was derived on the basis of an evaluation of national inventory reports of other countries (cf. Chapter 14.6.2).

The fact that aerobic wastewater treatment in relevant facilities produces no significant methane emissions can be confirmed in other countries (Sweden, Denmark).

#### *8.2.2.1.5 Source-specific recalculations (6.B.2)*

Table 84 provides an overview of the emissions reported to date in the inventory and those that will be reported in future. In the past, methane emissions were reported under "industrial wastewater", even though they occur in connection with household and commercial wastewater. This categorisation is corrected in the present report.

Table 84: Source-category-specific recalculations of methane emissions [Gg] in wastewater treatment

| | **1990** | **1991** | **1992** | **1993** | **1994** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **2001** | **2002** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Methane emissions (as previously reported in the inventory) | | | | | | | | | | | | | |
| Industrial wastewater | 51,91 | 29,6 | 14,8 | 9,2 | 9,2 | 9,7 | 9,7 | 9,7 | 10 | 10 | 10 | 10 | 10 |
| Household and commercial wastewater | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| Methane emissions (new calculation) | | | | | | | | | | | | | |
| Industrial wastewater | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Household and commercial wastewater | 54,1 | 51,7 | 49,4 | 47,0 | 44,6 | 42,3 | 31,6 | 21,0 | 10,3 | 9,3 | 8,3 | 7,3 | 6,3 |

The methane emissions from wastewater, as reported in past inventories – at least those for the years 1990 to 1994 –, consisted of methane emissions from open sludge putrification.

For this reason, in future these emissions will be reported under "sludge digestion" (cf. Chapter 8.2.2.2.5).

In recent years (1998 to 2001 and 1995 to 1997), reported emissions levels in Germany, 10 Gg and 9.7 Gg of methane, have remained fairly constant. Since procedures for determining methane emissions have been inadequately documented, the origins of these results cannot be clearly identified, however.

For this reason, methane emissions from wastewater treatment were recalculated, taking emissions from cesspools and septic tanks into account. It was found that emissions levels in this category continue to be similar to that found for the base year. Furthermore, emissions from cesspools and septic tanks, for 1998/1999, are similar in magnitude to estimated values to date. Since then, they have been lower than the values previously assumed. Because the existing emissions values have been inadequately documented, no further comparisons of the data are to be carried out.

#### *8.2.2.1.6 Planned improvements (6.B.2)*

Consideration is being given to carrying out a research project that would explore whether methane could indeed form in aerobic wastewater treatment, under certain conditions and in certain process steps.

### 8.2.2.2 Methane emissions from municipal wastewater treatment (6.B.2)

#### *8.2.2.2.1 Source category description (6.B.2)*

As a general rule, the treatment of sewage sludge comprises two treatment stages:

- Dehydration using
  - Mechanical techniques (chamber filter press, cyclone)
  - Evaporation in a sludge lagoon or drying beds
- Stabilisation
  - Aerobic stabilisation (open basin with oxygen introduction)
  - Stabilisation in the digestion tower (anaerobic)
  - Formerly: Open sludge digestion

With respect to population figures, mechanical *dehydration* before and after treatment in the digestion tower currently represents the main treatment method (exception: small sewage-treatment plants in rural areas). Moreover, sewage sludge is generally limed prior to subsequent use, which stabilises it still further.

*Sludge stabilisation* is carried out in order to prevent uncontrolled putrefaction. In facilities < 10,000 inhabitants, such stabilisation is usually carried out aerobically, with energy consumption, while for facilities > 30,000 inhabitants it it normally carried out anaerobically, with production of methane gas. The amount of methane gas produced depends especially on the composition of the sewage sludge, the temperature and the reaction conditions. Gas so produced is usually used for energy recovery in combined heat/power generating system (CHP). Where facilities are unable to use the methane gas cost-effectively in this manner, or when technical disruptions or overloads of attached CHPs occur, the methane gas may be flared off. In both treatment methods, no significant amounts of methane emissions are released into the environment.

In the early 1990s in eastern Germany, open sludge digestion was used for sludge stabilisation, a process that produced methane emissions. Open sludge digestion is now no longer used, however.

In Germany, sewage sludge from biological wastewater treatment is managed in the following three ways (where applicable, after dehydration and stabilisation):

- Landfill storage: resulting methane emissions are reported in the waste sector.
- Thermal disposal: no methane emissions occur.
- Recycling for substance recovery: The most important procedures for recycling sewage sludge for substance recovery include recycling in agriculture, pursuant to the Ordinance on Sewage Sludge, and use in recultivation measures and in composting. Emissions from recycling for substance recovery are also not reported under wastewater and sludge treatment.

#### *8.2.2.2.2 Methodological issues (6.B.2)*

Table 85 lists the emission factors for open sludge digestion and the methane emissions determined for that process.

Table 85: Methane emissions from open sludge digestion, in the new German Länder

| | **Units** | **1990** | **1991** | **1992** | **1993** | **1994** |
|---|---|---|---|---|---|---|
| Emission factor | kg $CH_4$/t TS | 210 | 210 | 210 | 210 | 210 |
| Sewage-sludge production | t TS | 247.190 | 140.952 | 72.762 | 37.524 | 0 |
| Methane emissions | t | 51.910 | 29.600 | 15.280 | 7.880 | 0 |

Emission factors derived from (FHG ISI, 1993)

An emission factor of 210 kg $CH_4$/t TS is used for open sludge digestion in eastern Germany, in keeping with the results of the study Fhg ISI (1993)[137]. The activity rates for the years 1990 to 1992 were communicated personally to the Federal Environmental Agency by the Chief Inspector of the former GDR's water-processing plants.

In light of the fact that open sludge digestion is prohibited in the Federal Republic of Germany, it was assumed that use of this treatment method was gradually reduced in the new German Länder until 1994 and was no longer used at all as of 1994. On the basis of this assumption, the Federal Environmental Agency used the same activity rates – i.e. quantities of sewage sludge produced – for the years 1992 to 1994.

#### *8.2.2.2.3 Uncertainties and time-series consistency (6.B.2)*

The uncertainties for calculation of emissions from open sludge digestion in eastern Germany have not been estimated to date.

The activity rates between 1990 and 1992 are based on a personal communication; those for 1993 and 1994, are based on estimates of the Federal Environmental Agency. As a result, a high degree of time-series consistency is not assured.

137 The emission factor was obtained via the relationship between methane emissions from psychrophilic sludge stabilisation in the new German Länder and the total amount of sewage sludge produced (p. 15; FHG-ISI, 1993)

#### *8.2.2.2.4 Source-specific quality assurance / control and verification (6.B.2)*

#### *8.2.2.2.5 Source-specific recalculations (6.B.2)*

Previous inventories reported methane emissions from sludge treatment, and from open sludge digestion, in the new German Länder under the category "treatment of industrial wastewater", and not under "sludge treatment". Table 86 provides an overview of the methane emissions to be reported under "sludge treatment"; in future, these emissions will be reported under this category in the CRF.

Table 86: Source-category-specific recalculations of methane emissions [Gg] in sludge treatment

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Methane emissions (as previously reported in the inventory) | | | | | | | | | | | | | |
| Industrial sludge treatment | IE | IE | IE | IE | IE | IE | IE | IE | NE | NE | NE | NE | NE |
| Treatment of household and commercial sludge | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| Methane emissions (new calculation) | | | | | | | | | | | | | |
| Industrial sludge treatment | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Treatment of household and commercial sludge | 51,9 | 29,6 | 15,3 | 7,9 | 0,0 | NO | NO | NO | NO | NO | NO | NO | NO |

#### *8.2.2.2.6 Planned improvements (6.B.2)*

At present, improvements seem neither necessary nor possible, since no further activity data can be obtained.

### 8.2.2.3 Nitrous oxide emissions from municipal wastewater (6.B.2)

#### *8.2.2.3.1 Source category description (6.B.2)*

Nitrous oxide (laughing-gas) emissions can occur as an auxiliary product of municipal wastewater treatment, especially in connection with denitrification, in which gaseous end products – but, mainly, molecular nitrogen – are formed from nitrate (AUST, o.J.).

#### *8.2.2.3.2 Methodological issues (6.B.2)*

Pursuant to the IPCC method, nitrous oxide emissions from household wastewater can be roughly determined via the average per-capita protein intake. The IPCC default values are used in each case for the nitrous-oxide emission factor per kg of nitrogen in wastewater, and for the nitrogen fraction in protein; the average per-capita protein intake and relevant population figures for Germany have to be determined on a Länder-specific basis.

Average protein intake per person and day:

- The 1991 food table for practical applications (SENSER et al, 1991) lists an average protein intake of 94 g/inhabitant and day.
- The nutrition report of the German Nutrition Association (Deutsche Gesellschaft für Ernährung - DGE, 2000)[138] used estimated food-consumption data for 1993 to

138 The nutrition report is published every four years.

estimate average daily protein intake (among other figures). From this data, an average value of about 76.5 g protein/person and day[139] was derived.

- The FAO determined the average protein intake in Germany, per person and day, to be between 91g and 98 g (cf Table 87).[140]

The FAO database is used for determination of the $N_2O$ emissions from wastewater, since that database is a consistent, internationally comparable time series. The Federal Environmental Agency has no information to the effect that the Länder-specific values in the food table and in the 2000 nutrition report are more precise or enjoy greater national acceptance.

Table 87: Daily protein intake per person in Germany

| | g/inhabitant and day | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1990** | **1991** | **1992** | **1993** | **1994** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **2001** | **2002** |
| Protein intake | 98 | 97 | 96 | 92 | 95 | 94 | 96 | 91 | 96 | 96 | 96 | 98 | 98 |

(FAO, o.J.)

Table 88: Population of Germany (1990-2002)

| | in thousands | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1990** | **1991** | **1992** | **1993** | **1994** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **2001** | **2002** |
| Inhabitants | 79.365 | 79.984 | 80.594 | 81.179 | 81.422 | 81.661 | 81.896 | 82.052 | 82.029 | 82.087 | 82.188 | 82.440 | 82.537 |

(DESTATIS, 2003)

The relevant nitrous oxide emissions can be determined with the data in Tables 87 and 88, via the IPCC method; cf. Table 89.

$N_2O_{(s)} = \mathrm{Pr}otein\ x\ Frac_{NPR} x\ NR_{PEOPLE} x\ EF_6$ with:

$N_2O_{(s)} = N_2O\ Emissions\ in\ human\ wastewater\ (kg\ N_2O - N/a)$

$\mathrm{Pr}otein = annual\ \ protein\ cons.\ (kg/person/a)$

$NR_{PEOPLE} = \ \ population\ of\ \ the\ country$

$EF_6 = emission\ \ factor\ (Default\ 0.01\ (0.002 - 0.12)\ kg\ N_2O - N/kg\ \ produced\ wastewater - N)$

$Frac_{NPR} = nitrogen\ \ fraction\ in\ \ protein\ (default = 0.16\ kg\ N/kg\ \ protein)$

Table 89: Nitrous oxide emissions in Germany, pursuant to the IPCC method, 1990-2002 (ÖKO-INSTITUT, 2004b)

| | in t $N_20$ | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $N_20$ emissions | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
| | 7.138 | 7.120 | 7.100 | 6.854 | 7.099 | 7.044 | 7.215 | 6.852 | 7.227 | 7.232 | 7.241 | 7.414 | 7.423 |

#### *8.2.2.3.3 Uncertainties and time-series consistency (6.B.2)*

The uncertainties in emissions determination have not yet been estimated.

139 This value was obtained with the help of the rough estimate that each population group in Germany consists of 50% men (81.5 g/day) and 50% women (71.6 g/day).

140 http://apps.fao.org/page/collections; e-mail correspondence with FAO (27 October 2003).

Calculations were based on the average daily protein requirements listed by the FAO database, to ensure that the time series is consistent and to prevent any need for extrapolation of individual values.

#### *8.2.2.3.4 Source-category-specific quality assurance / control and verification (6.B.2)*

Analysis of the national inventory reports of other countries shows that most Annex I countries, like Germany, use the IPCC method for determining $N_2O$ emissions. In addition, many countries use the FAO database; as a result, the emissions-determination process used by Germany is internationally comparable. An international comparison shows that the daily protein intake assumed for Germany lies within the middle of the overall range (cf. Table 106).

Plans within the framework of quality assurance call for checking the Länder-specific $N_2O$ emission factor used to date for wastewater treatment; this factor was determined in a national research project (Krauth et al, 1994) and in (UBA, 1993). The factor is 0.07 – 0.08 g $N_2O/m^3$ for wastewater treated in facilities with N elimination. While relevant research projects show that this factor applies to both municipal and industrial wastewater-treatment plants, it has not yet been scientifically confirmed.

#### *8.2.2.3.5 Source-specific recalculations (6.B.2)*

Between 1990 and 1996, $N_2O$ emissions were determined on the basis of a Länder-specific $N_2O$ emission factor and of activity rates of the Federal Statistical Office (Fachserie 19 Reihe 2.1) for the old German Länder. Inventories as of 1997 used estimated values for $N_2O$ emissions, due to a lack of relevant data in the new German Länder.

Consideration was giving to using a different calculation method – the IPCC method – since the Länder-specific $N_2O$ emission factor was not considered adequately confirmed for the old German Länder and since only rough estimates were being used for the new German Länder. The IPCC method tends to estimate emissions conservatively, since the method yields considerably higher emissions levels than those produced with the Länder-specific value used to date. Furthermore, in future $N_2O$ emissions will be reported under the category of household and commercial wastewater, since that is the category in which they actually occur.

Table 90: Source-category-specific recalculations of $N_2O$ emissions [Gg]

| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nitrous oxide emissions (in CRF to date) | | | | | | | | | | | | | |
| Industrial wastewater | 4,16 | 0,69 | 0,2 | 0,22 | 0,24 | 0,25 | 0,26 | 0,3 | 0,3 | 0,3 | 0,3 | 0,3 | 0,3 |
| Household and commercial wastewater | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE | IE |
| Nitrous oxide emissions (new calculation) | | | | | | | | | | | | | |
| Industrial wastewater | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| Treatment of household and commercial sludge | 7,14 | 7,12 | 7,1 | 6,85 | 7,1 | 7,04 | 7,22 | 6,85 | 7,26 | 7,23 | 7,24 | 7,41 | 7,42 |

#### *8.2.2.3.6 Planned improvements (6.B.2)*

Review is currently underway to determine whether the FAO database (FAO, o.J.) for daily protein intake should be replaced with data from the nutrition report (DGE, 2000), since the latter is based on studies of eating habits and thus probably reflects actual protein intake more precisely.

In addition, as described under 8.2.2.3.4, the $N_2O$ emission factor used to date, 0.07 – 0.08 g $N_2O/m^3$ of wastewater, is to be reviewed. If this emission factor can be confirmed – i.e. if it proves to be accurate for Germany – it will again be used in future.

# 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

Recalculations in accordance with the IPCC *Good Practice Guidance* have not been documented to date. The changes in methods begun in 2003, which will lead to significant changes in the inventories, have not yet been completed; as a result, only some recalculations for periods prior to 2004 are documented on a source-category-specific basis. Methodological conversions for implementing the *Good Practice Guidance* (GPG) in the inventories are taking more time than was originally expected – in part, because at the same time the relevant inventory-preparation processes are being critically reviewed and any changes always also take QC/QA requirements into account. For this reason, it continues to be the case that no sharp distinctions are made between methods descriptions and 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 procedures.

Only the 2004 inventory will provide the basis for systematic documentation of recalculations. This process will also be assisted by the CSE. As the calculation procedures are stored in the CSE, and the reported data stocks are "frozen" for archiving, old and new calculations can be compared with one another.

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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*"[141] (*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 evaluated uniformly at international level via application of the prescribed calculation methods (comparability), contain all the relevant emission sources and sinks in the reporting country (completeness), and be evaluated with error specification and be subject to permanent internal and external quality management (accuracy).

In order to be able to concentrate the many and detailed activities and capacities required for this purpose on the principal source categories of the inventory, the IPCC has introduced the definition of a "key source". This refers to those source categories which are highlighted in the national inventory system because their 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, in chapter 7, the methods to be applied for determining key sources. These methods make it possible, via inventory analysis for one year (Tier 1 Level Assessment), time-series analysis of inventory data (Tier 1 Trend Assessment) and detailed analysis of inventory data with error evaluation (Tier 2 Trend Assessment with consideration of inaccuracies), to identify the respective key sources.

For the identified key sources, the Parties are then required to use very detailed calculation methods, which are likewise prescribed in the Good Practice Guidance. Should this prove impossible for a variety of reasons (e.g. data availability for the required input variables, etc.), Parties are required to prove that the methods applied nationally at least achieve a comparable degree of accuracy in the calculation result. These records, as well as the key source analysis performed overall, must be outlined in the national inventory report to be prepared annually.

### 12.1 Description of the method for determining key sources

The results of the key source analysis based on the two Tier 1 techniques (Level and Trend) are outlined below. We also refer the reader to the description of the underlying methods in the *Good Practice Guidance*. In a departure from that source's proposal for organisation of the source categories to be included, a greater degree of detail was chosen for the present analysis. Annual emissions inventories were divided, in keeping with their $CO_2$-equivalent emissions, into a total of 174 individual activities.

141 This Report was produced as a response to a suggestion by the UN Framework Convention on Climate Change to the Intergovernmental Panel on Climate Change (IPCC). The work to determine uncertainties in inventories was to be completed, and a report submitted on "good practice" in inventory management.
Work was carried out with the aim of supporting governments in the preparation of their emissions inventories. The aim was to avoid over-valuation or under-valuation of the results and to reduce the inaccuracies of the inventories as far as possible.
This report is published on the Internet at : http://www.ipcc-nggip.iges.or.jp/public/gp/gpgaum.htm

### *12.1.1 Tier 1 Level Approach*

As a result of this approach, those source categories responsible for 95 % of total national emissions (als $CO_2$-equivalent emissions), in 1990 and 2002, 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 32 key sources are identified in 2002 using this approach (cf. Table 91).

Table 91: Key source categories for Germany (1990-2002) based on the Tier 1 Level Approach

| IPCC source category | Activity | Emissions of | 2002 in $CO_2$ equ. | Level assess-ment | Cumulative total | Key Source |
|---|---|---|---|---|---|---|
| 1A1a Public electricity and heat production | Solid fuels | $CO_2$ | 286.022,810 | 27,75 | 27,8 | ● |
| 1A3b. Transport, road transportation | Gasoline | $CO_2$ | 84.024,000 | 8,15 | 35,9 | ● |
| 1A3b. Transport, road transportation | Diesel oil | $CO_2$ | 81.927,100 | 7,95 | 43,9 | ● |
| 1A2a-f. Manufacturing industries and construction total | Solid fuels | $CO_2$ | 61.547,220 | 5,97 | 49,8 | ● |
| 1A4b. Other sectors residential | Liquid fuels | $CO_2$ | 59.475,768 | 5,77 | 55,6 | ● |
| 1A4b. Other sectors residential | Gaseous fuels | $CO_2$ | 57.624,000 | 5,59 | 61,2 | ● |
| 1A2a-f. Manufacturing industries and construction total | Gaseous fuels | $CO_2$ | 49.594,679 | 4,81 | 66,0 | ● |
| 1A1a Public electricity and heat production | Gaseous fuels | $CO_2$ | 26.008,603 | 2,52 | 68,5 | ● |
| 1A4a. Other sectors, commercial/institutional | Gaseous fuels | $CO_2$ | 25.988,591 | 2,52 | 71,0 | ● |
| 1A2a-f. Manufacturing industries and construction total | Liquid fuels | $CO_2$ | 20.506,201 | 1,99 | 73,0 | ● |
| 1A4a. Other sectors, commercial/institutional | Liquid fuels | $CO_2$ | 20.248,830 | 1,96 | 75,0 | ● |
| 4A.1. Enteric fermentation | Non-dairy cattle | $CH_4$ | 20.011,612 | 1,94 | 76,9 | ● |
| 1A1b. Petroleum refining | Liquid fuels | $CO_2$ | 18.509,179 | 1,80 | 78,7 | ● |
| 1A1c. Manufacture of solid fuels, and other energy industries | Solid fuels | $CO_2$ | 18.462,616 | 1,79 | 80,5 | ● |

| IPCC source category | Activity | Emissions of | 2002 in $CO_2$ equ. | Level assess-ment | Cumulative total | Key Source |
|---|---|---|---|---|---|---|
| 4D1. Agricultural soils | Direct soil emissions | $N_2O$ | 18.293,100 | 1,77 | 82,3 | ● |
| 4B1. Manure management | Dairy cattle | $CH_4$ | 12.856,979 | 1,25 | 83,5 | ● |
| 4A.1. Enteric fermentation | Dairy cattle | $CH_4$ | 12.581,482 | 1,22 | 84,8 | ● |
| 2A1. Mineral products, cement production | | $CO_2$ | 12.352,180 | 1,20 | 86,0 | ● |
| 4B8. Manure management | Swine | $CH_4$ | 12.262,169 | 1,19 | 87,2 | ● |
| 6A1 Managed waste disposal on land | Solid waste disposal on land | $CH_4$ | 11.921,594 | 1,16 | 88,3 | ● |
| 4D3. Agricultural soils | Indirect emissions | $N_2O$ | 11.284,000 | 1,09 | 89,4 | ● |
| 4B1. Manure management | Non-dairy cattle | $CH_4$ | 8.364,574 | 0,81 | 90,2 | ● |
| 1B2b. Fugitive emissions from fuels, natural gas | Natural gas | $CH_4$ | 7.216,411 | 0,70 | 90,9 | ● |
| 2F. Industrial processes | Consumption of halocarbons and $SF_6$ | HFCs | 7.035,400 | 0,68 | 91,6 | ● |
| 1A4c. Other sectors Agriculture/forestry/fisheries | Liquid fuels | $CO_2$ | 5.859,175 | 0,57 | 92,2 | ● |
| 2A2. Mineral products, lime production | | $CO_2$ | 5.551,040 | 0,54 | 92,7 | ● |
| 1B1a. Fugitive emissions from fuels and from coal mining and handling | Solid fuels | $CH_4$ | 5.433,456 | 0,53 | 93,2 | ● |
| 1A1a Public electricity and heat production | Liquid fuels | $CO_2$ | 4.355,777 | 0,42 | 93,7 | ● |
| 1A3a. Transport civil aviation | Aviation gasoline | $CO_2$ | 4.247,600 | 0,41 | 94,1 | ● |
| 2B2 Chemical industry | Nitric acid production | $N_2O$ | 4.007,215 | 0,39 | 94,5 | ● |
| 2F. Industrial processes | Consumption of halocarbons and $SF_6$ | $SF_6$ | 3.728,400 | 0,36 | 94,8 | ● |
| 1A3b. Transport, road transportation | Gasoline | $N_2O$ | 3.399,359 | 0,33 | 95,2 | ● |
| 1A1a Public electricity and heat production | Solid fuels | $N_2O$ | 3.386,149 | 0,33 | 95,5 | |
| 2B3 Chemical industry | Adipic acid production | $N_2O$ | 3.073,726 | 0,30 | 95,8 | |
| 1A4b. Other sectors residential | Solid fuels | $CO_2$ | 2.990,034 | 0,29 | 96,1 | |
| 1A3e. Transport, other transportation | Liquid fuels | $CO_2$ | 2.981,332 | 0,29 | 96,4 | |
| 6B1. Wastewater handling | Industrial wastewater | $N_2O$ | 2.300,200 | 0,22 | 96,6 | |
| 4D2. Agricultural soils | Animal production | $N_2O$ | 2.046,000 | 0,20 | 96,8 | |
| Total solvent and other product use | | $N_2O$ | 1.922,000 | 0,19 | 97,0 | |
| 2B1. Chemical industry | Ammonia production | $CO_2$ | 1.830,570 | 0,18 | 97,1 | |
| 1B1c. Fugitive emissions from fuels, other (abandoned mines) | Solid fuels | $CH_4$ | 1.827,000 | 0,18 | 97,3 | |
| 4B13. Manure management, other | Dairy cows | $N_2O$ | 1.626,268 | 0,16 | 97,5 | |
| 1A3c. Transport railways | Liquid fuels | $CO_2$ | 1.621,340 | 0,16 | 97,6 | |
| 2A7. Glass production | | $CO_2$ | 1.500,000 | 0,15 | 97,8 | |
| 1A1c. Manufacture of solid fuels, and other energy industries | Gaseous fuels | $CO_2$ | 1.378,534 | 0,13 | 97,9 | |
| 4B13. Manure management, other | Other cattle | $N_2O$ | 1.335,395 | 0,13 | 98,0 | |

| IPCC source category | Activity | Emissions of | 2002 in $CO_2$ equ. | Level assess-ment | Cumulative total | Key Source |
|---|---|---|---|---|---|---|
| 1A5 Other, including military fuel use under this category | Liquid fuels | $CO_2$ | 1.302,481 | 0,13 | 98,2 | |
| 2CE. Production of halocarbons and $SF_6$ | Production of HCFC-22 | HFCs | 1.211,750 | 0,12 | 98,3 | |
| 1A4a. Other sectors, commercial/institutional | Solid fuels | $CO_2$ | 1.191,809 | 0,12 | 98,4 | |
| 1A3b. Transport, road transportation | Diesel oil | $N_2O$ | 1.058,863 | 0,10 | 98,5 | |
| 1A2a-f. Manufacturing industries and construction total | Solid fuels | $N_2O$ | 1.017,356 | 0,10 | 98,6 | |
| 4A0.8. Enteric fermentation | Swine | $CH_4$ | 970,793 | 0,09 | 98,7 | |
| 2C3. Aluminium production | | $CO_2$ | 892,651 | 0,09 | 98,8 | |
| 1A4c. Other sectors Agriculture/forestry/fisheries | Gaseous fuels | $CO_2$ | 809,296 | 0,08 | 98,9 | |
| 4B13. Manure management, other | Swine | $N_2O$ | 784,829 | 0,08 | 98,9 | |
| 1A3e. Transport, other transportation | Gaseous fuels | $CO_2$ | 743,907 | 0,07 | 99,0 | |
| 1A3d. Transport navigation | Diesel oil | $CO_2$ | 737,558 | 0,07 | 99,1 | |
| 1A1b. Petroleum refining | Gaseous fuels | $CO_2$ | 692,198 | 0,07 | 99,2 | |
| 1A1a Public electricity and heat production | Other fuels | $CO_2$ | 673,073 | 0,07 | 99,2 | |
| 1A5 Other, including military fuel use under this category | Gaseous fuels | $CO_2$ | 586,113 | 0,06 | 99,3 | |
| 2A4. Soda ash | | $CO_2$ | 557,828 | 0,05 | 99,3 | |
| 4A0.3. Enteric fermentation | Sheep | $CH_4$ | 544,233 | 0,05 | 99,4 | |
| 1A1b. Petroleum refining | Solid fuels | $CO_2$ | 473,477 | 0,05 | 99,4 | |
| 4B13. Manure management, other | Poultry | $N_2O$ | 462,912 | 0,04 | 99,5 | |
| 1A4b. Other sectors residential | Biomass | $CH_4$ | 448,486 | 0,04 | 99,5 | |
| 2C3. Aluminium production | | PFCs | 431,010 | 0,04 | 99,6 | |
| 1A2a-f. Manufacturing industries and construction total | Other fuels | $CO_2$ | 384,574 | 0,04 | 99,6 | |
| 2F. Industrial processes | Consumption of halocarbons and $SF_6$ | PFCs | 355,000 | 0,03 | 99,6 | |
| 4B13. Manure management, other | Horses | $N_2O$ | 250,109 | 0,02 | 99,7 | |
| 1A1c. Manufacture of solid fuels, and other energy industries | Solid fuels | $N_2O$ | 241,130 | 0,02 | 99,7 | |
| 1A2a-f. Manufacturing industries and construction total | Gaseous fuels | $N_2O$ | 240,721 | 0,02 | 99,7 | |
| 1A3b. Transport, road transportation | Gasoline | $CH_4$ | 236,951 | 0,02 | 99,7 | |
| 1A1c. Manufacture of solid fuels, and other energy industries | Liquid fuels | $CO_2$ | 207,422 | 0,02 | 99,7 | |
| 4B9. Manure management | Poultry | $CH_4$ | 186,533 | 0,02 | 99,8 | |
| 4A0.6. Enteric fermentation | Horses | $CH_4$ | 185,581 | 0,02 | 99,8 | |
| 2C4. $SF_6$ used in aluminium and magnesium foundries | | $SF_6$ | 167,300 | 0,02 | 99,8 | |
| 1A4b. Other sectors residential | Liquid fuels | $N_2O$ | 152,031 | 0,01 | 99,8 | |
| 6B1. Wastewater handling | Industrial wastewater | $CH_4$ | 132,930 | 0,01 | 99,8 | |

| IPCC source category | Activity | Emissions of | 2002 in $CO_2$ equ. | Level assess-ment | Cumulative total | Key Source |
|---|---|---|---|---|---|---|
| 1A2a-f. Manufacturing industries and construction total | Liquid fuels | $N_2O$ | 107,943 | 0,01 | 99,8 | |
| 1A1a Public electricity and heat production | Gaseous fuels | $N_2O$ | 101,086 | 0,01 | 99,8 | |
| 1A4b. Other sectors residential | Gaseous fuels | $N_2O$ | 98,887 | 0,01 | 99,9 | |
| 1A1a Public electricity and heat production | Solid fuels | $CH_4$ | 85,927 | 0,01 | 99,9 | |
| 1B2a. Fugitive emissions from fuels, oil | Oil | $CH_4$ | 85,590 | 0,01 | 99,9 | |
| 1A4b. Other sectors residential | Biomass | $N_2O$ | 85,527 | 0,01 | 99,9 | |
| 1A4b. Other sectors residential | Solid fuels | $CH_4$ | 77,179 | 0,01 | 99,9 | |
| 1A4c. Other sectors Agriculture/forestry/fisheries | Solid fuels | $CO_2$ | 74,134 | 0,01 | 99,9 | |
| 1A2a-f. Manufacturing industries and construction total | Solid fuels | $CH_4$ | 66,131 | 0,01 | 99,9 | |
| 1A4c. Other sectors Agriculture/forestry/fisheries | Liquid fuels | $N_2O$ | 63,182 | 0,01 | 99,9 | |
| 1A5 Other, including military fuel use under this category | Solid fuels | $CO_2$ | 58,734 | 0,01 | 99,9 | |
| 1A1b. Petroleum refining | Liquid fuels | $N_2O$ | 58,723 | 0,01 | 99,9 | |
| 1A3c. Transport railways | Solid fuels | $CO_2$ | 53,838 | 0,01 | 99,9 | |
| 1A4a. Other sectors, commercial/institutional | Gaseous fuels | $N_2O$ | 49,726 | 0,00 | 99,9 | |
| 1A4b. Other sectors residential | Solid fuels | $N_2O$ | 48,564 | 0,00 | 99,9 | |
| 1A4a. Other sectors, commercial/institutional | Liquid fuels | $N_2O$ | 47,106 | 0,00 | 99,9 | |
| 1A3b. Transport, road transportation | Petroleum | $CO_2$ | 44,400 | 0,00 | 99,9 | |
| 1A3e. Transport, other transportation | Liquid fuels | $N_2O$ | 42,814 | 0,00 | 99,9 | |
| 1A1a Public electricity and heat production | Other fuels | $N_2O$ | 41,730 | 0,00 | 99,9 | |
| 1A4a. Other sectors, commercial/institutional | Biomass | $CH_4$ | 39,693 | 0,00 | 100,0 | |
| 1A2a-f. Manufacturing industries and construction total | Gaseous fuels | $CH_4$ | 37,242 | 0,00 | 100,0 | |
| 1A3b. Transport, road transportation | Diesel oil | $CH_4$ | 31,593 | 0,00 | 100,0 | |
| 4B6. Manure management | Horses | $CH_4$ | 28,050 | 0,00 | 100,0 | |
| 1A3a. Transport civil aviation | Aviation gasoline | $N_2O$ | 26,691 | 0,00 | 100,0 | |
| 1A4b. Other sectors residential | Gaseous fuels | $CH_4$ | 23,770 | 0,00 | 100,0 | |
| 1A4a. Other sectors, commercial/institutional | Solid fuels | $CH_4$ | 23,213 | 0,00 | 100,0 | |
| 1A3c. Transport railways | Liquid fuels | $N_2O$ | 23,093 | 0,00 | 100,0 | |
| 1B1b. Fugitive emissions from fuels, solid fuel transformation | Solid fuels | $CH_4$ | 22,762 | 0,00 | 100,0 | |
| 1A1a Public electricity and heat production | Liquid fuels | $N_2O$ | 19,813 | 0,00 | 100,0 | |
| 1A2a-f. Manufacturing industries and construction total | Other fuels | $N_2O$ | 17,883 | 0,00 | 100,0 | |

| IPCC source category | Activity | Emissions of | 2002 in $CO_2$ equ. | Level assess-ment | Cumulative total | Key Source |
|---|---|---|---|---|---|---|
| 1A4c. Other sectors Agriculture/forestry/fisheries | Biomass | $CH_4$ | 17,458 | 0,00 | 100,0 | |
| 2B4. Chemical industry | Carbide production | $CO_2$ | 15,042 | 0,00 | 100,0 | |
| 4B13. Manure management, other | Sheep | $N_2O$ | 15,021 | 0,00 | 100,0 | |
| 1A2a-f. Manufacturing industries and construction total | Liquid fuels | $CH_4$ | 14,387 | 0,00 | 100,0 | |
| 1A5 Other, including military fuel use under this category | Liquid fuels | $N_2O$ | 13,472 | 0,00 | 100,0 | |
| 4B3. Manure management | Sheep | $CH_4$ | 12,609 | 0,00 | 100,0 | |
| 1A3d. Transport navigation | Diesel oil | $N_2O$ | 10,505 | 0,00 | 100,0 | |
| 1A4c. Other sectors Agriculture/forestry/fisheries | Liquid fuels | $CH_4$ | 9,627 | 0,00 | 100,0 | |
| 1A4a. Other sectors, commercial/institutional | Solid fuels | $N_2O$ | 8,095 | 0,00 | 100,0 | |
| 1A1a Public electricity and heat production | Gaseous fuels | $CH_4$ | 7,765 | 0,00 | 100,0 | |
| 1A1b. Petroleum refining | Liquid fuels | $CH_4$ | 7,688 | 0,00 | 100,0 | |
| 1A3e. Transport, other transportation | Liquid fuels | $CH_4$ | 6,963 | 0,00 | 100,0 | |
| 1A1c. Manufacture of solid fuels, and other energy industries | Solid fuels | $CH_4$ | 6,517 | 0,00 | 100,0 | |
| 1A3b. Transport, road transportation | Liquid gas | $CO_2$ | 6,500 | 0,00 | 100,0 | |
| 1A1c. Manufacture of solid fuels, and other energy industries | Gaseous fuels | $N_2O$ | 6,461 | 0,00 | 100,0 | |
| 1A4a. Other sectors, commercial/institutional | Biomass | $N_2O$ | 6,455 | 0,00 | 100,0 | |
| 1A5 Other, including military fuel use under this category | Liquid fuels | $CH_4$ | 6,387 | 0,00 | 100,0 | |
| 1A3e. Transport, other transportation | Gaseous fuels | $N_2O$ | 4,942 | 0,00 | 100,0 | |
| 1A1b. Petroleum refining | Solid fuels | $N_2O$ | 4,930 | 0,00 | 100,0 | |
| 1A1c. Manufacture of solid fuels, and other energy industries | Other fuels | $CO_2$ | 4,557 | 0,00 | 100,0 | |
| 1A1b. Petroleum refining | Gaseous fuels | $N_2O$ | 3,948 | 0,00 | 100,0 | |
| 1A1a Public electricity and heat production | Liquid fuels | $CH_4$ | 3,914 | 0,00 | 100,0 | |
| 1A4b. Other sectors residential | Liquid fuels | $CH_4$ | 3,581 | 0,00 | 100,0 | |
| 1A4c. Other sectors Agriculture/forestry/fisheries | Biomass | $N_2O$ | 2,926 | 0,00 | 100,0 | |
| 1A3c. Transport railways | Liquid fuels | $CH_4$ | 2,301 | 0,00 | 100,0 | |
| 2C1. Metal production, iron and steel production | Other | $CH_4$ | 2,048 | 0,00 | 100,0 | |
| 1A1a Public electricity and heat production | Other fuels | $CH_4$ | 1,696 | 0,00 | 100,0 | |
| 1A1a Public electricity and heat production | Biomass | $N_2O$ | 1,635 | 0,00 | 100,0 | |
| 1A1c. Manufacture of solid fuels, and other energy industries | Biomass | $N_2O$ | 1,634 | 0,00 | 100,0 | |
| 1A4c. Other sectors Agriculture/forestry/fisheries | Gaseous fuels | $N_2O$ | 1,548 | 0,00 | 100,0 | |

| IPCC source category | Activity | Emissions of | 2002 in $CO_2$ equ. | Level assess-ment | Cumulative total | Key Source |
|---|---|---|---|---|---|---|
| 1A1c. Manufacture of solid fuels, and other energy industries | Liquid fuels | $N_2O$ | 1,212 | 0,00 | 100,0 | |
| 1A3a. Transport civil aviation | Aviation gasoline | $CH_4$ | 1,205 | 0,00 | 100,0 | |
| 1A4a. Other sectors, commercial/institutional | Gaseous fuels | $CH_4$ | 1,146 | 0,00 | 100,0 | |
| 1A1c. Manufacture of solid fuels, and other energy industries | Gaseous fuels | $CH_4$ | 1,138 | 0,00 | 100,0 | |
| 1A4c. Other sectors Agriculture/forestry/fisheries | Solid fuels | $N_2O$ | 1,127 | 0,00 | 100,0 | |
| 1A5 Other, including military fuel use under this category | Gaseous fuels | $N_2O$ | 0,941 | 0,00 | 100,0 | |
| 1A5 Other, including military fuel use under this category | Solid fuels | $N_2O$ | 0,813 | 0,00 | 100,0 | |
| 1A2a-f. Manufacturing industries and construction total | Other fuels | $CH_4$ | 0,686 | 0,00 | 100,0 | |
| 1A3d. Transport navigation | Diesel oil | $CH_4$ | 0,628 | 0,00 | 100,0 | |
| 1A3b. Transport, road transportation | Petroleum | $N_2O$ | 0,621 | 0,00 | 100,0 | |
| 1A3c. Transport railways | Solid fuels | $N_2O$ | 0,586 | 0,00 | 100,0 | |
| 1A3e. Transport, other transportation | Gaseous fuels | $CH_4$ | 0,558 | 0,00 | 100,0 | |
| 1A1b. Petroleum refining | Gaseous fuels | $CH_4$ | 0,338 | 0,00 | 100,0 | |
| 1A5 Other, including military fuel use under this category | Solid fuels | $CH_4$ | 0,309 | 0,00 | 100,0 | |
| 1A1c. Manufacture of solid fuels, and other energy industries | Biomass | $CH_4$ | 0,307 | 0,00 | 100,0 | |
| 1A4c. Other sectors Agriculture/forestry/fisheries | Solid fuels | $CH_4$ | 0,260 | 0,00 | 100,0 | |
| 1A1c. Manufacture of solid fuels, and other energy industries | Other fuels | $N_2O$ | 0,212 | 0,00 | 100,0 | |
| 1A1c. Manufacture of solid fuels, and other energy industries | Liquid fuels | $CH_4$ | 0,182 | 0,00 | 100,0 | |
| 1A3c. Transport railways | Solid fuels | $CH_4$ | 0,170 | 0,00 | 100,0 | |
| 1A4a. Other sectors, commercial/institutional | Liquid fuels | $CH_4$ | 0,135 | 0,00 | 100,0 | |
| 1A1b. Petroleum refining | Solid fuels | $CH_4$ | 0,130 | 0,00 | 100,0 | |
| 1A3b. Transport, road transportation | Liquid gas | $N_2O$ | 0,053 | 0,00 | 100,0 | |
| 1A4c. Other sectors Agriculture/forestry/fisheries | Gaseous fuels | $CH_4$ | 0,036 | 0,00 | 100,0 | |
| 1A1a Public electricity and heat production | Biomass | $CH_4$ | 0,028 | 0,00 | 100,0 | |
| 1A3b. Transport, road transportation | Petroleum | $CH_4$ | 0,024 | 0,00 | 100,0 | |
| 1A1c. Manufacture of solid fuels, and other energy industries | Other fuels | $CH_4$ | 0,009 | 0,00 | 100,0 | |
| 1A3b. Transport, road transportation | Liquid gas | $CH_4$ | 0,006 | 0,00 | 100,0 | |
| 1A5 Other, including military fuel use under this category | Gaseous fuels | $CH_4$ | 0,004 | 0,00 | 100,0 | |
| 1A1a Public electricity and heat production | Biomass | $CO_2$ | 0,000 | 0,00 | 100,0 | |

| IPCC source category | Activity | Emissions of | 2002 in $CO_2$ equ. | Level assess-ment | Cumulative total | Key Source |
|---|---|---|---|---|---|---|
| 1A2a-f. Manufacturing industries and construction total | Biomass | $CH_4$ | | 0,00 | 100,0 | |
| 1A2a-f. Manufacturing industries and construction total | Biomass | $N_2O$ | | 0,00 | 100,0 | |
| 1A3b. Transport, road transportation | Biomass | $CH_4$ | 0,000 | 0,00 | 100,0 | |
| 1A3b. Transport, road transportation | Biomass | $N_2O$ | 0,000 | 0,00 | 100,0 | |
| 1B2d. Fugitive emissions from fuels, other | Oil and gas | $CH_4$ | | 0,00 | 100,0 | |
| 2CE. Production of halocarbons and $SF_6$ | Fugitive emissions | $SF_6$ | 0,000 | 0,00 | 100,0 | |
| 2CE. Production of halocarbons and $SF_6$ | | PFCs | | 0,00 | 100,0 | |

### *12.1.2 Tier 1 Trend Approach*

As a result of this analysis, those source categories which have made a particular contribution to changes in total greenhouse gas emissions in 2002, in terms of the development of their contribution since 1990, are identified as key source categories (•). In this respect, it is irrelevant whether such changes have led to a reduction or an increase in total emissions. Calculations were performed using formula 7.2 from the Good Practice Guidance.

For the source category summary used in this analysis, a total of 32 key sources are identified using this approach (cf. Table 92).

Table 92: Key source categories for Germany (1990-2002) based on the Tier 1 Trend Approach

| IPCC source category | Activity | Emissions of | 1990 in $CO_2$ equ. | 2002 in $CO_2$ equ. | 1990-2002 $CO_2$ equ. | Trend assess-ment | Cumulative total | Key Source |
|---|---|---|---|---|---|---|---|---|
| 1A3b. Transport, road transportation | Diesel oil | $CO_2$ | 54.458,080 | 81.927,100 | 0,044478 | 9,91621819 | 9,9 | • |
| 1A2a-f. Manufacturing industries and construction total | Solid fuels | $CO_2$ | 120.249,786 | 61.547,220 | 0,044170 | 9,84742667 | 19,8 | • |
| 1A1a Public electricity and heat production | Solid fuels | $CO_2$ | 306.429,717 | 286.022,810 | 0,041548 | 9,26291886 | 29,0 | • |
| 1A4b. Other sectors residential | Gaseous fuels | $CO_2$ | 31.691,782 | 57.624,000 | 0,037749 | 8,41608427 | 37,4 | • |
| 1A4b. Other sectors residential | Solid fuels | $CO_2$ | 41.425,080 | 2.990,034 | 0,036942 | 8,23604594 | 45,7 | • |
| 1A1c. Manufacture of solid fuels, and other energy industries | Solid fuels | $CO_2$ | 56.384,031 | 18.462,616 | 0,033113 | 7,38231255 | 53,1 | • |
| 1A4a. Other sectors, commercial/institutional | Solid fuels | $CO_2$ | 20.901,797 | 1.191,809 | 0,019018 | 4,23992333 | 57,3 | • |
| 1A4a. Other sectors, commercial/institutional | Gaseous fuels | $CO_2$ | 13.633,411 | 25.988,591 | 0,017670 | 3,93949683 | 61,2 | • |
| 1B1a. Fugitive emissions from fuels and from coal mining and handling | Solid fuels | $CH_4$ | 23.817,421 | 5.433,456 | 0,016809 | 3,74748701 | 65,0 | • |
| 6A1 Managed waste disposal on land | Solid waste disposal on land | $CH_4$ | 31.478,863 | 11.921,594 | 0,016561 | 3,69224323 | 68,7 | • |
| 1A4b. Other sectors residential | Liquid fuels | $CO_2$ | 56.162,511 | 59.475,768 | 0,016029 | 3,57360187 | 72,3 | • |
| 2B3 Chemical industry | Adipic acid production | $N_2O$ | 18.804,600 | 3.073,726 | 0,014722 | 3,28220063 | 75,5 | • |

| IPCC source category | **Activity** | Emissions of | **1990** in $CO_2$ equ. | 2002 in $CO_2$ equ. | 1990-2002 $CO_2$ equ. | Trend assess-ment | Cumulative total | Key Source |
|---|---|---|---|---|---|---|---|---|
| 1A2a-f. Manufacturing industries and construction total | Gaseous fuels | $CO_2$ | 45.750,962 | 49.594,679 | 0,014423 | 3,21555085 | 78,8 | • |
| 1A1a Public electricity and heat production | Gaseous fuels | $CO_2$ | 18.463,251 | 26.008,603 | 0,012971 | 2,89184517 | 81,6 | • |
| 2F. Industrial processes | Consumption of halocarbons and $SF_6$ | HFCs | | 7.035,400 | 0,008393 | 1,87109416 | 83,5 | • |
| 1A3b. Transport, road transportation | Gasoline | $CO_2$ | 95.794,488 | 84.024,000 | 0,006558 | 1,46197100 | 85,0 | • |
| 1A1b. Petroleum refining | Liquid fuels | $CO_2$ | 16.008,949 | 18.509,179 | 0,006425 | 1,43241467 | 86,4 | • |
| 1A5 Other, including military fuel use under this category | Liquid fuels | $CO_2$ | 6.659,145 | 1.302,481 | 0,004958 | 1,10538815 | 87,5 | • |
| 1A4c. Other sectors Agriculture/forestry/fisheries | Solid fuels | $CO_2$ | 4.750,908 | 74,134 | 0,004557 | 1,01604954 | 88,5 | • |
| 1A5 Other, including military fuel use under this category | Solid fuels | $CO_2$ | 4.657,327 | 58,734 | 0,004484 | 0,99974316 | 89,5 | • |
| 1A2a-f. Manufacturing industries and construction total | Liquid fuels | $CO_2$ | 28.391,517 | 20.506,201 | 0,003301 | 0,73604523 | 90,3 | • |
| 1A1a Public electricity and heat production | Liquid fuels | $CO_2$ | 8.474,772 | 4.355,777 | 0,003091 | 0,68918386 | 91,0 | • |
| 1A4a. Other sectors, commercial/institutional | Liquid fuels | $CO_2$ | 27.280,448 | 20.248,830 | 0,002522 | 0,56226547 | 91,5 | • |
| 1A3a. Transport civil aviation | Aviation gasoline | $CO_2$ | 2.897,396 | 4.247,600 | 0,002234 | 0,49799340 | 92,0 | • |
| 6B1. Wastewater handling | Industrial wastewater | $CH_4$ | 2.226,210 | 132,930 | 0,002018 | 0,44999223 | 92,5 | • |
| 2CE. Production of halocarbons and $SF_6$ | Production of HCFC-22 | HFCs | 3.510,000 | 1.211,750 | 0,001987 | 0,44296005 | 92,9 | • |
| 2C3. Aluminium production | | PFCs | 2.486,000 | 431,010 | 0,001917 | 0,42735453 | 93,3 | • |
| 1A3b. Transport, road transportation | Gasoline | $N_2O$ | 2.227,031 | 3.399,359 | 0,001877 | 0,41854912 | 93,8 | • |
| 1A1b. Petroleum refining | Solid fuels | $CO_2$ | 2.381,264 | 473,477 | 0,001764 | 0,39322619 | 94,1 | • |
| 1A4b. Other sectors residential | Solid fuels | $CH_4$ | 1.809,335 | 77,179 | 0,001677 | 0,37393488 | 94,5 | • |
| 4A.1. Enteric fermentation | Non-dairy cattle | $CH_4$ | 20.011,612 | 17.664,908 | 0,001504 | 0,33523951 | 94,9 | • |
| 1A2a-f. Manufacturing industries and construction total | Other fuels | $CO_2$ | 1.922,710 | 384,574 | 0,001421 | 0,31689920 | 95,2 | • |

### *12.1.3 Evaluation*

The results presented are based on a highly detailed analysis carried out in conformance with regulations. A total of 44 key sources were identifed for the year 2002 (total for both TIER 1 procedures). These sources cause total $CO_2$-equivalent emissions of 977,605 Gg, which corresponds to a share of 96.3 % of the total emissions for 2002. These source categories are treated as key sources for all greenhouse gases, regardless of which of their components are the determining factors for their classification as key sources.

The result is summarised in Table 93 below.

Table 93: Key source categories for Germany (1990-2002) based on the Tier 1 Level and Trend Approach

| **IPCC SOURCE CATEGORIES** | ACTIVITY | **EMIS-SIONS OF** | **EMISSIONS Gg $CO_2$ EE** | **LEVEL 1990** | **LEVEL 2002** | **TREND 2002** |
|---|---|---|---|---|---|---|
| 1A1a Public electricity and heat production | Gaseous fuels | $CO_2$ | 26008,60 | • | • | • |
| 1A1a Public electricity and heat production | Liquid fuels | $CO_2$ | 4355,78 | • | • | • |

| IPCC SOURCE CATEGORIES | ACTIVITY | EMIS-SIONS OF | EMISSIONS Gg $CO_2$ EE | LEVEL 1990 | LEVEL 2002 | TREND 2002 |
|---|---|---|---|---|---|---|
| 1A1a Public electricity and heat production | Solid fuels | $CO_2$ | 286022,81 | ● | ● | ● |
| 1A1b. Petroleum refining | Liquid fuels | $CO_2$ | 18509,18 | ● | ● | ● |
| 1A1b. Petroleum refining | Solid fuels | $CO_2$ | 473,48 | | | ● |
| 1A1c. Manufacture of solid fuels, and other energy industries | Solid fuels | $CO_2$ | 18462,62 | ● | ● | ● |
| 1A2a-f. Manufacturing industries and construction total | Gaseous fuels | $CO_2$ | 49594,68 | ● | ● | ● |
| 1A2a-f. Manufacturing industries and construction total | Liquid fuels | $CO_2$ | 20506,20 | ● | ● | ● |
| 1A2a-f. Manufacturing industries and construction total | Other fuels | $CO_2$ | 384,57 | | | ● |
| 1A2a-f. Manufacturing industries and construction total | Solid fuels | $CO_2$ | 61547,22 | ● | ● | ● |
| 1A3a. Transport civil aviation | Aviation gasoline | $CO_2$ | 4247,60 | | ● | ● |
| 1A3b. Transport, road transportation | Diesel oil | $CO_2$ | 81927,10 | ● | ● | ● |
| 1A3b. Transport, road transportation | Gasoline | $CO_2$ | 84024,00 | ● | ● | ● |
| 1A3b. Transport, road transportation | Gasoline | $N_2O$ | 3399,36 | | ● | ● |
| 1A3e. Transport, other transportation | Liquid fuels | $CO_2$ | 2981,33 | ● | | |
| 1A4a. Other sectors, commercial/institutional | Gaseous fuels | $CO_2$ | 25988,59 | ● | ● | ● |
| 1A4a. Other sectors, commercial/institutional | Liquid fuels | $CO_2$ | 20248,83 | ● | ● | ● |
| 1A4a. Other sectors, commercial/institutional | Solid fuels | $CO_2$ | 1191,81 | ● | | ● |
| 1A4b. Other sectors residential | Gaseous fuels | $CO_2$ | 57624,00 | ● | ● | ● |
| 1A4b. Other sectors residential | Liquid fuels | $CO_2$ | 59475,77 | ● | ● | ● |
| 1A4b. Other sectors residential | Solid fuels | $CH_4$ | 77,18 | | | ● |
| 1A4b. Other sectors residential | Solid fuels | $CO_2$ | 2990,03 | ● | | ● |
| 1A4c. Other sectors Agriculture/forestry/fisheries | Liquid fuels | $CO_2$ | 5859,17 | ● | ● | |
| 1A4c. Other sectors Agriculture/forestry/fisheries | Solid fuels | $CO_2$ | 74,13 | ● | | ● |
| 1A5 Other, including military fuel use under this category | Liquid fuels | $CO_2$ | 1302,48 | ● | | ● |
| 1A5 Other, including military fuel use under this category | Solid fuels | $CO_2$ | 58,73 | ● | | ● |
| 1B1a. Fugitive emissions from fuels and from coal mining and handling | Solid fuels | $CH_4$ | 5433,46 | ● | ● | ● |
| 1B2b. Fugitive emissions from fuels, natural gas | Natural gas | $CH_4$ | 7216,41 | ● | ● | |
| 2A1. Mineral products, cement production | | $CO_2$ | 12352,18 | ● | ● | |
| 2A2. Mineral products, lime production | | $CO_2$ | 5551,04 | ● | ● | |
| 2B2 Chemical industry | Nitric acid production | $N_2O$ | 4007,22 | ● | ● | |
| 2B3 Chemical industry | Adipic acid production | $N_2O$ | 3073,73 | ● | | ● |
| 2C3. Aluminium production | | PFCs | 431,01 | | | ● |
| 2CE. Production of halocarbons and $SF_6$ | Production of HCFC-22 | HFCs | 1211,75 | ● | | ● |
| 2F. Industrial processes | Consumption of halocarbons and $SF_6$ | HFCs | 7035,40 | | ● | ● |
| 2F. Industrial processes | Consumption of halocarbons and $SF_6$ | $SF_6$ | 2740,62 | ● | ● | |
| 4A.1. Enteric fermentation | Dairy cattle | $CH_4$ | 9809,83 | ● | ● | |
| 4A.1. Enteric fermentation | Non-dairy cattle | $CH_4$ | 15517,48 | ● | ● | ● |
| 4B1. Manure management | Dairy cattle | $CH_4$ | 10451,82 | ● | ● | |
| 4B1. Manure management | Non-dairy cattle | $CH_4$ | 5996,13 | ● | ● | |
| 4B8. Manure management | Swine | $CH_4$ | 10791,36 | ● | ● | |
| 4D1. Agricultural soils | Direct soil emissions | $N_2O$ | 18293,10 | ● | ● | |

| IPCC SOURCE CATEGORIES | ACTIVITY | EMIS-SIONS OF | EMISSIONS Gg $CO_2$ EE | LEVEL 1990 | LEVEL 2002 | TREND 2002 |
|---|---|---|---|---|---|---|
| 4D3. Agricultural soils | Indirect emissions | $N_2O$ | 11284,00 | ● | ● | |
| 6A1 Managed waste disposal on land | Solid waste disposal on land | $CH_4$ | 11921,59 | ● | ● | ● |
| 6B1. Wastewater handling | Industrial wastewater | $CH_4$ | 132,93 | | | ● |

In subsequent work in the research project on quality assurance of the inventories, it will then be necessary to identify key sources based on the Tier 2 methodology.

# 13 ANNEX 2: DETAILED DISCUSSION OF METHODOLOGY AND DATA FOR ESTIMATING $CO_2$ EMISSIONS FROM FOSSIL FUEL COMBUSTION

## 13.1 Working Group on Energy Balances, and its most important databases

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

The energy balance is prepared by the Working Group on Energy Balances (AGEB), whose members include energy industry associations and energy industry research institutes. The members of the Working Group on Energy Balances (AGEB) include (as of: May 2002):

- Six energy industry associations
  Bundesverband der deutschen Gas- und 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 – e.V. (VDEW) (Association of German Power Utilities), Frankfurt am Main,
  Verband der Energie- und Kraftwirtschaft e.V. (VIK) (Association of Industrial Energy and Power Producers), Essen
- as well as three economic research institutes:
  Deutsches Institut für Wirtschaftsforschung (DIW) (German Institute for Economic Research), Berlin,
  Energiewirtschaftliches Institut an der Universität Köln (EWI) (Institute of Energy Economics at the University of Cologne), Cologne,
  Rheinisch-Westfälisches Institut für Wirtschaftsforschung (RWI) (Rhine-Westphalian Institute for Economic Research), Essen.

Until 1994, energy balances were prepared by the General Association of the German Hard Coal Industry (GVSt) in Essen.

Since the 1995 balance year, overall responsibility for the preparation of energy balances has lain with the German Institute for Economic Research (DIW) in Berlin, although the Association of the German Petroleum Industry (MMW) supplies petroleum data and the other

associations represented in the AGEB check the data, particularly when it refers to their own particular energy resources. Overall, with due regard for the available data, the energy balances provide a reliable picture of energy production and use in the German economy.

The most important sources are listed in Table 94. As they indicate, official (e.g. Federal Statistical Office) and semi-official (e.g. coal industry statistics) reporting plays a key role in this context. However, these sources do not provide all necessary data. For this reason, association statistics are also used. In a number of categories, furthermore, experts personally provide relevant data – in categories, for example, such as non-energy-related consumption by the chemicals industry.

Table 94: Data sources for energy balances (ZIESING et al, 2003)

| | |
|---|---|
| **All energy resources** | **Federal Ministry of Economics and Labour**<br>Electricity Industry Department – Annual statistical reports<br>Gas Industry Department – Annual statistical reports<br>**Federal Statistical Office**<br>Annual figures for the manufacturing industry<br>Fachserie (Specialised series) Manufacturing Industry<br>- Series 3.1 Production in the manufacturing industry<br>- Series 4.1.1 Employment, revenue and energy supplies of mining and manufacturing companies<br>- Series 6.4 Power generation facilities of mining and manufacturing companies<br>Fachserie (Specialised series) Foreign Trade<br>- Series 2 Foreign trade by types of goods and countries<br>Selected figures on the energy industry<br>**Association of German Power Utilities (VDEW)**<br>VDEW annual statistics<br>VDEW surveys on the use of renewable energy resources<br>Market research results, company data, calculations by the Working Group on Energy Balances (AGEB) |
| **Hard coal and lignite** | **Statistik der Kohlenwirtschaft e.V. (Coal Industry Association statistics)**<br>Coal mining in the energy industry of the Federal Republic of Germany – annual reports<br>Coal industry statistics<br>Sales statistics and other unpublished energy statistics |
| **Petroleum** | **Federal Office of Economics and Export Control**<br>Official petroleum statistics for the Federal Republic of Germany<br>**Mineralölwirtschaftsverband e.V. (MWV) (Association of the German Petroleum Industry)**<br>Petroleum statistics – annual reports<br>**Wirtschaftsverband Erdöl- and Erdgasgewinnung e.V. (Association of the Petroleum and Natural Gas Extraction Industry)**<br>Annual reports<br>**Federal Ministry for Food, Agriculture and Forestry**<br>Diesel consumption by agriculture |
| **Gases** | **Federal Statistical Office, Düsseldorf branch**<br>Iron and steel statistics: fuel, gas and electricity statistics<br>**Wirtschaftsverband Erdöl- and Erdgasgewinnung e.V. (Association of the Petroleum and Natural Gas Extraction Industry)**<br>Annual reports<br>**Bundesverband der deutschen Gas- and Wasserwirtschaft e.V. (BGW) (Association of the German Gas and Water Industry) Gas Statistics – Annual Reports**<br>Gas statistics – annual reports<br>**Statistik der Kohlenwirtschaft e.V. (Coal Industry Association statistics)**<br>Gas Statistics<br>**Deutscher Verband Flüssiggas e.V. (German Liquid Petroleum Gas Association)**<br>The LPG market – annual reports |
| **Other energy resources** | **Arbeitsgemeinschaft Fernwärme e.V. (Working Group on District Heating)**<br>District heating reports |
| **"Non-energy resources"** | **Mineralölwirtschaftsverband e.V. (MWV) (Association of the German Petroleum Industry)**<br>**Verband der Chemischen Industrie e.V. (VCI) (Chemicals Industry Association)** |

## 13.2 Structure of the energy balances

The energy balances, which are structured in matrix form, provide an overview of the interconnections within the energy sector. As a result, they not only provide information about consumption of energy resources in the various source categories, they also show the relevant flows of such resources, from production to use in the various production, transformation and consumption areas (cf. Figure 29). The ***production balance*** shows

- Domestic production
- Imports
- Removals from stocks
- Exports
- Maritime bunkering
- Additions to stocks

of energy resources, and it summarises them under ***primary energy consumption***. The primary energy balance provides the basis for calculations under the IPCC reference procedure (PROGNOS, 2000). The ***consumption balance*** provides a key basis for preparation of emissions inventories. The usage balance can also be used for determination of primary energy consumption. It comprises

The transformation balance
Flaring and line losses
Non-energy-related consumption, and
Final energy consumption.

Differences between the production and usage balances are compensated for in the position "Statistical differences".

The ***transformation balance***, as part of the usage balance, shows what energy resources are transformed, as well as what other resources they are transformed into. The transformation production shows the results of such transformation. Energy transformation can involve transformation of one substance into another – such as transformation of crude oil (transformation input) into petroleum products (transformation production) – or physical transformation – such as combustion of hard coal (transformation input) – in power stations, for generation of electrical energy (transformation production). The energy consumption in the transformation sector shows how much energy was needed for operation of transformation systems (the transformation sector's own consumption). The transformation balance is differentiated in accordance with 12 different types of plants.

Figure 29: Line structure of the energy balances until 1994 and as of 1995 (AGEB)

[Energy Balance until 1994; Energy Balance of the Federal Republic of Germany as of 1995;
Endenergieverbrauch = Final energy consumption; Umwandlungsbilanz = Transformation balance;

Primärenergiebilanz = Primary energy balance; nach Sektoren = By sectors; Verbrauch in der Energiegewinnung ... = Consumption in energy production and in transformation sectors; Umwandlungsausstoß = Transformation emissions; Umwandlungseinsatz = Transformation input; dazu folgende Tabellen:

| Energy Balance until 1994 | Line |
|---|---|
| Domestic production | 1 |
| Imports | 2 |
| Removals from stocks | 3 |
| Domestic energy production | 4 |
| Exports | 5 |
| Maritime bunkering | 6 |
| Additions to stocks | 7 |
| **Domestic primary energy consumption** | **8** |
| Coking plants | 9 |
| Municipal gas works | 10 |
| Hard-coal briquetting plants | 11 |
| Lignite briquetting plants | 12 |
| Public district heat plants | 13 |
| Mine power stations | 14 |
| Other industrial thermal power stations | 15 |
| Nuclear power stations | 16 |
| Hydroelectric power stations | 17 |
| Thermal power stations, district heat stations | 18 |
| Blast furnaces | 19 |
| Refineries | 20 |
| Other energy producers | 21 |
| **Total transformation input** | **22** |
| Coking plants | 23 |
| Municipal gas works | 24 |
| Hard-coal briquetting plants | 25 |
| Lignite briquetting plants | 26 |
| Public district heat plants | 27 |
| Mine power stations | 28 |
| Other industrial thermal power stations | 29 |
| Nuclear power stations | 30 |
| Hydroelectric power stations | 31 |
| Thermal power stations, district heat stations | 32 |
| Blast furnaces | 33 |
| Refineries | 34 |
| Other energy producers | 35 |
| **Total transformation emissions** | 36 |
| Hard-coal mines, hard-coal briquetting plants | 37 |
| Coking plants | 38 |
| Municipal gas works | 39 |
| Lignite mines, briquetting plants | 40 |
| Power stations | 41 |
| Oil and gas production | 42 |
| Refineries | 43 |
| Other energy producers | 44 |
| Total energy consumption in the transformation sector | 45 |
| Flaring and line losses, evaluation difference | 46 |
| Domestic energy supply and transformation balance | 47 |
| Non-energy-related consumption | 48 |
| Statistical differences | 49 |
| **Final energy consumption** | **50** |

| | |
|---|---|
| Other mining | 51 |
| Non-metallic minerals | 52 |
| Iron and steel | 53 |
| Iron and steel foundries (including malleable casting) | 54 |
| Drawing shops and cold rolling mills | 55 |
| Non-ferrous metal products and casting | 56 |
| Chemical industry | 57 |
| Pulp and paper | 58 |
| Rubber processing | 59 |
| Other basic materials and producer's goods | 60 |
| **Basic materials and producer's goods** | **51-60** |
| Machine tools | 61 |
| Automotive, aircraft and spacecraft | 62 |
| Electrical engineering, precision mechanics, optics | 63 |
| Ironware, tinware and metalware | 64 |
| Other manufacturing of industrial goods | 65 |
| **Manufacturing of industrial goods** | **61-65** |
| Glass and fine ceramics | 66 |
| Production of plastic products | 67 |
| Textiles | 68 |
| Other manufacturing of consumables | 69 |
| Manufacturing of consumables | 66-69 |
| Sugar industry | 70 |
| Other food industry | 71 |
| Drink industry | 72 |
| **Food and drink industry** | **70-72** |
| Other mining and manufacturing, total | 73 |
| Railway transport | 74 |
| Road transport | 75 |
| Air transport | 76 |
| Coastal and inland shipping | 77 |
| Total transport | 78 |
| Total households and small consumers | 79 |
| Military agencies | 80 |

| **Energy Balance of the Federal Republic of Germany as of 1995** | **Line** |
|---|---|
| Domestic production | 1 |
| Imports | 2 |
| Removals from stocks | 3 |
| Domestic energy production | 4 |
| Exports | 5 |
| Maritime bunkering | 6 |
| Additions to stocks | 7 |
| **Domestic primary energy consumption** | **8** |
| Coking plants | 9 |
| Hard-coal and lignite briquetting plants | 10 |
| Public thermal power stations (not including CHP stations) | 11 |
| Industrial thermal power stations | 12 |
| Nuclear power stations | 13 |
| Hydroelectric power stations, windpower and photovoltaic systems | 14 |
| Public CHP stations | 15 |
| District heat stations | 16 |
| Blast furnaces | 17 |

| | |
|---|---|
| Refineries | 18 |
| Other energy producers | 19 |
| **Total transformation input** | **20** |
| Coking plants | 21 |
| Hard-coal and lignite briquetting plants | 22 |
| Public thermal power stations (not including CHP stations) | 23 |
| Industrial thermal power stations | 24 |
| Nuclear power stations | 25 |
| Hydroelectric power stations, windpower and photovoltaic systems | 26 |
| Public CHP stations | 27 |
| District heat stations | 28 |
| Blast furnaces | 29 |
| Refineries | 30 |
| Other energy producers | 31 |
| **Total transformation emissions** | 32 |
| Coking plants | 33 |
| Hard-coal mines, hard-coal briquetting plants | 34 |
| Lignite mines, briquetting plants | 35 |
| Power stations | 36 |
| Oil and gas production | 37 |
| Refineries | 38 |
| Other energy producers | 39 |
| Total energy consumption in the transformation sector | 40 |
| Flaring and line losses | 41 |
| Domestic energy supply and transformation sector | 42 |
| Non-energy-related consumption | 43 |
| Statistical differences | 44 |
| **Final energy consumption** | **45** |
| Non-metallic minerals, other mining | 46 |
| Food and tobacco | 47 |
| Paper | 48 |
| Primary chemicals | 49 |
| Other chemical industry | 50 |
| Rubber and plastic products | 51 |
| Glass and ceramics | 52 |
| Processing of non-metallic minerals | 53 |
| Metal products | 54 |
| Non-ferrous metal products and casting | 55 |
| Metal processing | 56 |
| Machine tools | 57 |
| Automotive industry | 58 |
| Other industrial sectors | **59** |
| Total mining, extraction of non-metallic minerals, manufacturing | 60 |
| Railway transport | 61 |
| Road transport | 62 |
| Air transport | 63 |
| Coastal and inland shipping | 64 |
| Total transport | 65 |
| Households | 66 |
| Commerce, trade, services and other consumers | 67 |
| Military agencies | 68 |

***Non-energy consumption***, as a component of the consumption balance, is shown as a total, without allocation to plant types or branches of industry. It describes which energy resources are used as raw materials (e.g. in the chemicals industry, transformation of energy resources into plastics).

Finally, the consumption balance indicates the final consumption sectors in which energy is transformed into the useful energy ultimately needed (such as power, light, room and process heating) (***final energy consumption***). This includes industry, sub-divided into 14 sectors, transport, households and commercial use, trade, services and other consumers (including agriculture).

Figure 29 shows the structure of the production and consumption balances in the energy balances until 1994 and as of 1995.

**Energy resource structure in energy balances ...**

**Through 1994**

| | |
|---|---|
| Hard coal | HC coal |
| | HC coke |
| | HC briquettes |
| | HC raw tar |
| | HC pitch |
| | HC other |
| | Crude benzene |
| Lignite | L coal |
| | L briquettes |
| | L coke |
| | L dust coal |
| | Hard lignite |
| Other solid fuels | Firewood |
| | Peat |
| | Sewage sludge |
| Petroleum | Oil |
| | Gasoline |
| | Raw gasoline |
| | Jet kerosine |
| | Schw. Flkr. [??] |
| | Diesel |
| | Heating oil, light. |
| | Heating oil, heavy. |
| | Petrol coke |
| | Other petroleum products |
| Gases | LP gas |
| | Refinery gas |
| | Coke-oven gas |
| | Blast-furnace |
| | Natural gas |
| | Petroleum gas |
| | Pit gas |
| | Landfill gas |
| Electricity and other energy resources | Electricity |
| | Hydropower |
| | Nuclear power |
| | District heat |
| | Other energy resources |
| Total energy resources | Primary energy resources |
| | Secondary energy resources |
| | Total |

**As of 1995**

| | |
|---|---|
| Hard coal | HC coal |
| | HC briquettes |
| | HC coke |
| | Other HC products |
| Lignite | L coal |
| | L briquettes |
| | Other L products |
| | Hard lignite |
| Petroleum | Oil |
| | Gasoline |
| | Raw gasoline |
| | Jet kerosine |
| | Diesel fuel |
| | Heating oil, light |
| | Heating oil, heavy |
| | Petrol coke |
| | LP gas |
| | Refinery gas |
| | Other petroleum products |
| Gases | Coke-oven and city gas |
| | Blast-furn. & converter gas |
| | Natural gas, petroleum gas |
| | Pit gas |
| Renewable energies | Hydropower |
| | Wind and photovol. systems |
| | Waste and other biomass |
| | Other renewable energies |
| Electricity and other energy resources | Electricity |
| | Nuclear power |
| | District heat |
| Total energy resources | Primary energy resources |
| | Secondary energy resources |
| | Total |

Figure 30: Energy resources in the Federal Energy Balance (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

The main group structure (until 1994 and as of 1995) is shown in Figure 30. Via the "Renewable energies" satellite balance, renewable energies can be further broken down as of 1996 (AGEB).

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 heat. 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.

## 13.3 Shifting of statistical differences into the sector "households and small consumers"

The AGEB energy balances, for the old German Länder, and the IfE energy balances, for the new German Länder, are being aggregated for the new energy balances prepared in the framework of the EUROSTAT project (ZIESING et al, 2003) for the year 1990, and for Germany as a whole. In keeping with the system used since 1995, the following change, *inter alia*, has been made in the original balances for 1990 and for the years 1991 to 1994:

The statistical differences listed separately for electrical energy in the energy balances for the old German Länder, until 1994, are now assigned, more properly, to the area of households and small consumers (new name: commerce, trade, services).

The statistical differences transferred to the sector households and small consumers, in the area of electrical energy, consist of the following values, which are added to the sector's consumption:

| Figures in GWh | 1990 | 1991 | 1992 | 1993 | 1994 |
|---|---|---|---|---|---|
| Allocation of statistical differences in electrical energy to the households sector | 8658 | 13848 | 14748 | 16522 | 18682 |

## 13.4 Preparation of provisional energy balances onwards from 1999 by the 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 for the energy balance*** are posted every summer on the homepage of the Working Group on Energy Balances (AGEB), and are thus available to the general public; in each case, they include data for the previous year. However, it should be noted that the data in the evaluation tables, where not directly derived from the final energy balances for previous years, is of a provisional nature.

The *evaluation tables on the energy balance* contain the following information:

- Structure of energy consumption, by sectors
- Primary energy consumption, by energy resources
- Domestic primary energy production, by energy resources
- Total final energy consumption, by energy resources
- Final energy consumption by the rest of the mining and manufacturing sectors, by energy resources
- Final energy consumption by traffic, by energy resources
- Final energy consumption by households, by energy resources
- Final energy consumption by the trade, commerce and services sector, by energy resources
- Final energy consumption by military agencies, by energy resources
- Use of energy resources for power generation.

The Federal Environmental Agency has supplemented the transformation balance for 1999, thereby producing provisional energy balances for 2000 and 2001. It has accomplished this by adding key data, arranged by source categories, on primary energy consumption, fuel input for power generation, the domestic energy supply pursuant to the transformation balance (this consists of primary consumption, minus transformation losses and energy consumption in the transformation sector), non-energy-related consumption and final energy consumption.

## 13.5 Methodological issues: Energy-related activity rates

Essentially, the inventories for air pollutants prepared by the UBA are strictly based on the energy balances for Germany prepared by the Working Group on Energy Balances (AGEB). In some areas, however, the activity rates determined from the energy balance have been supplemented with activity rates from other sources; this is the case, for example, for firewood consumption in the source categories households and small consumers (trade, commerce, services).

### *13.5.1 Supplements to the energy balance data*

In the area of waste incineration, the Federal Environmental Agency has undertaken an initial supplement to the energy balance data up until 1994.

Lines 11, 15 and 16 of the energy balance (in the version from 1995; in the version valid until 1994, this affects lines 13 and 18) contain data on the use of sewage sludge, waste etc. in public thermal power plants (line 11 in the version from 1995; line 13 in the version valid until 1994), public heat/power plants and district heat plants (lines 15 and 16 in the version from 1995; line 18 in the version valid until 1994).

The Federal Environmental Agency has supplemented this data with its own estimates, based on an evaluation of operator data, on total input of household waste in waste incineration plants. The difference between the overall total calculated in this way, for the use of household waste for the public electricity and district heat supply, and the energy balance data is distributed in proportion to the energy balance data. Until the year 1994, such supplementation was carried out only for the old *Länder*; for the new *Länder*, the approach was based on the energy balance data excluding any supplements (cf. Table 95)

Table 95: Supplementation of the activity rates for household-waste input in thermal power plants, public heating plants and district heat plants, old *Länder*, 1990-1994, and Germany, 1995-1998

| | Public thermal power stations | | | | CHP plants, district heat plants | | | |
|---|---|---|---|---|---|---|---|---|
| | Energy B | CSE | | | Energy B | CSE | | |
| | l. 13/11 | Energy B | Additional | Total | l. 18/15+16 | Energy B | Additional | Total |
| | TJ | | | | | | | |
| 1990 | 22216 | 22216 | 9967 | 32183 | 20970 | 20970 | 9407 | 30377 |
| 1991 | 23491 | 23491 | 11423 | 34914 | 20294 | 20294 | 9868 | 30162 |
| 1992 | 25952 | 25952 | 12339 | 38291 | 19892 | 19892 | 9457 | 29349 |
| 1993 | 25637 | 25637 | 11964 | 37601 | 22149 | 22149 | 10335 | 32484 |
| 1994 | 29384 | 29384 | 12463 | 41847 | 21372 | 21372 | 9064 | 30436 |
| 1995 | 27143 | 27143 | - | 27143 | 9203 | 9203 | - | 9203 |
| 1996 | 29233 | 29233 | - | 29233 | 7516 | 7516 | - | 7516 |
| 1997 | 32575 | 32575 | - | 32575 | 7730 | 7730 | - | 7730 |
| 1998 | 29847 | 29847 | - | 29847 | 12189 | 12189 | - | 12189 |
| Remark: from 1990 to 1994, old German Länder; as of 1995, Germany | | | | | | | | |

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

For the period until 1994, inclusion of the additional activity data yields additional $CO_2$ emissions of about 300,000 t. As of 1995, the currently available data contains no further such supplements (the relevant time series have been established, however).

A similar procedure is adopted for waste incineration in industrial thermal power plants. However, in such cases, supplementation of fuel quantities is linked to a differentiation of fuels for spent sulphite liquor, which is not emissions-relevant in relation to energy-related $CO_2$ emissions. The basis in such cases consists of figures on total industrial-waste incineration, where such figures are available (DESTATIS). The input of sewage sludge, waste etc. in industrial thermal power plants recorded in the energy balance (line 15 of energy balances up to 1994, and line 12 in energy balances from 1995 onwards) and in other industrial combustion plants (line 73 in the energy balances up to 1994, and line 60 in energy balances from 1995 onwards) is deducted from this total.

This difference is allocated to the input of spent sulphite liquor in industrial thermal power plants, which must be attributed to heat generation, whilst the quantity of fuel allocated to the use of spent sulphite liquor for electricity generation in industrial thermal power plants is deducted from the total use of sewage sludge, waste etc. reported in the energy balance for industrial heating and power stations (line 15 up to 1994, and line 12 from 1995 onwards). For the new German Länder, the total input of sewage sludge, waste etc. reported in the energy balance is allocated to the use of industrial waste.

In the current version of the Central System of Emissions, however, this method has not been maintained for the period from 1995 onwards. In such cases, the activity data currently in the system differs substantially from the energy balance data.

Table 96: Supplementation and differentiation of the activity rates for the use of industrial waste and spent sulphite liquor in industrial thermal power plants and other industrial heat producers, old *Länder*, 1990-1994, and Germany, 1995-1998

| | Industrial thermal power stations | | | | Industrial heat producers | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Energy B | CSE | | | Energy B | CSE | | | |
| | L. 15/12 | Energy B | Of this, industrial w. | Of this, w.sulphite liq | L. 73/60 | Energy B | Of this, industrial w. | Added Industrial w. | Added w. sulph. liq. |
| | TJ | | | | | | | | |
| 1990 | 31921 | 31921 | 28690 | 3231 | 0 | 0 | 0 | 0 | 9655 |
| 1991 | 31344 | 31344 | 28257 | 3087 | 0 | 0 | 0 | 14677 | 9259 |
| 1992 | 28157 | 28157 | 25164 | 2993 | 537 | 537 | 537 | 14763 | 8977 |
| 1993 | 28041 | 28041 | 24683 | 3358 | 8852 | 11149 | 11149 | 5918 | 10073 |
| 1994 | 32290 | 32290 | 28890 | 3400 | 5661 | 5661 | 5661 | 15612 | 10000 |
| 1995 | 32918 | - | - | - | 10472 | 4155 | 4155 | 5559 | - |
| 1996 | 35510 | - | - | - | 10038 | 3389 | 3389 | 5446 | - |
| 1997 | 37457 | - | - | - | 10038 | 2450 | 2450 | 4212 | - |
| 1998 | 56442 | - | - | - | 14254 | 3820 | 3820 | 1212 | - |
| Remarks: from 1990 to 1994, old German Länder, as of 1995, Germany. UBA data for 1993 and as of 1995 requires clarification. | | | | | | | | | |

(AGEB, UBA, Öko-Institut)

Finally, with regard to the use of waste, combustion in other plants of the transformation sector also deserves mention. From 1993 to 1994, the energy balances for the old *Länder* include data on the use of sewage sludge and waste under "energy consumption in the transformation sector for coke ovens" (line 38 of the energy balance); from 1995 onwards, the corresponding data for Germany is listed under "consumption in energy production and in the transformation sectors for other energy producers" (line 39 of the energy balance).

In the Central System for Emissions (CSE), this is interpreted as the use of plastic wastes. The data previously included in the CSE is consistent with the corresponding energy balance data until 1994, but from 1995 onwards there is a deviation. Here too, there is a need for clarification.

Table 97: Supplementation and differentiation of the activity rates for the use of sewage sludge and waste in the transformation sector for coking plants and in the transformation sectors for other energy producers, old *Länder*, 1990-1994, and Germany, 1995-1998

| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|
| | TJ | | | | | |
| Energy Balance (lines 38 and 39) | 5540 | 6212 | 11511 | 12969 | 13707 | 14080 |
| Data implemented in CSE | 5540 | 6212 | 11485 | 10818 | 8387 | 14879 |
| Remark: until 1994, old German Länder; as of 1995, Germany | | | | | | |

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

The energy balance has also been supplemented (in a second instance) with regard to use of natural gas by compressors in the natural gas network. This is calculated by means of a fixed-rate factor (0.005) that is linked to consumption of natural gas in Germany. The corresponding activity rates until 1994 – for the inventory data analysed in detail to date – are not deducted from the energy consumption data in the transformation sector listed in line 42 or 44 (until 1994). In other words, these are included as additional emissions. For Germany as a whole, in the first half of the 1990s, this produced annual emissions of approximately 700,000 tonnes of $CO_2$. From 1995 onwards, the use of natural gas for gas compressors is deducted from the energy balance data; however, there is still a need for clarification vis-à-vis the precise procedure (Ziesing et al., 2003).

### *13.5.2 Reclassification of energy balance data*

A series of reclassifications have been carried out as part of the Federal Environmental Agency's preparation of the inventories. The involve reclassification, between various fuels, and transfers of some fuel inputs to other consumption sectors.

The following reclassifications were carried out:

- Until 1994, use of jet kerosene in the commerce, trade and services sector (energy balance line 79) was allocated to petroleum use in small combustion installations. From 1995 onwards, use of jet kerosene in the trade, commerce and services sector (line 74), which now also includes the military, has been allocated, as a whole, to military air traffic. However, this transfer represents an emissions volume of no more than 30,000 tonnes of $CO_2$. This reclassification will only be implemented in the Central System for Emissions (CSE).
- Jet kerosene in the transport sector is allocated to international air traffic at a fixed rate of 80 %. This allocation is only implemented in the CSE.

In source-category-specific allocation, only a few additional deviations – that cancel each other out – are to be expected.

## 13.6 Uncertainties and time series consistency in the energy balance

In an endeavour to ensure that energy balances are always meaningful, it is necessary to make allowance for changes in the underlying statistics, for changes in the energy sector and for changes in requirements of data users. Such changes were made as early as the 1970s. Partly as a result of increasing energy-market liberalisation, and in conjunction with the formation of a single European market, the condition of the statistical energy database (along with that of other data) worsened in that period (Ziesing et al., 2003). By contrast, the Energy Statistics Act, which entered into force in 2003, will have a positive effect.

Energy balances from the year 1950 are available for the Federal Republic of Germany in the territorial delimitation prior to 3 October 1990. Moreover, energy balances have been drawn up for the years 1991 to 1994 separately for the old and new *Länder*, and for Germany as a whole. With the conversion of the official statistics to the classification of industrial sectors (edition 1993, WZ 93), since 1995 only energy balances for Germany as a whole (in the territorial delimitation of 3 October 1990) have been submitted. The most recent energy balance is available for the year 1999.

### *13.6.1 The balance year 1990 and the energy balances for 1991 to 1994*

The base year 1990 plays a key role in national emissions inventories, and it is especially important as a reference year for agreed emissions-reduction targets under climate protection policy. For Germany, admittedly, this is linked to the problem that the country did not have the same national territorial status throughout the entire year of 1990. Radical changes in the territory of the GDR and the new *Länder*, including profound economic woes and fundamental organisational/structural problems, greatly complicated the process of collecting energy statistics in eastern Germany for 1990. This also had certain repercussions for the old *Länder*, for which the AGEB was still able to prepare and publish balances in the conventional manner (ZIESING et al, 2003).

For the GDR / new German Länder, the Institute for Energy and Environment (IfE) in Leipzig assumed the tasks of preparing an energy balance for 1990 that would be compatible with western German balances and of presenting the pertinent underlying data in detail (IFE, 1991). In this effort, the Institute had access to a study, carried out under the direction of DIW Berlin (German Institute for Economic Research), whose aims included preparing suitable energy balances for the GDR and the years 1970 to 1989 (DIW, 1991).

The AGEB energy balances, for the old German Länder, and the IfE energy balances, for the new German Länder, are being aggregated for the new energy balances prepared in the framework of the EUROSTAT project (ZIESING et al, 2003) for the year 1990, and for Germany as a whole. In keeping with the system in force as of 1995, the changes described below have been made in the original balances for 1990 and for the years 1991 to 1994 (cf. ZIESING et al, 2003).

In keeping with the procedure used by international organisations (IEA, EUROSTAT, ECE), the so-called "efficiency approach" is used, instead of the formerly used "substitution approach", for energy balances for Germany since 1995.

This approach is used for assessment of energy resources for which there is no standardised measure for conversion (such as calorific value). The categories involved include foreign trade in electricity, hydroelectric and wind power, photovoltaic systems and nuclear power.

The statistical differences listed separately for electrical energy in the energy balances for the old German Länder, until 1994, are now assigned, more properly, to the area of households and small consumers (new name: trade, commerce, services) (data in Chapter 13.3).

Due to a lack of relevant data, it was not possible to adapt the differentiation of final energy consumption by source categories in the manufacturing sector, for which the system changed considerably as of 1995 via transition from the production sector system (SYPRO) to the economic-sector classification system (Klassifikation der Wirtschaftszweige), 1993 edition (DESTATIS, 2002c).

The aforementioned changes have been used to revise the energy balances for Germany, and for the old and new German Länder, for all years from 1990 to 1994.

In the view of DIW Berlin, these energy balances may be considered the standard energy-statistical basis for determining energy-relevant $CO_2$ emissions in Germany.

Starting with the energy balance for 1995, a further series of adjustments became necessary. These essentially concern methodological changes for the evaluation of energy resources in accordance with standard international procedures, for which there is no uniform conversion yardstick such as calorific value, as well as amendments to individual columns (energy resources) and – due to a new system for the branches of industry in the manufacturing sector (WZ 93) – lines (source categories) in the energy balance matrix. Moreover, from 1995 onwards, energy balances were only submitted for the Federal Republic of Germany as a whole, since the database no longer permits consistently separate representation for the old and new *Länder*. The structures in energy balances until 1994, and as of 1995, are shown in Figures 29 and 30.

## 13.7 Documentation of the data for the BEU module

The BEU module is based on a data-documentation process. Such documentation is divided into four steps:

- Description of the sector, and provision of a list of literature references
- Compilation of data from energy balance and from additional sources, with citing of relevant sources
- Data supplementation and evaluation
- Definition of model data

All four work steps are divided in accordance with the source categories within the BEU structure.

In the first step, the relevant sector is described – for example, via provision of production data and the sector's importance within the energy balance. Any special statistical aspects are noted, and origins of the pertinent data are precisely cited.

Data evaluation takes place in the second step (data library). In addition to fuel inputs, data for other source-category-specific, energy-related characteristics (survey aspects) is included in the evaluation. Such data includes, for example, thermal combustion output, emissions, electrical output, power generation and steam generating capacity of power-station boilers. In individual cases, other data is included as well, if it supports conclusions regarding energy input and generation – for example, production data. The data is then prepared in time-series form. On this level, bases for source-specific recalculations are also documented.

In the third step (supplementation and evaluation),

- Uncertainties and time-series consistency are studied, and
- Source-specific quality assurance / control and verification are carried out.

These studies apply to all survey characteristics contained in the data library. The processes of selection of a form for time-series presentation, inclusion of data from various different sources and consideration of other survey characteristics all provide opportunities to check data consistency and quality:

- Time-series presentation makes it possible to identify data items that don't fit within the overall pattern,
- Via comparison of data with similar survey characteristics, but from different sources, sources can be confirmed, rejected or corrected,
- Via addition of data with other survey characteristics, plausibility of unusual data items can be checked (for example, comparison of power generation and fuel input),
- Linking with data with other survey characteristics (such as derivation of efficiencies, determination of fuel inputs from thermal combustion output and their use over time) makes it possible to replace data and close gaps as necessary,
- Enquiries of plant operators can be carried out in order to supplement or correct data,
- Comparison of data with different survey characteristics makes it possible to determine whether data for a certain year, or survey characteristics within a time series (such as older characteristics), always covers the same group of plants (for example, the emissions for a given plant may be listed, but the relevant fuel input is lacking).

These review options cannot be generally formalised. The question of which options can be used depends on the individual case in question and the available data. Any reviews and evaluations are referred to in the documentation.

This evaluation provides the basis for the fourth step, selection of model data. Data for all surveyed characteristics, assessed as sufficiently reliable, is compiled and then combined in the model with data of other source categories / sub-sectors. In the model, the data is linked with the energy balance, and the fuel inputs are entered in the BEU module. The BEU module, and the data for other survey characteristics, provide the basis for forecasts and scenarios regarding the impacts of emissions-reduction measures.

To date, documentation has been carried out for the lignite mining sector. This documentation covers the period 1992 – 1999.

### *13.7.1 Lignite mining*

#### 13.7.1.1 Description of the sector

In 2002, a total of 175.4 Mt of crude lignite were mined in the German lignite mining sector. Lignite mining is carried out in 6 districts (Reviere), with the following production quantities:

| | |
|---|---|
| Rhineland | 94,349 kt |
| Helmstedt | 4,073 kt |
| Hesse | 165 kt |
| Bavaria | 59 kt |
| Lausitz | 57,503 kt |
| Central Germany (Mitteldeutschland) | 19,215 kt |

Of this quantity of mined crude lignite, a total of 153.2 Mt (91%) was converted into electrical power in public thermal power stations.

The lignite mining sector's activities, in addition to mining crude lignite, include producing products from lignite. In 2002, more than 5 Mt of lignite products were produced:

- Lignite briquettes 1.740 Mt
- Dust coal, dry coal and fluidised bed coal 3.222 Mt
- Lignite coke 0.177 Mt

Crude lignite is processed in lignite briquetting plants. Lignite briquetting plants are operated in the Rhineland, Lausitz and central German districts.

In order to meet their own energy demands, briquetting plants operate their own mine power stations. At present, such mine power stations have an electrical output of about 400 MW, and they generate some 2000 GWh of electrical energy. In addition, as combined heat/power generating systems, they generate process steam that is used to dry crude lignite in coal processing.

The briquetting plants in the Lausitz and Mitteldeutschland (central Germany) districts no longer operating their own mine power stations. The remaining briquetting plants obtain electrical power and process steam either from power stations that were integrated within the public grid in 1994 or from new power stations that have come on line (public grid) since 1998. In energy statistics, these power stations are listed as part of the public grid.

In lignite mining, combustion-related emissions occur through operation of:

- Mine power stations, with fuel inputs for generation of electricity and heat
- Other heat generators needed for operation of lignite mines and briquetting plants

The Energy Balance for the Federal Republic of Germany does not have a separate balance line for mine power stations. Until 1994, fuel inputs for electricity generation, by power stations in the hard-coal mining sector, were summarised in line 14, under the heading "Mine and mine-pit power stations" ("Zechen- und Grubenkraftwerke").

Until that year, it was not difficult to separate fuel inputs in line 14 by hard-coal and lignite mining. Since no mine power stations are operated in the new German Länder, line 14 includes only the fuel inputs for pit (Grube) power stations. In the old German Länder, only crude lignite was used in mine-pit power stations, and thus it was possible to assign the remaining fuel inputs to mine (Zeche) power stations.

In early 1995, when the new economic-sector system (WZ 93) was introduced, mine (Zeche and Grube) power stations were combined with other industrial power stations (includes power stations in the sector "Production of non-metallic minerals, other mining and production", power stations of oil refineries and power stations of Deutsche Bahn AG), in line 12 "Industrial thermal power stations". In addition, the new system did not make a distinction between the old and new German Länder.

Pit (Grube) power stations, in contrast to other industrial power stations, have a special position with regard to allocation of fuel inputs for heat generation. As of balance year 1980, in the energy balance this fuel input is no longer allocated to the own consumption of lignite pits and briguetting plants (until 1994, line 40, as of 1995, line 35). Since then, it has been combined with raw-material input, for transformation, of lignite briquetting plants (until 1994, line 12; as of 1995, line 10, "Hard-coal and lignite briquetting plants". Unlike inputs for transformation (crude lignite that is dried and then processed into products), these quantities are burned and produce emissions. For this reason, they must be calculated out of the transformation input.

For it to be possible to continue to identify lignite mining as a source category, and to update its energy data, additional statistics and information have to be evaluated.

The following compilation shows this additional sources, along with the energy balance. The evaluated data has been combined, in the data library, in time-series form. The short-form names of the sources are used.

#### *13.7.1.1.1 Remarks on data sources*

GDR Statistics 1989:

The former GDR kept detailed statistics on power stations from 1970 to 1989. These documents were not available to the general public.

These statistics contain information about all of the GDR's power stations, broken down by economic sectors. The statistics include detailed information about equipment (for example, numbers of steam boilers, along with their dates of production and steam generating capacity; numbers and routed outputs of turbines and generators), fuels used and generation of electricity, process heat and district heat.

The 1989 statistics were evaluated for the lignite mining sector, with regard to generator performance and steam generating capacity. Taking into account the dates on which these plants were decommissioned (cf. the source Directive 88/609/EEC), it was possible to extrapolate the above figures, approximately, until 1999 and to use them for sector differentiation and plausibility checks.

DEBRIV, 2003a
In 1993, the Federal Environmental Agency, working from considerations of thermodynamics, derived a procedure for determining use of crude lignite products, in drying of crude lignite, from produced quantities of lignite products. Operators of briquetting plants then used this procedure, on the basis of their specific circumstances (for example, moisture content of crude lignite and products, plants' efficiency coefficients), to determine energy consumption factors. DEBRIV also prepared findings and transmitted the findings with the aforementioned letter.

DEBRIV, 2003b
This source was compiled by the Association of the German lignite industry (Dachverband der deutschen Braunkohlenindustrie - DEBRIV), on the basis of data provided by member companies for the period 1992 to 2001. Along with data on public lignite power stations, this source also provides information about pit (Grube) power stations.

For the new German Länder, and for the aforementioned period, the source provides information on rated electrical output, electricity generation and fuel input in electricity generation. The figures on fuel inputs for heat generation in these plants are incomplete and were not adopted.

The data has been aggregated into two operator groups. In the course of the period in question, the operator groups were repeatedly restructured and renamed. For this reason, the chronological development of survey characteristics for this sector can be derived only by summing over the operator groups.

For the old German Länder, data on pit (Grube) power stations is included only for the years 1998 and 1999.

DEBRIV o. J.
This report series presents the activities of the lignite industry. It contains overviews and tables with figures on lignite production, product production, lignite input in power stations, the stations' electrical output and the stations' expected development. This source can be used to close gaps in data and to confirm some data from other sources.

Jahrbuch Bergbau o.J.
Chapter 1.2 ‚Braunkohle' (Lignite) of this yearbook presents reports of lignite-industry companies, with relevant data. From this data, time series – for example, on power generation of mine-pit power stations in the Rhineland – and quantity data on lignite products, by companies and regions, have been compiled for the data library.

LAUBAG 2002
The LAUBAG letters are the results of a study on mine-pit power stations in the Lausitz district. From these letters, additional information was gleaned, especially information on the old power station "Schwarze Pumpe", that supplemented information from other sources.

RHEINBRAUN
The information consists of an excerpt, prepared by the company, from emissions declarations submitted in the framework of compliance with the German Ordinance on large combustion plants (Großfeuerungsanlagen-Verordnung – 13th. BImSchV). This information complements the information in the source Directive 88/609/EEC.

Directive 88/609/EEC
This is the EU Directive on large combustion plants. This directive requires Member States to provide information, at two-year intervals, on progress in reducing emissions from large combustion plants. Information is requested on thermal output of combustion, as well as on $SO_2$ and $NO_X$ emissions. The old German Länder have been subject to reporting obligations since 1990, while the new German Länder have been so subject since 1992.

In Germany, Länder immission-control authorities compile data for their areas of responsibility and provide it to the Federal Environmental Agency. The Federal Environmental Agency aggregates the data at the federal level and reports the result to the EU.

Information provided by the Länder in addition to requested information varies greatly in structure. Such information includes details about the operator, the type of plant in question (power station, combustion plant), the relevant economic sector, the location and the fuels used. Because such information varies in structure and comprehensiveness, it is not possible to compile an overview for all of Germany based on such characteristics. For some source categories, such an overview can be prepared through addition of other statistics or through enquiries directed to supervisory authorities and operators. This is the case for the lignite mining sector. The relevant emissions data varies in quality. A distinction must be made between annual data updating on the basis of emissions declarations and annual data updating on the basis of information regarding the relevant previous years. Information of the latter sort can normally be recognised in that its data remains unchanged over certain periods of time.

The Federal Environmental Agency's data compilation for pit (Grube) power stations is oriented, initially, to the former GDR's division of its lignite mining sector into collective combines (Kombinaten); for later periods, the compilation is oriented to the companies that emerged from such combines. The compilation also includes dates of plant decommissioning. Decommissioning dates are used in order to update data, for the entire group of plants in question, with regard to trends for other survey characteristics (such as electrical output).

Federal Statistical Office (DESTATIS, h)
The Federal Statistical Office also collects energy data within the framework of its official statistics on the manufacturing sector. This data is published, inter alia, in Fachserie (specialised series) 4, Reihe (series) 6.4, power-generation plants of mining and manufacturing companies.

VIK

The Association of the Energy and Power Generation Industry (VIK) has compiled time series from the Federal Statistical Office's annual reports. These time series are incorporated within the data library for the lignite mining sector (electrical output, steam generating capacity, electrical work and fuel input for power generation in the lignite mining sector).

#### 13.7.1.2 Electrical output of mine-pit power stations

Statistically, electrical output is the characteristic value for describing an economic sector's power stations. Formerly, statistics listed gross bottleneck output (Bruttoengpassleistung). Increasingly, plant operators have been recording and reporting their plants' net bottleneck output, and thus statistics include a mixture of both types of figures. This fact hampers statistical comparisons and time-series analysis.

For mine-pit power stations, data of the Federal Statistical Office (old and new German Länder, separate until 1994 and combined for all Germany as of 1995) and data in DEBRIV 2001 has been evaluated. Furthermore, the former GDR's power-station statistics (DDR-Statistik, 1989) for 1989 were included, and extrapolated.

Comparisons with the two other sets of statistics make it possible to delimit the sector and to categorise plants by districts (Reviere).

Such extrapolation was carried out on the basis of the decommissioning dates pursuant to Directive 88/609 EEC and of other information on reassignment of power stations (for example, to the public sector). The resulting extrapolation is presented in the outline of GDR statistics, by collective combines, in Tables II 1.5.4.1 to II 1.5.4.3, and it is summarised in II 1.5.4.4.

In Table II 1.5.1, locations of power stations have been allocated to the Mitteldeutschland and Lausitz districts. Power stations of the former Senftenberg lignite collective combine are allocated to the Lausitz district, while power stations of the former Bitterfeld lignite collective combine are allocated to the Mitteldeutschland district. The Lausitz district, except for the power stations in Espenhain, includes all plants of the former Schwarze Pumpe gas combine.

Table II 1.5.1 shows this reorganisation, and in Table II 1.5.2, these districts are completed through addition of the Rhineland district.

These figures are compared to the aggregated data of the Federal Statistical Office (Table II 1.5.3). In preparation of the Table, an effort was made to determine what locations the Federal Statistical Office did not include and which it included additionally (with grey background until 1994). Direct comparison of the data for the new German Länder is possible only until 1994. The figures yield a good approximation to the data of the Federal Statistical Office.

| Power station | Federal Statistical Office (II 1.5.3) | DEBRIV (II 1.5.7) | Federal Environmental Agency (II 1.5.8) |
|---|---|---|---|
| Brieske | Missing value for 1997 | Continuous time series, no value for 1997 | Continuous time series until 1998 |
| Sonne | Additional value for 1998 | Time series until 1996 | Time series until 1996 |
| Schwarze Pumpe 1 | No values for 1992 and 1997 | Continuous time series from 1992 to 1997 (i.e. listed as a mine-pit power station) | Continuous time series from 1992 to 1997 |
| Schwarze Pumpe 3 | No data for 1992, 1993, 1995, 1997 | Value available only for 1994 | Not a mine-pit power station |
| Schwarze Pumpe 4 | No values for 1993-1995, but there is a value for 1996 | Value available only for 1994 | Not a mine-pit power station |
| Amsdorf | Data for 1995 and 1997 is lacking | Data for 1995, 1996 and 1997 is lacking | Continuous time series from 1992 to 1999 |

Direct comparison with the extrapolated data as of 1995 is not possible, since the Federal Statistical Office only provides figures for Germany. Nonetheless, it is possible to determine what locations in the new German Länder were surveyed, or additional included, in the time series for Germany (grey background as of 1995), as well as approximately what data for the Rhineland district the data of the Federal Statistical Office is based on. It must be remembered that the basic statistical data for the Rhineland is known:

- Listed for 1990 to 1994 (old German Länder)
- Data for 2000 and 2001 is identical with the data for Germany (plants in the new German Länder were decommissioned or were no longer classified with the mine-pit power stations)

This basic data indicates that plants in the old German Länder, as a whole, had relatively constant electrical output. This is confirmed in that the gross bottleneck output in the Rhineland district is 386 MW for the entire period (the net output does not remain constant, even in cases in which the plant itself does not change). If, as of 1995, one subtracts the sum for the various locations from the figures for Germany, then a plausible time series results for the Rheinland district (cf. Table II 1.5.3, 2$^{nd}$ line).

The same approach was carried out with the figures in DEBRIV 2001 (Tab. II 1.5.6).

For Table II 1.5.7, an attempt was made to determine what locations DEBRIV does not include, when compared with our extrapolation (this was not possible for 1994, since DEBRIV lists electrical output incompletely).

From the two comparisons, the conclusions can be drawn, with respect to the original extrapolation pursuant to Table II 1.5.1, that the Schwarze Pumpe 3 and 4 power stations have not been counted among the mine-pit power stations, and that the Amsdorf power station also has not been counted as part of this sector as of 1999.

The extrapolation was modified in keeping with these conclusions (II 1.5.8).

Table II 1.5.9 shows trends in electrical output of mine-pit power stations, by districts, in Germany.

#### 13.7.1.3 Power generation (electrical work) in mine-pit power stations

Longer time series for electrical work in mine-pit power stations can be derived from data of

- Federal Statistical Office (Stat. BA)
- DEBRIV, 2003b
- "Bergbau, Energie" ("mining, energy") Yearbook

Time series for the old and new German Länder until 1994, and for Germany as of 1995, can be derived from publications of the Federal Statistical Office.

DEBRIV 2003b reports on the new German Länder from 1992 to 2001, and the "Bergbau und Energie" yearbook fills in all the data gaps for the period 1992 to 2001, for the old German Länder.

Table II 1.6.1 presents the data of the Federal Statistical Office and the time series, based on the yearbook, for the old German Länder. For the comparison period 1992 to 1994, the figures from both sources are identical for the old German Länder (cf. Table 1.6.1.1 and 1.6.6.4). In II 1.6.1, the Federal Statistical Office's time series for the new German Länder was added in the form of a difference to the data for Germany; this was made possible via completion of the time series for the old German Länder, for the period 1995 to 2001.

A comparison of this addition with the data for the new German Länder pursuant to DEBRIV is shown in Table II 1.6.2. Following initial good agreement, the data sets begin to diverge in later periods. The discrepancies are a result of the gaps found in both sources. The two sources can be harmonised well using the individual-plant data in the data library.

For example, the data of the Federal Statistical Office does not include the Amsdorf power stations as of 1996; furthermore, it categorises the Deuben power station inconsistently and in 1998 it does not include the Brieske power station (cf. Table II 1.6.3), while the DEBRIV data does not include the Schwarze Pumpe power station in 1998 (cf. Table II 1.6.4). When such gaps are filled in in both sets of statistics, the statistics agree nearly completely. The resulting agreement has been incorporated within Table II 1.6.5. It shows power generation in the old and new German Länder, and in Germany as a whole, until 2001.

#### 13.7.1.4 Fuel input in mine-pit power stations

The following remarks refer to

- Fuel input for power generation
- Fuel input for heat generation (drying of crude lignite)
- Total fuel input

In Germany, mine-pit power stations are operated in the Rheinland (old German Länder), Lausitz (new German Länder) and Mitteldeutschland (new German Länder) districts.

An important aspect is to break down fuel inputs in accordance with these districts, since the districts must be differentiated by emission factors, due to variations in their fuel characteristics (e.g. carbon content, sulphur content, water content and net calorific value).

#### *13.7.1.4.1 Fuel input for power generation*

Data on fuel inputs for power generation are compiled in the data library. The most important sources include:

- AGEB (old and new German Länder), until 1994
- Federal Statistical Office (old and new German Länder until 1994, and Germany as of 1995)
- DEBRIV (new German Länder), until 2001

The first result of these evaluations is shown in Table II 1.7.5, which summarises the relevant comparison and evaluation of the various statistics and literature information.

Specifically:

1) Table II 1.7.1 (for the old German Länder) and II 1.7.2 (for the new German Länder) show the comparison between Federal Statistical Office and AGEB data until 1994.
   For the old German Länder, the two sources are identical; for the new German Länder, comparison is possible only for 1994. This comparison shows good agreement.
   For the new German Länder, DEBRIV (pursuant to Table II 1.7.2.5) was included in this comparison (II 1.7.2).
   For 1992 and 1993, the DEBRIV data show minor discrepancies with the Energy Balance; for 1994, they deviate more strongly from the Energy Balance. On the basis of their good agreement with Federal Statistical Office data, and of their completeness, the AGEB data for the period 1992 to 1994 are included in Table II 1.7.5.

2) As of 1995, the Federal Statistical Office data for Germany, pursuant to Table 1.7.1.1, and the results pursuant to DEBRIV (Table II 1.7.2.5), for the new German Länder, are combined.
   The difference between the two data sets is an estimate of the fuel input for the old German Länder (Table 1.7.3). Apart from the years 1998 and 1999, this estimate fits well in the known data for the period 1992 to 1994, and for the period as of 2000, for Germany (since that year: Germany = old German Länder). Since power generation for 1998 and 1999 in these plants (cf. Table II 1.6.5) shows no unusual feature, the estimate for these years is rejected and replaced with DEBRIV data (Table II 1.7.1.2). In addition, the last plants still in operation in the new German Länder, in 1998 and 1999, can be identified from data of Federal Statistical Office and DEBRIV (Table II 1.7.4).
   When the DEBRIV data for the old German Länder is added, calculations produce the fuel inputs shown in Table II 1.7.4. Together with figures in Table II 1.7.3 (except for those for 1998 and 1999), the data was included in Table II 1.7.5.

3) Table II 1.7.5 includes a first breakdown of fuel inputs by districts (Reviere). With decommissioning of mine-pit power stations in the Mitteldeutschland district in 1996, the data for the new German Länder, as of 1997, is identical with that for the Lausitz district. The time series for the Lausitz district ends with the decommissioning of the last pit power station in 1999.

Tables II 1.7.7 and II 1.7.8 provide a differentiated presentation of the fuel inputs shown in Table II 1.7.5. Until 1994, AGEB figures for lignite were used; as of 1995, the DEBRIV figures for lignite were used.

For other fuels, as of 1995 data of the Federal Statistical Office is used to complete the time series after 1994. It should be noted that the figures for Germany apply to the new German Länder, since only crude lignite was used in the old German Länder.

#### *13.7.1.4.2 Fuel input for heat generation (drying of crude lignite)*

Table II-1.8.2 shows fuel input for production, in the Rheinland district, of products from crude lignite; it is broken down by products. This table is the result of calculation with the production data in Table I 1.15.6.1 and the specific energy consumption for production (per tonne of these products; Table 1.15.2.1).

Tables II-1.8.3 and II-1.8.4 list the data for the Lausitz and Mitteldeutschland districts. As of 1995, an additional breakdown by manufacturers of lignite products is carried out for the Mitteldeutschland district. This breakdown is necessary, since the MIBRAG power stations have been part of the public grid since 1995 and their fuel inputs for heat generation must be assigned to the public district heat network. For the firm of ROMONTA, which operates the Amsdorf power station, production of small quantities of other lignite is only a by-product of mineral-wax production, which requires most of the process steam used by the company.

The specific fuel inputs for mineral-wax production are not known; as a result, they have to be disregarded here.

Statistically, fuel inputs of other operators must be classified as part of briquetting plants' own consumption.

Table II-1.8.1 summarises fuel inputs for lignite drying, by products.

#### *13.7.1.4.3 Fuel input for heat and power generation, by districts*

Table II 1.7.10 summarises the results to date on lignite input in power stations in the new German Länder. Lignite inputs for heat generation have already been broken down by districts. Such a breakdown remains to be carried out for power generation.

To this end, the following approximation was used:
From the quotient of a) the entire fuel input in the new German Länder and b) the thermal output from combustion in power stations (Table II 1.1.3), the duration of utilisation of the thermal output from combustion is determined. The thermal outputs from combustion, in the Lausitz and Mitteldeutschland districts, are multiplied by this duration of utilisation. This approach is based on the assumption that the utilisation duration is the same in both districts. The result, in each case, is the district's total fuel input. The fuel input for heat generation is then deducted from this total fuel input. The difference is the fuel input for power generation, by district.

The fuel input for power generation, as shown in Table II 1.7.8, consists of crude lignite and lignite products. Lignite products have also been broken down by districts.
This is done on the basis of the districts' production data (Table 1.15.6.2 and 1.15.6.3). In Table II 1.6.20, the product shares for the various districts are shown. These quotients are used to break products down by districts (results shown in Tables II 1.7.21 and II 1.7.22). Table II 1.7.23 also includes these results for the Rheinland district.

The other energy resources are not broken down by districts (Table II 1.7.24).

For fuel inputs for heat generation in the Lausitz and Mitteldeutschland districts, it is assumed that only crude lignite is used (Tables II 1.7.25 and II 1.7.26). This assumption holds for the Rheinland district (Table II 1.7.27).

Tables II 1.7.29 and II 1.7.30 present the relevant results, broken down by fuel input for electricity and power generation and by districts.

Tables II 1.7.31 through II 1.7.33 present fuel inputs for electricity and heat production, for purposes of further calculation (emission factors).

#### *13.7.1.4.4 Planned improvements*

In drying of lignite, part of each quantity lignite is burned (emissions-relevant use for energy recovery) in order to dry the other part (substance recycling, no combustion, no $CO_2$ emissions). Previously, statistics listed the entire mass flow for crude lignite, with the result that the emissions-causing portion of the flow had to be calculated before activity rates – for emissions calculation – could be calculated.

The procedure that the Federal Environmental Agency has used to date – and that is still used in the present inventory report – is currently being modified. Correction of the base year, on the basis of a new calculation method, from 17 million tonnes (the figure currently used) to 15 million tonnes, is being discussed. Relevant consultations of the national group of experts will be completed in May 2004. Correction of the activity rates would affect the entire time series from 1990-2002 – including, especially, the base year, 1990.

### 13.7.1.5 Thermal output from combustion, $SO_2$ and $NO_X$ emissions from mine-pit power stations

In immission-control law, the thermal outputs of combustion plants fired with standard types of fuels are the key criteria used for classifying plants (subject to licensing requirements, not subject to licensing requirements); such thermal outputs is also the key used for defining graduated scales of standards, in legal ordinances and administrative provisions pursuant to the Federal Immission Control Act (BImSchV).

Where data on fuel inputs is lacking or is unreliable, thermal output from combustion, linked with its use over time, is an important figure for determining or estimating fuel inputs and for checking plausibility of fuel-input data.

In energy balance structures, thermal output from combustion is an important structural element for allocating sub-quantities of listed fuel inputs, for delimiting inputs from those of other plants of a given industrial sector and for representing emissions time series. In this light, the thermal output from combustion was used in preparation of the Balance of Emissions Causes (Bilanz der Emissionsursachen - BEU).

In Germany, plants' thermal output from combustion is not recorded in statistics. The data for large combustion plants used here comes from compilations relative to EU Member States' reporting obligations under Directive 88/609/EEC on large combustion plants. This directive requires Member States to provide information, at two-year intervals, on progress in reducing emissions from large combustion plants, and to report such information to the EU. The information obligations include data on thermal output from combustion and on $SO_2$ and $NO_X$

emissions. For Germany, these obligations have been in force since 1990 (old German Länder) and since 1992 (new German Länder).

In Germany, Länder immission-control authorities compile data for their areas of responsibility and provide it to the Federal Environmental Agency. The Federal Environmental Agency processes the relevant documents and reports the results to the EU. Information provided by the Länder in addition to requested information varies greatly in structure. Such additional information, which varies in composition and completeness, includes information on the plant operator, the type of plant in question (for example, power stations, district heat plants, industrial combustion plants), the plant's location, the relevant industrial sector and the fuels used. Due to the structural and content differences in such information, it is not possible to use it to prepare a standardised, complete compilation for all of Germany. With additional effort, it is usually possible to classify the plants by sectors.

The relevant emissions data varies in quality. A distinction must be made between annual use of data from plant operators' emissions declarations and updating/extrapolation on the basis of data provided in earlier years. The latter type of data can be recognised in that it exhibits data constancy over certain time periods. The quality of data can be evaluated during further processing (for example, plausibility of emission factors, in terms of their levels and development over time).

The Federal Environmental Agency's data compilation for pit (Grube) power stations in the new German Länder is oriented, initially, to the former GDR's division of its lignite mining sector into collective energy combines (Kombinaten); for later periods, the compilation is oriented to the companies that emerged from such combines. The compilation also contains dates for decommissioning of plants, with the result that other characteristics of the total group of plants in question (such as electrical output) can also be determined.

Table II 1.1.1 provides a compilation, from the data library, relative to thermal output from combustion. Table II 1.1.2 takes account of reallocation of plants into the public grid and of transfers into (regional) districts. For purposes of further calculations relative to fuel inputs, the relevant output percentages are determined for the decommissioning years in question (Table II 1.1.3), and Table II 1.1.4 summarises the decommissioning data.
The relevant $SO_2$ and $NO_X$ emissions are shown in Tables II 1.2.1 and II 1.2.2 and in Tables II 1.3.1 and II 1.3.2.

#### 13.7.1.6 Compilation of model data (last revision: 31 January 2004)

II-1.5.9 Electrical output of mine-pit power stations in Germany: New definition of districts and corrected extrapolation of the former GDR's statistics (own calculations)

II-1.6.5 Power generation in mine-pit power stations in Germany (own calculation)

II-1.7.29 Fuel input for power generation in mine-pit power stations in Germany (own calculation)

II-1.7.30 Fuel input for heat generation in mine-pit power stations in Germany (own calculation)

II-1.1.5 Thermal output from combustion in mine-pit power stations in Germany (own calculation, last revised 31 December of the relevant year)

II-1.2.1 $SO_2$ emissions generation in mine-pit power stations in Germany (own calculation)

II-1.2.2 $SO_2$ emission in mine-pit power stations in Germany, taking reallocations into other source categories into account (own calculation)

II-1.3.1 $NO_x$ emissions generation in mine-pit power stations in Germany (own calculation)

II-1.3.2 $NO_x$ emission in mine-pit power stations in Germany, taking reallocations into other source categories into account (own calculation)

II-1.5.9 Electrical output of mine-pit power stations in Germany: New definition of districts and corrected extrapolation of GDR statistics (own calculations)

| | | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|
| Total | MW | 2.434 | 2.411 | 2.041 | 1.767 | 1.104 | 1.081 | 525 | 410 | 360 |
| Rheinland (Tab. II-1.5.3) | MW | 371 | 377 | 358 | 352 | 362 | 386 | 380 | 365 | 360 |
| Lausitz (new definition) | MW | 1.278 | 1.278 | 1.195 | 1.166 | 716 | 650 | 100 | 0 | 0 |
| Mitteldeutschland (new definition) | MW | 785 | 756 | 489 | 249 | 26 | 45 | 45 | 45 | 0 |

Sources:
Table II-1.5.3 (Rheinland) and II-1.5.8 (Lausitz, Mitteldeutschland)
Remark:

II-1.6.5 Power generation in mine-pit power stations in Germany (own calculation)

| | | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|
| Germany | GWh | 10.292 | 9.533 | 8.888 | 7.224 | 5.559 | 4.361 | 3.536 | 2.297 | 2.063 |
| Old German Länder | GWh | 1.958 | 2.057 | 2.029 | 1.947 | 2.191 | 2.206 | 2.126 | 2.064 | 2.063 |
| New German Länder | GWh | 8.334 | 7.476 | 6.859 | 5.277 | 3.368 | 2.155 | 1.410 | 233 | 0 |

Sources
NGL (1992-2001) pursuant to F. Stat. Office as in Tab. II-1.6.3
OGL (1992-2001) pursuant to F. Stat. Office as in Tab. II-1.6.1

II-1.7.29 Fuel input for power generation in mine-pit power stations in Germany (own calculation)

| | | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|
| Total | TJ | 116.163 | 109.514 | 96.668 | 84.253 | 62.905 | 47.057 | 37.414 | 21.425 | 17.324 |
| Crude lignite, Rheinland district | TJ | 14.590 | 15.819 | 15.537 | 16.645 | 16.706 | 17.654 | 18.570 | 18.092 | 17.324 |
| Raw lignite, Lausitz district | TJ | 57.489 | 52.022 | 37.914 | 40.497 | 28.720 | 23.483 | 15.890 | 875 | 0 |
| Raw lignite, Mitteldeutschland district | TJ | 23.529 | 27.727 | 27.262 | 13.030 | 9.082 | 4.166 | 2.955 | 2.459 | 0 |
| Lignite briquettes, Lausitz district | TJ | 0 | 0 | 0 | 73 | 36 | 0 | 0 | 0 | 0 |
| Dry coal and coal dust, Lausitz district | TJ | 3.798 | 3.977 | 8.955 | 4.459 | 1.544 | 0 | 0 | 0 | 0 |
| Dry coal and coal dust, Mitteldeutschland district | TJ | 15.300 | 8.269 | 4.914 | 5.829 | 952 | 0 | 0 | 0 | 0 |
| Heavy heating oil, NGL, total | TJ | 82 | 41 | 41 | 34 | 3 | 3 | 0 | 0 | 0 |
| Coke-oven and city gas, NGL, total | TJ | 0 | 0 | 0 | 2.090 | 2.933 | 993 | 0 | 0 | 0 |
| Natural gas, NGL, total | TJ | 32 | 32 | 32 | 20 | 1.759 | 3 | 0 | 0 | 0 |
| Sewage sludge and waste, NGL, total | TJ | 1.343 | 1.627 | 2.013 | 1.576 | 1.170 | 755 | 0 | 0 | 0 |

*Source:*
Tables II-1.7.21, II-1.7.22, II-1.7.23, II-1.7.24
Remark: Lausitz and Mitteldeutschland have been redefined in Table II-1.1.1
Remark: the term "sewage sludge, waste" has been taken from the Energy Balance. In lignite power stations in the new German Länder, this refers to residues from lignite processing: carbonising, gasification, and abrasion in product manufacturing.

II-1.7.30 Fuel input for heat generation in mine-pit power stations in Germany (own calculation)

| | | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|
| insgesamt | TJ | 52.425 | 43.903 | 31.767 | 26.009 | 24.694 | 20.480 | 16.452 | 15.490 | 12.139 |
| Crude lignite, Rheinland district | TJ | 18.175 | 17.107 | 15.720 | 14.817 | 14.893 | 14.161 | 12.526 | 11.660 | 12.139 |
| Raw lignite, Lausitz district | TJ | 20.231 | 16.807 | 12.771 | 9.485 | 9.083 | 6.319 | 3.926 | 3.830 | 0 |
| Raw lignite, Mitteldeutschland district | TJ | 14.018 | 9.989 | 3.276 | 1.707 | 718 | 0 | 0 | 0 | 0 |
| Lignite briquettes, Lausitz district | TJ | | | | | | | | | |
| Dry coal and coal dust, Lausitz district | TJ | | | | | | | | | |
| Dry coal and coal dust, Mitteldeutschland district | TJ | | | | | | | | | |
| Heavy heating oil, NGL, total | TJ | | | | | | | | | |
| Coke-oven and city gas, NGL, total | TJ | | | | | | | | | |
| Natural gas, NGL, total | TJ | | | | | | | | | |
| Sewage sludge and waste, NGL, total | TJ | | | | | | | | | |

*Source:*
Tables II-1.7.25, II-1.7.26, II-1.7.27
Remark: Lausitz and Mitteldeutschland have been redefined in Table II-1.1.1
Remark: the term "sewage sludge, waste" has been taken from the Energy Balance. In lignite power stations in the new German Länder, this refers to residues from lignite processing: carbonising, gasification, and abrasion in product manufacturing.

II-1.1.5 Thermal output from combustion of mine-pit power stations in Germany (own calculation, last revision 31 December)

| | | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|
| Total | MW | 12.935 | 12.701 | 10.777 | 6.480 | 4.071 | 3.642 | 1.890 | 1.496 | 1.496 |
| Lausitz (new definition) | MW | | | | | | | | | |
| Mitteldeutschland (new definition) | MW | | | | | | | | | |
| Rheinland | MW | | | | | | | | | |

*Sources:*
Table II-1.1.2 and 1.1.8.2
Remark:
Division of "Schwarz Pumpe" gas combine: Espenhain power station went to Mitteldeutschland district, all other power stations went to Lausitz district
Rheinland assumed to be constant as of 1996

II-1.2.1 $SO_2$ emissions in mine-pit power stations in Germany (own calculation)

| | | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|
| Total | t/a | 359.138 | 338.421 | 258.291 | 177.290 | 131.606 | k.A | k.A | k.A | k.A |
| Lausitz district (new definition) | t/a | | | | | | | | | |
| Mitteldeutschland district (new definition) | t/a | | | | | | | | | |
| Rheinland district | t/a | | | | | | | | | |

II-1.2.2 $SO_2$ Emissions in mine-pit power stations in Germany, taking account of reallocation into other sectors (own calculation)

| | | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|
| Total | t/a | 359.138 | 338.421 | 231.264 | 110.628 | 81.878 | 33.147 | 17.840 | 2.623 | 0 |
| Lausitz district (new definition) | t/a | | | | | | | | | |
| Mitteldeutschland district (new definition) | t/a | | | | | | | | | |
| Rheinland district | t/a | | | | | | | | | |

II-1.3.1 $NO_X$ emissions in mine-pit power stations in Germany (own calculation)

| | | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|
| Total | t/a | 37.708 | 33.946 | 26.729 | 22.118 | 16.108 | k.A | k.A | k.A | k.A |
| Lausitz district (new definition) | t/a | | | | | | | | | |
| Mitteldeutschland district (new definition) | t/a | | | | | | | | | |
| Rheinland district | t/a | | | | | | | | | |

II-1.3.2 $NO_X$ emissions in mine-pit power stations in Germany, taking account of reallocations into other sectors (own calculations)

| | | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|---|---|---|---|---|---|
| Total | t/a | 37.708 | 33.946 | 25.370 | 18.452 | 12.896 | k.A | k.A | k.A | k.A |
| Lausitz district (new definition) | t/a | | | | | | | | | |
| Mitteldeutschland district (new definition) | t/a | | | | | | | | | |
| Rheinland district | t/a | | | | | | | | | |

[k.A. = no data available]

## 13.8 $CO_2$ emission factors

The emission factors on which the inventory is based have been derived from the list of $CO_2$ emission factors for the German National Allocation Plan. Relevant documentation is currently being prepared.

Table 98: $CO_2$ emission factors for the German National Allocation Plan (last revised: 27.10.2003)

| | | $CO_2$ emission factor | Remarks |
|---|---|---|---|
| Hard coal | | | |
| Ballast hard coal | | t $CO_2$/TJ 90 | |
| Anthracite | | | |
| | Ruhr (use in power stations) | t $CO_2$/TJ 95 | |
| | Heat generation | t $CO_2$/TJ 98 | |
| Whole coal, Germany | | t $CO_2$/TJ 93 | |
| | Ruhr | t $CO_2$/TJ 93 | |
| | Saar | t $CO_2$/TJ 92 | |
| Whole coal, import | | t $CO_2$/TJ 95 | General value for orientation |
| | South Africa | t $CO_2$/TJ 96 | General value for orientation, exporting mine pits |
| | Goedehoop | t $CO_2$/TJ 95 | |
| | Kleinkopje | t $CO_2$/TJ 98 | |
| | Forzando | t $CO_2$/TJ 95 | |
| | Arthur Taylor | t $CO_2$/TJ 97 | |
| | Koornfontein | t $CO_2$/TJ 97 | |
| | Douglas P2 | t $CO_2$/TJ 97 | |
| | Middelburg | t $CO_2$/TJ 95 | |
| | Twistdraai | t $CO_2$/TJ 92 | |
| | Kromdraai | t $CO_2$/TJ 95 | |
| | ATC 1 | t $CO_2$/TJ 97 | |
| | Kangra | t $CO_2$/TJ 98 | |
| | Columbia | t $CO_2$/TJ 94 | General value for orientation, exporting mine pits |
| | Cerrejon | t $CO_2$/TJ 93 | |
| | Cerrejon Central | t $CO_2$/TJ 93 | |
| | Cerrejon Prodeco | t $CO_2$/TJ 95 | |
| | Cerrejon Carbocol | t $CO_2$/TJ 95 | |
| | Cerrejon Norte | t $CO_2$/TJ 94 | |
| | Drummond | t $CO_2$/TJ 95 | |
| | Primero | t $CO_2$/TJ 93 | |
| | Venezuela | t $CO_2$/TJ 93 | General value for orientation, exporting mine pits |
| | Guasare | t $CO_2$/TJ 95 | |
| | Paso Diablo | t $CO_2$/TJ 91 | |
| | USA | t $CO_2$/TJ 94 | General value for orientation, exporting mine pits |
| | Kerr McGee | t $CO_2$/TJ 94 | |
| | AMCI | t $CO_2$/TJ 94 | |
| | Scotts Branch | t $CO_2$/TJ 94 | |

| | | | |
|---|---|---|---|
| ANR | t $CO_2$/TJ | 94 | |
| Drayton | t $CO_2$/TJ | 95 | |
| Permeke | t $CO_2$/TJ | 94 | |
| Baltimore | t $CO_2$/TJ | 95 | |
| Consol | t $CO_2$/TJ | 94 | |
| Canada | | | |
| Mountian | t $CO_2$/TJ | 95 | |
| Poland | t $CO_2$/TJ | 94 | General value for orientation, exporting mine pits |
| Mischkohle | t $CO_2$/TJ | 96 | |
| Poduff | t $CO_2$/TJ | 95 | |
| Anna | t $CO_2$/TJ | 95 | |
| Makoszowy | t $CO_2$/TJ | 93 | |
| Halemba | t $CO_2$/TJ | 93 | |
| Qualität 6000 | t $CO_2$/TJ | 93 | |
| Australia | t $CO_2$/TJ | 95 | General value for orientation, exporting mine pits |
| Stewarton | t $CO_2$/TJ | 93 | |
| Ulan | t $CO_2$/TJ | 94 | |
| Newlands | t $CO_2$/TJ | 94 | |
| Hunter Mischkohle | t $CO_2$/TJ | 95 | |
| MIM | t $CO_2$/TJ | 95 | |
| Blair Athol | t $CO_2$/TJ | 96 | |
| Drayton | t $CO_2$/TJ | 95 | |
| Burton | t $CO_2$/TJ | 94 | |
| South Black Water | t $CO_2$/TJ | 96 | |
| South Walker Creek | t $CO_2$/TJ | 96 | |
| Indonesia | t $CO_2$/TJ | 95 | General value for orientation, exporting mine pits |
| Satui | t $CO_2$/TJ | 95 | |
| Pinang | t $CO_2$/TJ | 96 | |
| Kaltim Prima | t $CO_2$/TJ | 94 | |
| Spitzbergen | | | |
| SVEA | t $CO_2$/TJ | 94 | |
| Russia | t $CO_2$/TJ | 95 | General value for orientation, exporting mine pits |
| Kuzbass | t $CO_2$/TJ | 94 | |
| Kedrowsky | t $CO_2$/TJ | 100 | |
| Murmask-Mischkohle | t $CO_2$/TJ | 96 | |
| Vorgashore | t $CO_2$/TJ | 95 | |
| Kusheyakovsky | t $CO_2$/TJ | 93 | |
| Prokopievskugol | t $CO_2$/TJ | 93 | |

| | | | |
|---|---|---|---|
| | China (Chenhua) | t $CO_2$/TJ 95 | General value for orientation, exporting mine pits |
| | Nantun | t $CO_2$/TJ 96 | |
| | Yanzhou | t $CO_2$/TJ 95 | |
| Hard-coal briquettes | | t $CO_2$/TJ 93 | |
| Hard-coal coke | | t $CO_2$/TJ 105 | |
| Lignite | | | |
| Crude lignite | | | |
| | Rheinland | t $CO_2$/TJ 114 | |
| | Lausitz | t $CO_2$/TJ 113 | |
| | Mitteldeutschland | t $CO_2$/TJ 104 | |
| | Helmstedt | t $CO_2$/TJ 111 | |
| | Hessen (Hirschberg) | t $CO_2$/TJ 111 | |
| Fluidised-bed lignite | | | |
| | Rheinland | t $CO_2$/TJ 98 | |
| | Lausitz | t $CO_2$/TJ 101 | |
| Lignite dust | | | |
| | Rheinland | t $CO_2$/TJ 98 | |
| | Lausitz | t $CO_2$/TJ 99 | |
| | Mitteldeutschland | t $CO_2$/TJ 94 | |
| Lignite briquettes | | | |
| | Rheinland | t $CO_2$/TJ 99 | |
| | Lausitz | t $CO_2$/TJ 101 | |
| | Mitteldeutschland | t $CO_2$/TJ 98 | |
| Lignite coke | | | |
| | Rheinland | t $CO_2$/TJ 108 | |
| Hard lignite | | t $CO_2$/TJ 97 | |
| Fuel peat | | t $CO_2$/TJ 98 | |
| Oil products | | | |
| Crude oil | | t $CO_2$/TJ 80 | |
| Crude petrol | | t $CO_2$/TJ 80 | |
| Engine petrol | | t $CO_2$/TJ 72 | |
| Diesel fuel | | t $CO_2$/TJ 74 | |
| Petroleum and aircraft-engine kerosine | | t $CO_2$/TJ 74 | |
| Heating oil, light | | t $CO_2$/TJ 74 | |
| Heating oil, heavy | | t $CO_2$/TJ 78 | |
| LP gas (butane) | | t $CO_2$/TJ 64 | |
| LP gas (propane) | | t $CO_2$/TJ 65 | |
| Refinery gas | | t $CO_2$/TJ 60 | Considerable range; must be specifically determined in each case |
| Petroleum coke | | t $CO_2$/TJ 101 | |
| Methanol | | t $CO_2$/TJ 71 | |
| Other oil products | | t $CO_2$/TJ 80 | |
| Gases | | | |
| Natural gas L, Netherlands | | t $CO_2$/TJ 56 | |

| | | | | |
|---|---|---|---|---|
| Natural gas H, mixed | | t $CO_2$/TJ | 56 | |
| Natural gas H, Russia | | t $CO_2$/TJ | 55 | |
| Natural gas, Altmark | | t $CO_2$/TJ | 56 | |
| Petroleum gas | | t $CO_2$/TJ | 58 | |
| Coking plant gas | | t $CO_2$/TJ | 40 | Considerable range; must be specifically determined in each case |
| City gas (old German Länder) | | t $CO_2$/TJ | 40 | |
| City gas (new German Länder) | | t $CO_2$/TJ | 50 | |
| City gas (gas separated under high pressure from natural gas) | | t $CO_2$/TJ | 53 | West Berlin until 1995 |
| Blast furnace gas | | t $CO_2$/TJ | 268 | Considerable range; for plant-specific study, must be specifically determined in each case; for national inventories, for reasons of consistency, 105 t $CO_2$/TJ |
| Converter gas | | t $CO_2$/TJ | 183 | Considerable range; for plant-specific study, must be specifically determined in each case; for national inventories, for reasons of consistency, 105 t $CO_2$/TJ |
| Pit gas | | t $CO_2$/TJ | 55 | |
| Biogas | | t $CO_2$/TJ | 0 | Where recognised as biomass |
| Gas from sewage treatment | | t $CO_2$/TJ | 0 | Where recognised as biomass |
| Other fuels | | | | |
| Household waste | | t $CO_2$/TJ | 15 | |
| Industrial waste | | t $CO_2$/TJ | 20 | Lignite waste, only new German Länder: 94 t/TJ |
| Sewage sludge | | | | No EF available |
| Firewood and other biomass | | t $CO_2$/TJ | 0 | Where recognised as biomass |

Sources: Federal Environmental Agency, figures from companies and associations, AG Energiebilanzen, ifeu-Institut für Energie und Umweltforschung, calculations of Öko-Institut

# 14 ANNEX 3: OTHER DETAILED METHODOLOGICAL DESCRIPTIONS FOR INDIVIDUAL SOURCE OR SINK CATEGORIES (WHERE RELEVANT)

## 14.1 Other detailed methodological descriptions for the source category "energy" (1)

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

### *14.1.1 Energy Industries (1.A.1)*

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

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

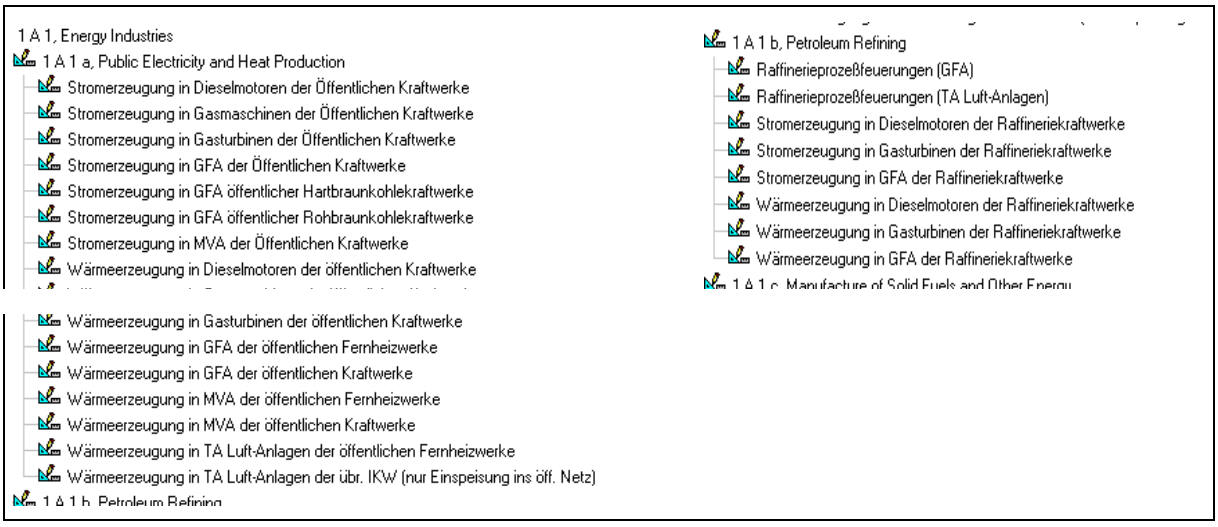



Figure 31: Structural allocation, 1.A.1a Public electricity and heat production, and 1.A.1b Refineries

Under source category 1.A.1c, Manufacture of solid fuels and other energy, the CSE includes electricity and heat production of mine-pit power stations, of the lignite mining sector, of the hard-coal-mining sector, of other mine power stations and of mine and mine-pit power stations, as well as production of hard-coal coke, other process combustion and heat production in the transformation sector.

Figure 32: Structural allocation, 1.A.1c Manufacture of solid fuels and other energy

### *14.1.2 Manufacturing industries and construction (1.A.2)*

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

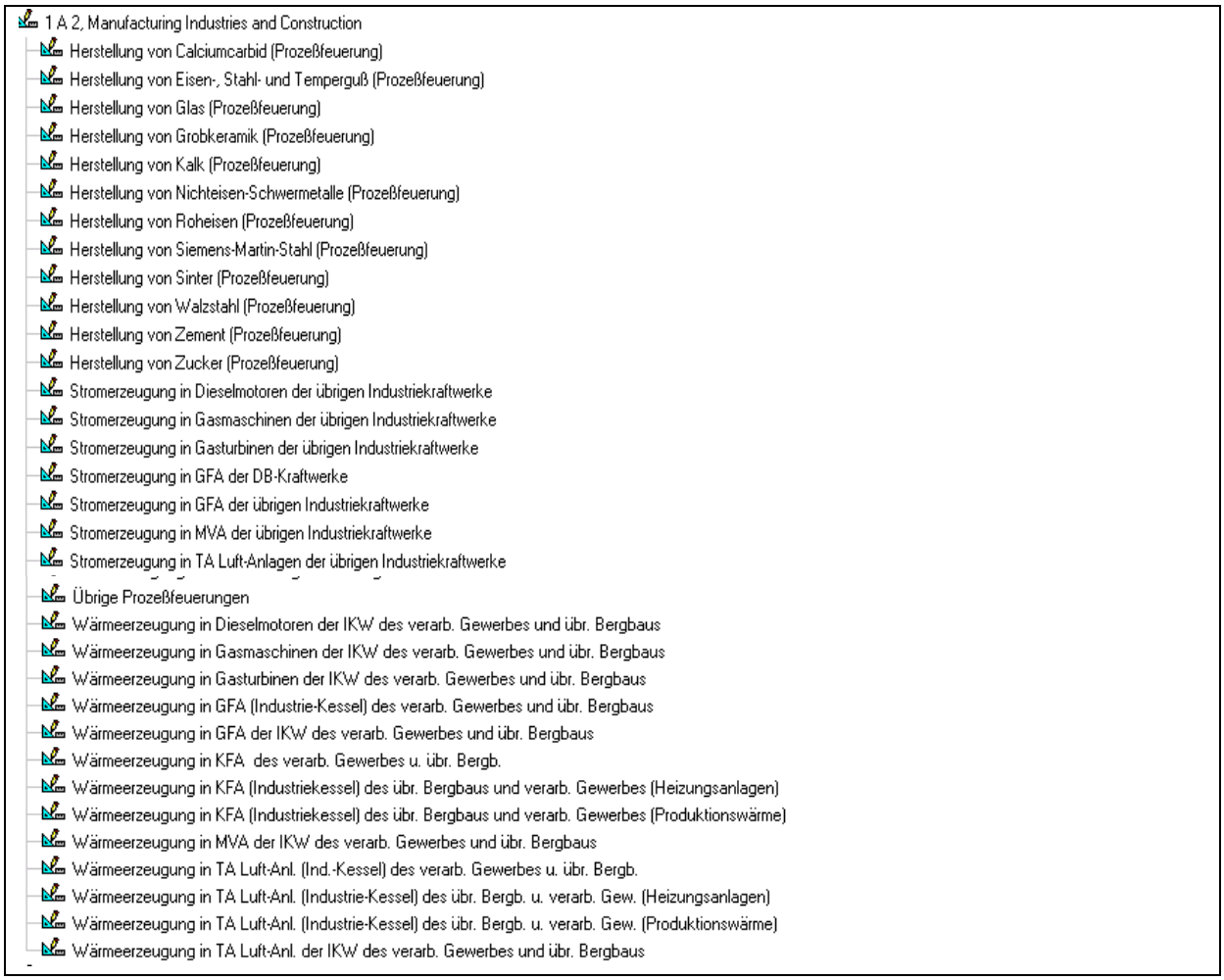



Figure 33: Structural allocation, 1.A.2 Manufacturing industries and construction

### *14.1.3 Transport (1.A.3)*

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

Figure 34: Structural allocation, 1.A.3a Civil aviation

Source category 1.A.3b Road transport includes mopeds, motorcycles, diesel-engine automobiles, petrol-engine automobiles, buses, light utility vehicles with diesel and petrol engines and heavy utility vehicles, broken down by emissions-reduction equipment.

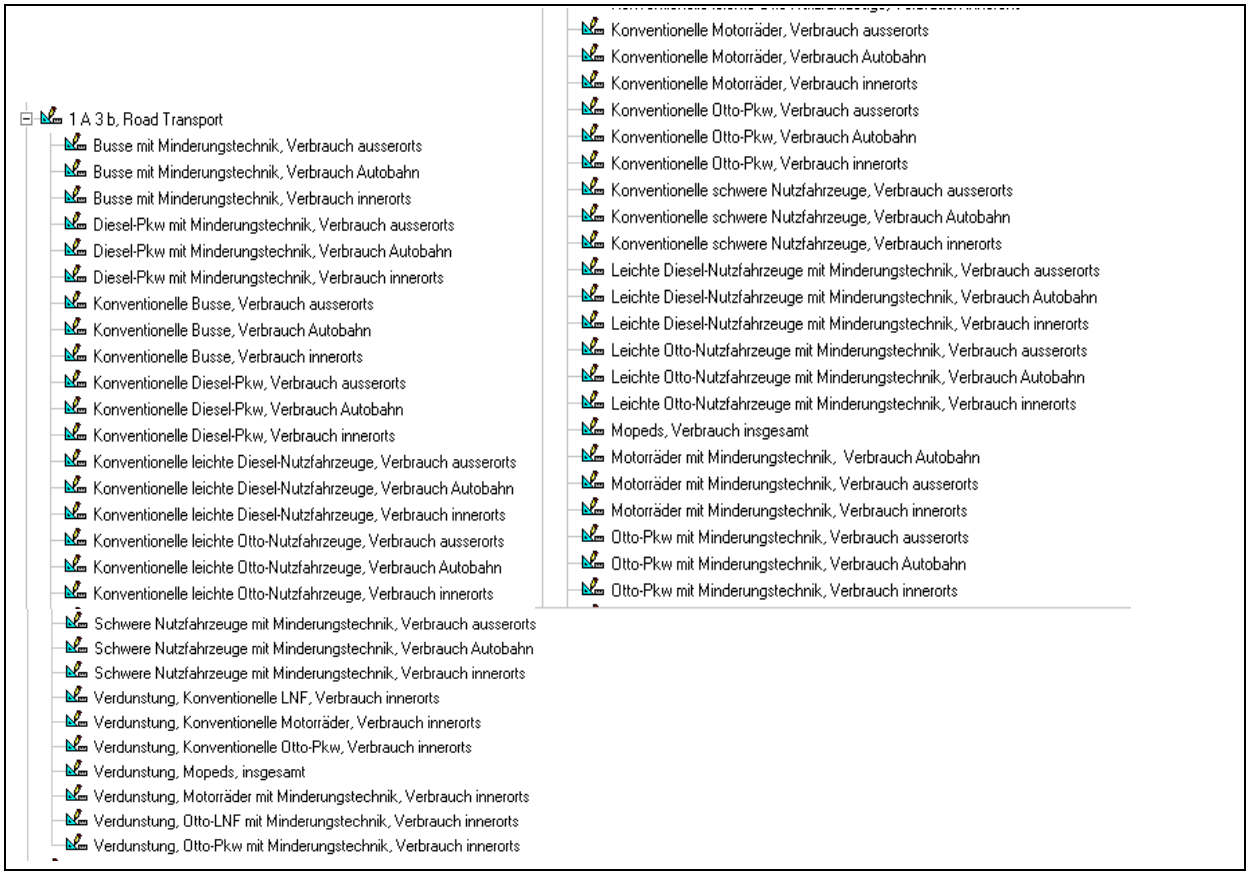



Figure 35: Structural allocation, 1.A.3b Road transport

Source category 1.A.3c Railways is not further sub-divided in the CSE. Under source category 1.A.3d Navigation, the CSE includes coastal and inland fishing and coastal and inland shipping. Source category 1.A.3e Other: pipelines, construction (off road) includes, in the CSE, construction transports and gas turbines in natural-gas-compressor stations.

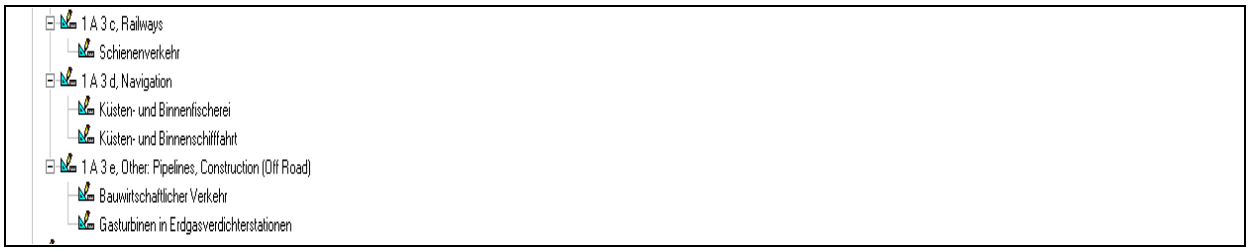



Figure 36: Structural allocation, 1.A.3c Railways, 1.A.3d Navigation and 1.A.3e Other

#### 14.1.3.1 Derivation of activity rates for road transport (1.A.3b)

##### *14.1.3.1.1 Cross-check with Energy Balance*

The basis for CSE data collection for the road-transport sector consists of energy consumption data provided by the Working Group on Energy Balances (AGEB). For each year, the sum of the activity rates for the various individual structural elements must correspond to the Energy Balance data, in TJ. The relevant basic Energy Balance data is shown in Table 99 below.

Table 99: Energy balances, 1990-2002

| Year | Region/ Country | Line | Petrol | Petroleum | Diesel fuel | Liquid gas | Biodiesel |
|---|---|---|---|---|---|---|---|
| Energy consumption in road transports, pursuant to energy balances 90-99 (last revision: 12/2002), in TJ | | | | | | | |
| 1990 | ABL | 75 | 1159942 | 0 | 657443 | 138 | 0 |
| 1990 | NBL | 75 | 170537 | 0 | 78477 | 0 | 0 |
| 1991 | ABL | 75 | 1156589 | 0 | 700405 | 137 | 0 |
| 1991 | NBL | 75 | 175696 | 0 | 84769 | 0 | 0 |
| 1992 | ABL | 75 | 1157939 | 0 | 740248 | 229 | 0 |
| 1992 | NBL | 75 | 186190 | 0 | 113254 | 0 | 0 |
| 1993 | ABL | 75 | 1158636 | 473 | 777146 | 184 | 0 |
| 1993 | NBL | 75 | 191981 | 0 | 130641 | 0 | 0 |
| 1994 | ABL | 75 | 1082653 | 559 | 787800 | 184 | 0 |
| 1994 | NBL | 75 | 193984 | 0 | 144260 | 0 | 0 |
| 1995 | D | 62 | 1299982 | 610 | 964013 | 138 | 1504 |
| 1996 | D | 62 | 1299879 | 638 | 964580 | 115 | 2046 |
| 1997 | D | 62 | 1297487 | 357 | 979586 | 106 | 3652 |
| 1998 | D | 62 | 1300463 | 637 | 1022794 | 106 | 4081 |
| 1999 | D | 62 | 1300602 | 637 | 1097036 | 100 | 5370 |
| Provisional figures, pursuant to evaluation tables * | | | | | | | |
| 2000 | D | 62 | 1238000 | 600 | 1107754 | 100 | 14000 |
| 2001 | D | 62 | 1200000 | 600 | 1098117 | 100 | 19000 |
| 2002 | D | 62 | 1167000 | 600 | 1107123 | 100 | 23000 |

ABL = old German Länder; NBL = new German Länder; D = Germany
Sources:
Energy balances 90-99 (AGEB, Last revision: 12/2002), in TJ
Evaluation tables (Auswertetabellen), Energy Balance:
for petrol: Energy Balance evaluation tables, last revision 31 July 2003; diesel fuel: Energy Balance evaluation tables, last revision 31 July 2003, (figures for diesel fuel) – (figures for railways and inland shipping); biodiesel: Energy Balance evaluation tables, last revision 31 July 2003, (figures for other fuels) – 1 PJ [approximation]

The Energy Balance is also used to model transport-quantity structures in TREMOD. For example, the German Institute for Economic Research (DIW) carries out a fuel-consumption

calculation in order to derive total mileage travelled (DIW, 2002). Some of the results of the calculation, for automobile traffic, are entered into TREMOD. The DIW uses a fuel-consumption calculation in order to determine total domestic mileage; TREMOD uses some other sources and assumptions to estimate total domestic mileage – especially for goods transports (cf. the detailed description in IFEU, 2002). This estimate also takes the basic figures of the Energy Balance into account.

On the other hand, due to the many dependencies and uncertainties in the model, and to the basic data that must be taken into account, no feasible means is available for comparing mileage and energy consumption, for each year and each vehicle layer, in such a manner that the results yield the Energy Balance sum and the mileage and average energy consumption figures in the time series are plausible. For this reason, the TREMOD results for the energy consumption are corrected, at the end of the process, in such a manner that the total for each reference year corresponds to the relevant figure in the Energy Balance.

Since TREMOD calculates energy consumption in tonnes, the results first have to be converted into TJ. For this purpose the net calorific values of the Working Group on Energy Balances (AGEB) are used (cf. Table 100).

Table 100: Net calorific values for petrol and diesel fuel

| **Year** | Petrol | Diesel fuel |
|---|---|---|
| 1990-1992 | 43.543 MJ/kg | 42.704 MJ/kg |
| As of 1993 | 43.543 MJ/kg | 42.960 MJ/kg |

Source: Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen)

In TREMOD, the correction factors are derived separately for the categories "automobiles" and "other motor vehicles". The reason for this differentiation is that to date TREMOD contains relatively low basic consumption values for diesel automobiles; these values yield an average fuel consumption that is considerably below the DIW values (DIW, 2002). For this reason, upward correction for the consumption figures for diesel automobiles is considerably greater than that for the consumption figures for diesel-powered utility vehicles. This differentiation was applies as of the reference year 1994.

For 2002, provisional Energy Balance data is now available, but no data on transport quantities is yet available. The transport quantities in TREMOD 2002 are thus still scenario figures. The correction factors will thus certainly change as soon as the model is updated to 2002 in the mileage category.

Table 101 below summarises the correction factors used.

Table 101: Correction factors for adjustment to the Energy Balance

| Year | Country | Petrol | | Diesel fuel | |
|---|---|---|---|---|---|
| | | **Automobiles** | **Other** | **Automobiles** | **Other** |
| 1990 | ABL | 1,0182 | 1,0182 | 1,0660 | 1,0660 |
| 1990 | NBL | 1,0091 | 1,0091 | 1,5264 | 1,5264 |
| 1991 | ABL | 1,0189 | 1,0189 | 1,0309 | 1,0309 |
| 1991 | NBL | 1,0638 | 1,0638 | 1,0597 | 1,0597 |
| 1992 | ABL | 1,0253 | 1,0253 | 1,0745 | 1,0745 |
| 1992 | NBL | 1,0246 | 1,0246 | 1,1146 | 1,1146 |
| 1993 | ABL | 1,0582 | 1,0582 | 1,1563 | 1,1563 |
| 1993 | NBL | 0,9808 | 0,9808 | 1,0702 | 1,0702 |
| 1994 | ABL | 1,0500 | 1 | 1,2 | 1,0434 |
| 1994 | NBL | 1,0500 | 1 | 1,2 | 1,0434 |
| 1995 | D | 1,0694 | 1 | 1,2 | 1,0422 |
| 1996 | D | 1,0699 | 1 | 1,2 | 1,0389 |
| 1997 | D | 1,0674 | 1 | 1,19 | 1,0226 |
| 1998 | D | 1,0570 | 1 | 1,183 | 1,0515 |
| 1999 | D | 1,0474 | 1 | 1,19 | 1,0709 |
| 2000 | D | 1,0401 | 1 | 1,20 | 1,0627 |
| 2001 | D | 1,0421 | 1 | 1,20 | 1,0134 |
| 2002 | D | 1,0207 | 1 | 1,18 | 0,9887 |
| Remarks: Until 1993, for ABL (old German Länder) and NBL (new German Länder) no differentiation by vehicle categories; in 1994, correction factors for ABL and NBL as in D as a whole | | | | | |

#### *14.1.3.1.2 Allocation of biodiesel, petroleum and LP gas to the structural elements*

In the Energy Balance, biodiesel, petroleum and LP gas are listed in the transport sector; for this reason, they have not been included in TREMOD, to date, as separate categories. For purposes of importing into CSE, the results for these fuels are thus derived additionally. To this end, the energy consumption, pursuant to the Energy Balance, is allocated to the relevant structural elements in keeping with the specifications of the Federal Environmental Agency:

- **Biodiesel** is allocated to all structural elements with diesel engines, in keeping with their percentage shares of consumption of conventional diesel fuel.
- **Petroleum** is allocated to buses on roads outside of municipalities – and, thus, to the structural elements SV BUS KOAO and SV BUS MTAO – in keeping with their percentage shares of consumption of conventional diesel fuel
- **LP gas** is allocated to conventional automobiles, with petrol engines, on municipal roads (structural element SV PKWO KOIO).

#### *14.1.3.1.3 Activity rate for evaporation*

The activity rate for evaporation emissions is set as total petrol consumption, on municipal roads, pursuant to TREMOD; the corresponding figure for mopeds is the total consumption. The values corrected for the Energy Balance are used.

### 14.1.3.2 Derivation of emission factors

#### *14.1.3.2.1 Emission factors from TREMOD*

In the CSE, emission factors for the "engines" ("Antrieb") category are listed in kg/TJ, while those for the "Evaporation" category are given in kg/t. For the subtances "petrol" and "diesel fuel", these values can be derived from TREMOD for all structural elements. To this end, emissions (in tonnes) and energy consumption (in TJ; converted from the results "energy

consumption in t", using the net calorific values pursuant to Table 100) are derived from the TREMOD results and allocated to the relevant structural elements. The emission factor for each structural element then results as the quotient resulting from emissions, in tonnes per structural element, divided by the energy consumption, per structural element, in TJ. A similar procedure is used to obtain the emission factors for evaporation (evaporation emissions, in kg / consumption on municipal roads, in t).

For purposes of this derivation, TREMOD results without correction to the Energy Balance are used, since such correction is already contained in the activity rates for the CSE. Use of the corrected values (emissions and energy consumption) leads to the same results, however, since the correction factor cancels out in calculation of mean emission factors (emissions corrected / energy corrected = emissions uncorrected / energy uncorrected).

#### *14.1.3.2.2 Emission factors for biodiesel, petroleum and LP gas*

For all structural elements, the emission factors for biodiesel and petroleum, in keeping with the Federal Environmental Agency's specifications, are set to the same values as those for conventional diesel fuel. Exceptions:

- The $CO_2$ emission factor for biodiesel is set to "0"
- The $SO_2$ emission factor for Petroleum: in those years in which diesel fuel has a higher value, this factor is set to 24 kg/TJ. In all other years, the lower value for diesel fuel is used.

The emission factors for automobiles that run on LP gas are set as follows, in keeping with the Federal Environmental Agency's specifications:

Table 102: Emission factors for automobiles that run on LP gas

| **Gas** | Type of vehicle | Structural element | **EBL** | **Units** | **1995-2001** |
|---|---|---|---|---|---|
| $CH_4$ | Automobile | SV PKWO KOIO | EBL 62 | kg/TJ | 3 |
| CO | Automobile | SV PKWO KOIO | EBL 62 | kg/TJ | 350 |
| $CO_2$ | Automobile | SV PKWO KOIO | EBL 62 | kg/TJ | 65'000,00 |
| $N_2O$ | Automobile | SV PKWO KOIO | EBL 62 | kg/TJ | 1,7 |
| $NH_3$ | Automobile | SV PKWO KOIO | EBL 62 | kg/TJ | 0,5 |
| NMVOC | Automobile | SV PKWO KOIO | EBL 62 | kg/TJ | 157 |
| NOx | Automobile | SV PKWO KOIO | EBL 62 | kg/TJ | 975 |
| $SO_2$ | Automobile | SV PKWO KOIO | EBL 62 | kg/TJ | 1,7 |

### 14.1.3.3 Expansion to include natural gas as a fuel

TREMOD updating includes the option of listing natural gas as a fuel, if the Working Group on Energy Balances (AGEB) lists natural gas as a transport fuel in future. In the present interface, this is possible only if the allocation criteria are precisely defined, in a manner similar to that used for biodiesel, natural gas and petroleum:

- Listing of the affected structural elements and their respective percentage shares of consumption
- Listing of emission factors for the relevant structural elements

Furthermore, general data tables could now be defined into which these figures could be explicitly entered. The relevant minimum requirements are shown in the following tables (Tables 103 and 104):

Table 103: Entry structure for natural gas: Structural element's percentage share of energy consumption

| Material | Structural element | Share/year |
|---|---|---|
| Natural gas | For example, SV BUS MTIO | 60% |
| Natural gas | ... | ... |
| Natural gas | Total | 100% |

Table 104: Entry structure for natural gas: Emission factors

| **Gas** | Structural element | **Units** | Values/reference year |
|---|---|---|---|
| CHx | For example, SV BUS MTIO | kg/TJ | |
| CO | For example, SV BUS MTIO | kg/TJ | |
| COx | For example, SV BUS MTIO | kg/TJ | |
| NxO | For example, SV BUS MTIO | kg/TJ | |
| NHx | For example, SV BUS MTIO | kg/TJ | |
| NMVOC | For example, SV BUS MTIO | kg/TJ | |
| NOx | For example, SV BUS MTIO | kg/TJ | |
| SOx | For example, SV BUS MTIO | kg/TJ | |

Alternatively, the percentage shares for structural elements can be given in a form similar to that used for existing structures (as is done for petroleum and biodiesel). To this end, a suitable calculation rule would have to be defined and developed (for example, breakdown of natural gas by the vehicle categories BUS, LNF and SNF on municipal roads, in keeping with the various categories' shares of diesel-fuel consumption). This approach is more complex, and it is more difficult to adapt to changed allocation rules, but it offers the advantage that the percentage shares do not have to be defined explicitly, for each year, in a table.

Since it is difficult to specify a relevant calculation rule at present, natural-gas tables should be added to the current interface; these tables could then be filled as necessary. Such tables will also be integrated into the final version if necessary. In future, an attempt should be made to integrate the fuels biodiesel, petroleum, LP gas and natural gas directly within TREMOD, however.

#### 14.1.3.4 Derivation of data for western and eastern Germany, 1994

TREMOD distinguishes between old and new German Länder only until 1993. Since CSE also requires such differentiation for 1994, a relevant breakdown must be made using simplifying assumptions. The parameters include:

- The sum total of activity rates for engines (Antrieb) must correspond to the relevant Energy Balance values (in each case, old and new German Länder).

- In the overall result, emissions resulting from linking activity rates with emission factors must correspond to the TREMOD results for Germany.
- With these parameters, the present study can carry out a relevant breakdown only under the following assumptions:
- The emission factors for old and new German Länder are set, for all structural elements, to the relevant values for all of Germany in 1994.
- The structural elements' percentage shares of the activity rates, for each fuel, are considered to be the same in each case for the old and new German Länder, and they correspond to the relevant values for all of Germany in 1994.

With these assumptions, the aforementioned conditions are met. A third condition is not met, however: the plausibility of emissions results in the time series, in each case, for the old/new German Länder. For this condition to be fulfilled, the 1994 should be remodelled in TREMOD; this should be done via separate derivation of vehicle stocks and mileages for the old and new German Länder, followed by recalculation of emissions on the basis of this data.

### *14.1.4 Other source categories (1.A.4)*

In the CSE, source category 1.A.4 Other sectors includes heat production of other small consumers, mobile sources and heat production of households, as well as agricultural traffic and heat production in agriculture and horticulture.

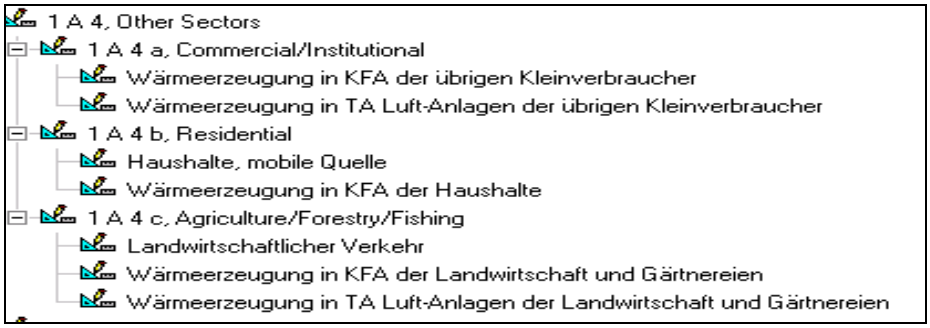



Figure 37: Structural allocation, 1.A.4 Other sectors

### *14.1.5 Other: Military (1.A.5)*

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

Figure 38: Structural allocation, 1.A.5 Other: Military

### *14.1.6 Fugitive emissions from solid fuels (1.B.1)*

In the CSE, source category 1.B.1a Mining includes pit gas, lignite mining, hard-coal mining and storage and decommissioned mines.

CSE source category 1.B.1b Solid fuel transformation includes hard-coal-coke production, briquette production, lignite-dust processing and hard-coal processing.

Figure 39: Structural allocation, 1.B.1 Solid fuels

### *14.1.7 Oil and natural gas (1.B.2)*

Source category 1.B.2a Oil includes consumption of petrol, oil extraction, refinery operations and desulphurisation in refineries.

CSE source category 1.B.2b Natural gas includes natural-gas extraction and use, natural-gas and oil processing, high-pressure natural-gas networks, long-distance natural gas transports and natural gas and sulphur production.

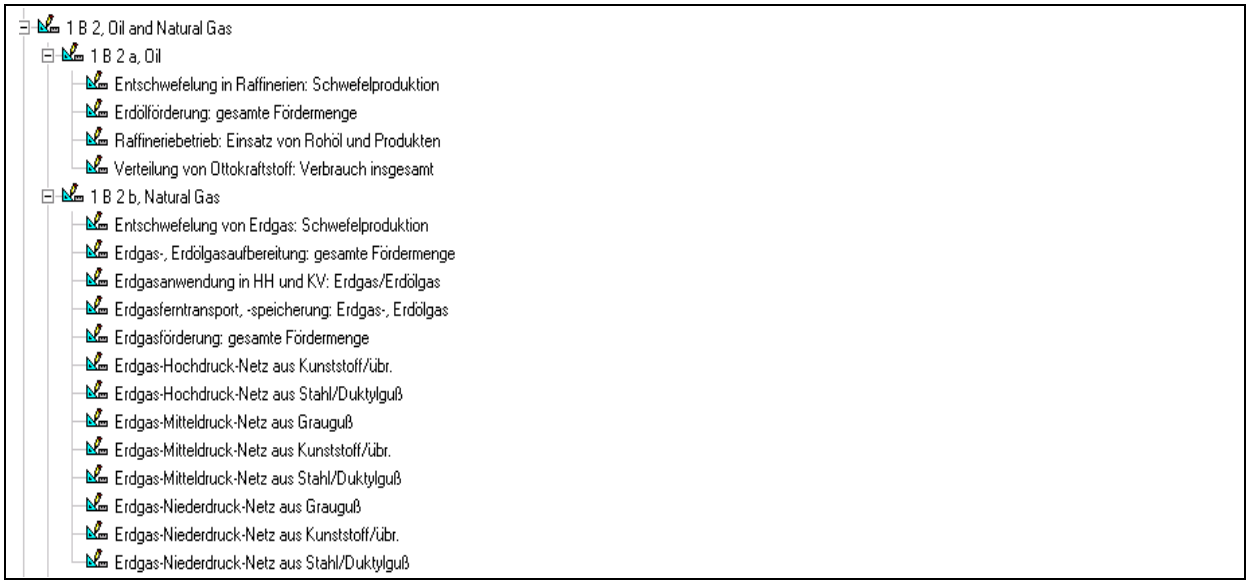



Figure 40: Structural allocation, 1.B.2a Oil, and 1.B2b Natural gas

Source category 1.B.2c Flaring of natural gas is not listed as such in the CSE. In the CSE, high-pressure city-gas networks and city-gas processing and use are assigned to the CRF-mandated category 1.B.2d Other. Use of city gas was discontinued in 1994.

Figure 41: Structural allocation, 1.B.2c Flaring of natural gas, and 1.B.2d Other

### *14.1.8 Aviation and Marine (1.BU.1/1.BU.2)*

In reporting, international transports are included only for informational purposes, i.e. the relevant individual positions are not listed among total national emissions. International civil aviation is separately listed as such in the CSE. The international Marine category includes international blue-water fisheries and blue-water shipping.

Figure 42: Structural allocation, 1.BU.1 Civil aviation (international) and 1.BU.2 Marine (international)

## 14.2 Other detailed methodological descriptions for the source category "industrial processes" (2)

### *14.2.1 Mineral products (2.A)*

Source category 2.A Mineral products is divided into the sub-categories 2.A.1 through 2.A.7. These include Cement production, divided into cement clinker production and cement production (2.A.1), Lime production (2.A.2), Soda ash production and use (2.A.4), Asphalt roofing (2.A.5) and, under Other (2.A.7), glass production, coarse ceramics and salt and potassium salt production.

No data on Limestone and dolomite use (2.A.3) is collected.

Figure 43: Structural allocation, 2.A Mineral products

### *14.2.2 Chemical industry (2.B)*

Source category 2.B is sub-divided into sub-categories 2.B.1 through 2.B.5. These include ammonia production (2.B.1), nitric acid production (2.B.2), adipic acid production (2.B.3) and carbide production (2.B.4).

In the CSE, sub-category Other (2.B.5) includes fertiliser and nitrous oxide production, organic products, soot and titanium-oxide product and sulphuric acid production.

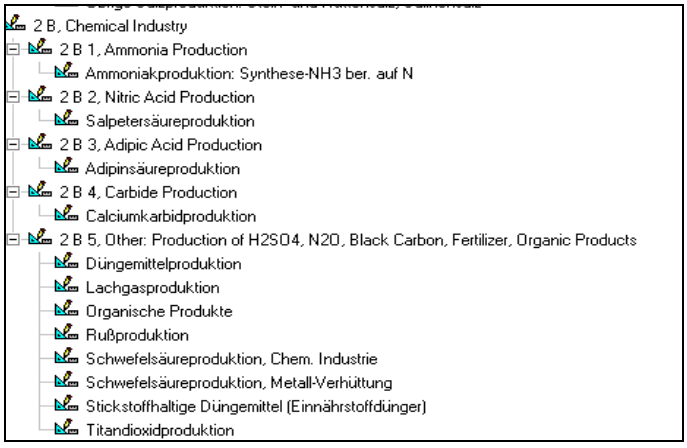



Figure 44: Structural allocation, 2.B Chemical industry

### *14.2.3 Metal production (2.C)*

Source category 2.C is sub-divided into sub-categories 2.C.1 through 2.C.5. In the CSE, sub-category Iron and steel production (2.C.1) includes iron and steel production and malleable castings, pig-iron production, sinter production and steel products. Production of ferroalloys (2.C.2) is listed directly as such in the CSE. Aluminium production (2.C.3) is sub-divided into primary aluminium and resmelted aluminium. Use of $SF_6$ in aluminium and magnesium production (2.C.5) is not further sub-divided. In the CSE, sub-category Other (2.C.5) includes lead production, hot galvanising, copper production and zinc production.

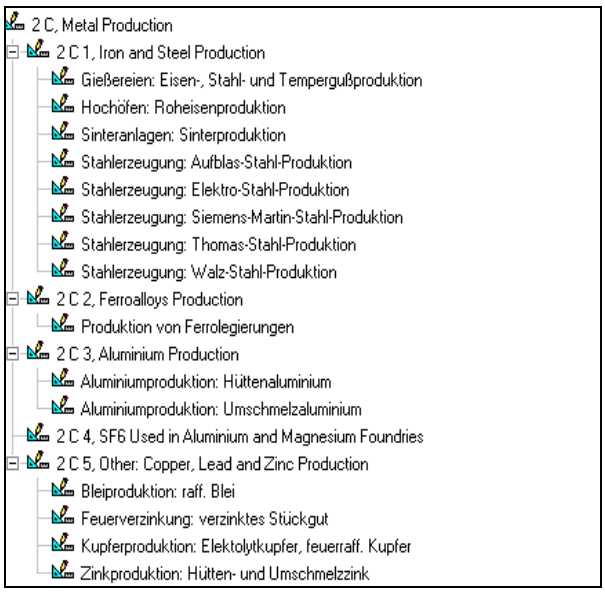



Figure 45: Structural allocation, 2.C Metal production

### *14.2.4 Other production (2.D)*

Source category 2D Other production is divided into the sub-categories 2.D.1 and 2.D.2. In the CSE, 2.D.1 Pulp and paper includes pressboard production and pulp processing, while 2.D.2 Food and drink includes production of beer, bread, spirits, wine and sugar.

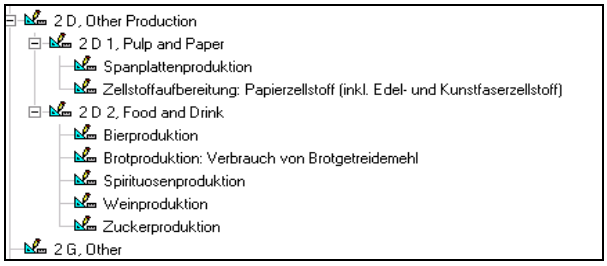



Figure 46: Structural allocation, 2.D Other production

## 14.3 Other detailed methodological descriptions for the source category "solvents and other product use" (3)

Source category 3 Solvent and other product use is divided into the sub-categories 3.A through 3.D. These include emissions from painting and lacquering (3.A), Degreasing and dry cleaning (3.B) and production and use of chemical products (3.C). CSE sub-category Other (3.D) comprises nitrous oxide emissions, emissions from SCR installations and other solvent use.

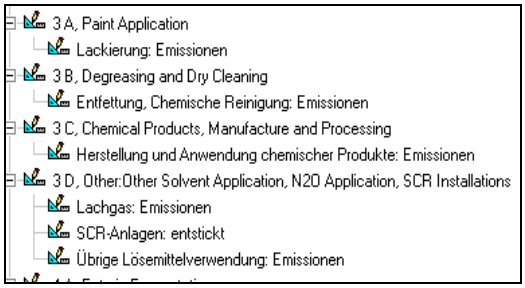



Figure 47: Structural allocation, 3 Solvents and other product use

## 14.4 Other detailed methodological descriptions for the source category "agriculture" (4)

Source category 4 Agriculture is divided into the sub-categories 4.A through 4.D. These include Fermentation emissions (4.A), Fertiliser management (4.B), Rice cultivation (4.C) and Agricultural soils (4.D). No emissions from rice cultivation occur in Germany.

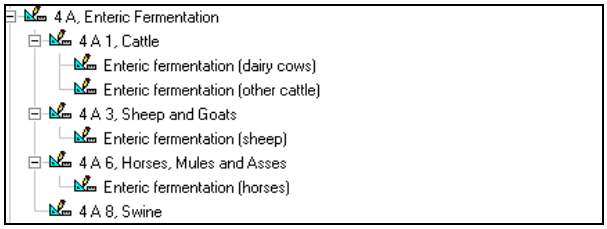



Figure 48: Structural allocation, 4.A Fermentations

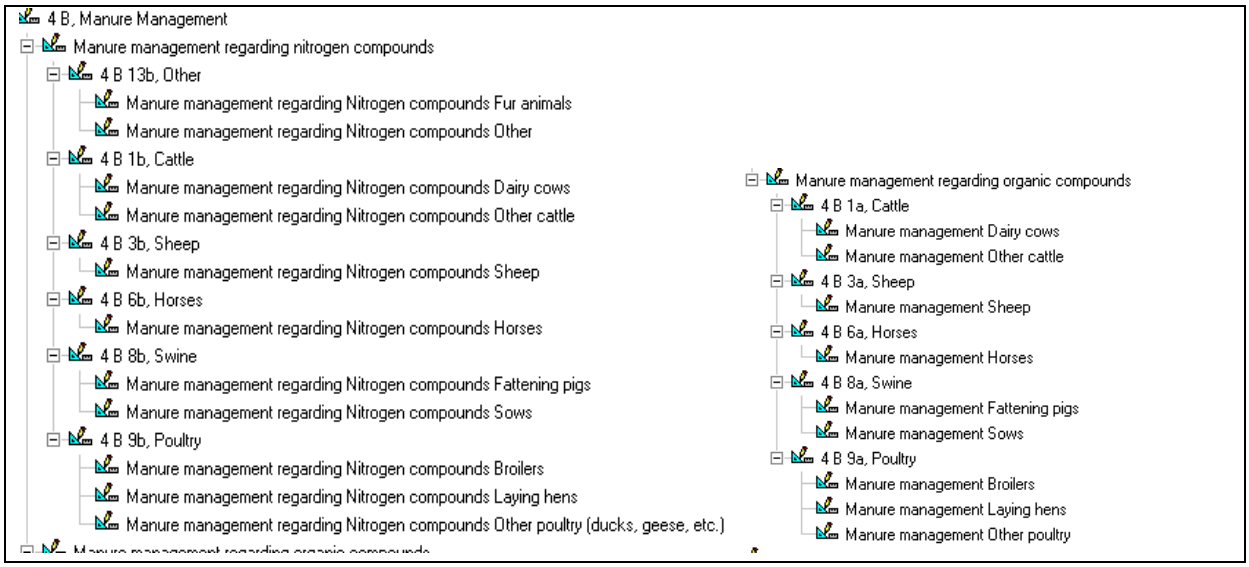



Figure 49: Structural allocation, 4.B Manure management

In the CSE, source category 4.D Agricultural soils includes crop cultivation with and without fertiliser use.

Figure 50: Structural allocation, 4.D Agricultural soils

### *14.4.1 Agriculture (4) – Data on steps for improving future inventories*

- Collection of regional data, especially with regard to frequency distribution in connection with keeping of farm animals
- Collection of regional data on use of mineral fertilisers
- Enhancement of spatial resolution of data on emissions of reactive gases ($CH_4$,NO)
- Development of procedures, adapted to German data sets, for determining $CH_4$ emissions from enteric fermentation as a function of yields and feeding, for the most important animal categories
- Inclusion of immobilisation and mobilisation of N-species in manure management in connection with straw-based procedures
- Inclusion of procedures for biogas collection
- Enhancement of chronological resolution, to one month, of data on emissions of reactive gases (especially $NH_3$)

### *14.4.2 Agriculture (4) – data for forecasts of agricultural emissions*

At a meeting in Luxemburg on 26 June 2003, the ministers of agriculture of the European Union approved a far-reaching reform of the Common Agricultural Policy. This reform permits numerous options. At the time the present report was prepared, the various degrees of national latitude could not yet be estimated; several months are expected to pass before administrative directions are issued. Extensive income redistributions are expected; these are likely to lead to considerable changes, especially in numbers of cattle. In light of the importance of cattle farming with regard to methane and ammonia emissions, neither any scenario modelling nor extrapolation of the *status quo* seems at all useful.

## 14.5 Other detailed methodological descriptions for the source/sink category Land-use change and forestry (5)

Source / sink category 5 Land-use change and forestry is divided into sub-categories 5.A through 5.D. These include changes in forest and other wood biomass stocks (5.A), Forest and grassland conversion (5.B), Abandonment of managed lands (5.C) and $CO_2$ emissions and removals from soil (5.D).

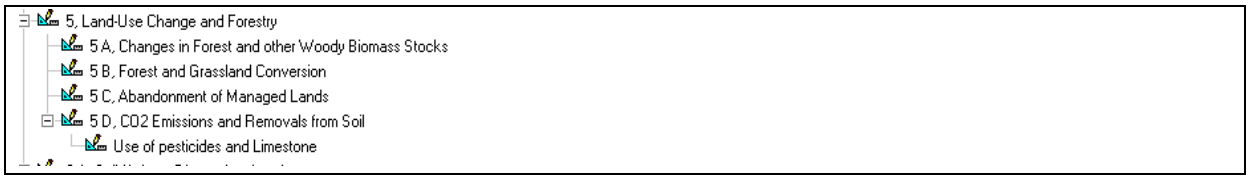



Figure 51: Structural allocation, 5.D Land-use change and forestry

## 14.6 Other detailed methodological descriptions for the source category "Waste and wastewater" (6)

Source category 6 Waste is divided into the sub-categories 6.A, 6.B, 6.C and 6.D. In the CSE, sub-category 6.A Solid waste disposal on land includes landfilled household waste and sewage sludge. Under sub-category 6.B Wastewater handling, the CSE lists wastewater quantities, treatment of sewage sludge and sewage-sludge production in wastewater treatment. CSE sub-category 6.D Other waste includes spread sewage sludge.

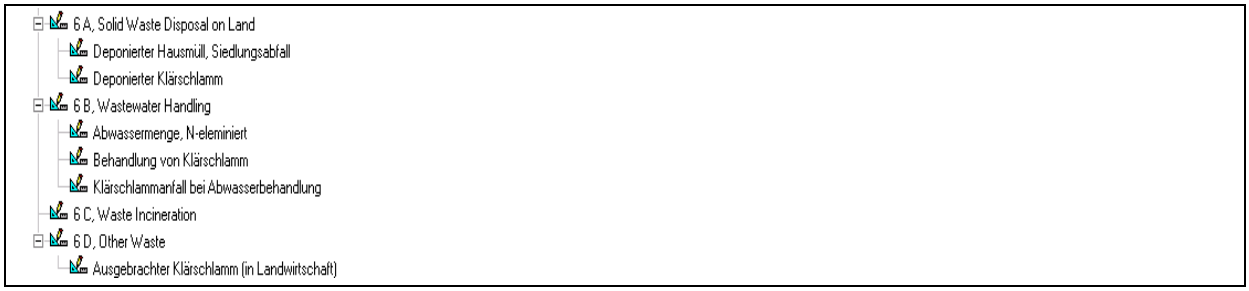



Figure 52: Structural allocation, 6 Waste and wastewater

### *14.6.1 Waste (6.A) – data for the Tier 2 approach, as used*

Activity data for the relevant quantities of municipal waste, and for the quantities landfilled, was collected for the following fractions:

- Household waste, commercial waste similar to household waste and collected via public waste collection
- Commercial waste similar to household waste, but not collected via public waste collection (not including household waste and bulky waste)
- Mixed municipal waste and other types of such waste
- Bulky waste
- Compostable waste collected in "Biotonne" bins / compostable waste delivered separately
- Separated waste (glass, paper, plastics, electronic components)
- Road sweepings (including waste from public wastepaper baskets)
- Market waste

- Garden and park waste

The new Environmental Statistics Act (UstatG) permits collection of statistics on all key components of managed waste; in contrast to earlier procedures, however, waste quantities and waste origins must now be estimated on the basis of waste delivered to waste-management facilities. As a result, findings from statistical waste surveys carried out as of 1996 are only partly comparable with published figures for 1993 and earlier.

### *14.6.2 Wastewater (6.B) – Data for determination of emission factors for wastewater and sewage-sludge treatment (6.B.2)*

Under the IPCC method, percentage levels of aerobic and anaerobic wastewater and sewage-sludge treatment should be determined via characterisation of wastewater and sewage-sludge treatment systems at the national level.

Evaluation of national inventory reports shows that various countries have used widely differing approaches to determine their country-specific emission factors. In some countries, the available data is not adequate to permit direct use of the IPCC method, and thus such countries have used alternative calculation methods or aggregated values. The evaluation reveals the following:

- A few countries list specific methane conversion factors for national treatment systems (Czech Republic, U.S., Finland; cf. Table 105). In addition, sub-categorisation of wastewater systems is not standardised.
- In some countries, it is assumed that wastewater treatment normally occurs, either aerobically or anaerobically, in closed systems with methane collection, but that small quantities of methane can still escape in exceptional situations. In such cases, very low MCF are chosen for treatment of municipal wastewater (Finland, Czech Republic).
- The UK uses a national method based on characterisation of sludge-treatment processes.
- In some countries, emission factors are determined not via organic load, percentage level of anaerobic treatment and MCF – as called for by the IPCC – but via population equivalents (Canada, Austria, Germany).
- Only Austria explicitly differentiates its emission factors by mechanical, biological and other treatment.

Table 105: Reported methane conversion factors in national inventory reports

| MCF | Czech Republic | Finland | U.S. |
|---|---|---|---|
| Management of household and commercial wastewater | | 0,025 | 0,05 |
| aerobically treated municipal wastewater | 0,05 | | |
| anaerobically treated municipal wastewater | 0,5 | | |
| on-site treatment | 0,15 | | |
| untreated household and commercial wastewater | | | |
| discharge into rivers | 0,05 | | |
| septic tanks | | | 0,5 |
| Industrial wastewater treatment | | 0,01 | |
| aerobically treated industrial wastewater | 0,06 | | |
| anaerobically treated industrial wastewater | 0,7 | | |
| untreated industrial wastewater | 0,05 | | |
| differs by sector | | | 0,05 - 0,77 |
| Sludge treatment | | | |
| aerobic treatment of sludge from municipal wastewater | 0,1 | | |
| anaerobic treatment of sludge from municipal wastewater | 0,5 | | |
| aerobic treatment of sludge from industrial wastewater | 0,1 | | |
| anaerobic treatment of sludge from industrial wastewater | 0,3 | | |

Source: National inventory reports

Further information on determination of methane emissions from wastewater and sewage-sludge treatment of other countries is provided by (ÖKO-INSTITUT, 2004b).

### *14.6.3 Determination of nitrous oxide emissions from wastewater treatment (6.B.2)*

The IPCC Guidelines describe a method for estimating nitrous oxide emissions from wastewater treatment. An evaluation of experience gained by other countries (further information in ÖKO-INSTITUT, 2004b) shows that all countries that determine nitrous oxide emissions from wastewater treatment either use the IPCC method or make country-specific adjustments to the IPCC method:

- One exception is Belgium, which determines emissions on the basis of the EMEP/CORINAIR manual.
- Some countries also determine nitrous oxide emissions from industrial wastewater, although the IPCC does not describe any method for this (Austria, New Zealand, Sweden and, in future, U.S.).
- The most important relevant country-specific adjustments include consideration of industrial wastewater (see above), determination of nitrogen loads in wastewater-treatment systems instead of determination of daily human protein intake (Sweden) and consideration of other nitrogen sources in municipal wastewater (U.S.).
- In those countries in which nitrous oxide emissions are determined, inter alia, via nitrogen fractions in protein, the IPCC default value is used.
- All countries use the IPCC default value in cases in which the emission factor (kg $N_2O$-N/kg wastewater N) is relevant for determination of nitrous oxide emissions.
- Data on average per-capita protein intake comes either from national studies and data (UK, Australia) or from the FAO database (U.S., Austria, etc.); such data varies widely. The protein intake for the UK, which was determined via a national survey, is much lower than the others; this is due to the method by which the average value

was determined. Table 106 lists average daily protein intake, along with the pertinent data source, for those countries that list this data item explicitly in their national inventory reports.

Table 106: Average daily and annual protein intake

| Country | Protein [kg / person & year] | Protein [kg / person & day] | Data source |
|---|---|---|---|
| UK | 8,65 | 0,024 | National Food Survey (DEFRA, 2001). The data is based on a survey of food consumption at home and thus is likely to be a low estimate. |
| Australia | 36,28 | 0,099 | Australian Institute of Health and Welfare (de Looper and Bhatia |
| U.S. | 41 (1996) | 0,112 | FAO database |
| | 41 x1,75 | 0,197 | Adjustment via comprehensive method |
| Sweden | 32,85 | 0,090 | National data |
| Canada | 40,15 | 0,110 | No data source listed |
| Germany | 34,68 | 0,095 | FAO database (average, 1990-2001) |
| New Zealand | 4,75 | 0,013 | With regard to wastewater nitrogen |
| Belgium | | | FAO database |
| Cz. Republic | 25,00 | 0,068 | No data source listed |

Source: National inventory reports

# 15 ANNEX 4: $CO_2$ REFERENCE APPROACH AND COMPARISON WITH THE SECTORAL APPROACH, AND RELEVANT INFORMATION ON THE NATIONAL ENERGY BALANCE

Information on the $CO_2$ reference approach, a comparison with the sectoral approach and relevant information on the national energy balance is found in Chapter 3.1.12.

# 16 ANNEX 5: ASSESSMENT OF COMPLETENESS, AND ASSESSMENT OF POTENTIALLY EXCLUDED SOURCES AND SINKS OF GREENHOUSE GAS EMISSIONS

To date, no detailed information is available on assessment of completeness and of potentially excluded sources and sinks of greenhouse gas emissions.

# 17 ANNEX 6: ADDITIONAL INFORMATION TO BE CONSIDERED AS PART OF THE NIR SUBMISSION (WHERE RELEVANT) OR OTHER USEFUL REFERENCE INFORMATION

## 17.1 German National System of Emissions Inventories

**Artcle 5.1** of the Kyoto Protocol mandates the establishment of National Systems for preparation of greenhouse-gas emissions inventories. Under this provision, industrialised countries (Annex I Countries) commit themselves to installing, by no later than 2007, **National Systems** that support determination of greenhouse-gas emissions from sources and greenhouse-gas emissions removals via sinks. Via the *Decision of the European Parliament and the Council on a system for monitoring of greenhouse-gas emissions in the Community and for implementation of the Kyoto Protocol of 11 February 2004*, Germany is also obligated to prepare **national inventory systems** under the Kyoto Protocol, with this process to begin no later than 31 December 2005.

### *17.1.1 Tasks of the National System*

The purpose of the National System is to ensure, by means of continual quality management and ongoing inventory improvement, that the methodological provisions of the IPCC uidelines and the GPG are extensively applied.
It comprises all institutional, legal and procedural facilities and agreements to be reached and established in Annex 1 countries of the Framework Convention on Climate for emissions calculation reporting and for archiving of all relevant inventory information. As a result, in preparation of emissions inventories, a National System must involve all those institutions and resources of the relevant country that are able to make highly competent contributions to such inventories. Such efforts include the following tasks:

- Establishment of a national agency for co-ordinating emissions reporting[142]
- Specification / documentation of institutional facilities, legal agreements and procedures on emissions calculation and reporting
- Archiving of all inventory information
- Initiation of measures for improving emissions inventories

Extensive organisational scope is granted to the Parties for the concrete institutionalisation of the National System. Figure 53 provides a schematic overview of the functions that must be provided and of the institutions to be involved in implementing the National System. Germany's National System does not have to be created from scratch; it is being built on existing relevant inventory-preparation structures and procedures and adapted to international requirements, and improved, as necessary.

142 The co-ordinating agency (Single National Entity – SNE) is charged with serving as the central point of contact for all participants in the National System. It is required to provide a framework for transparent, consistent, complete, comparable and precise inventories.

**The National System**

In preparation of emissions inventories, the National System should involve all of the state's institutions that can make highly competent contributions to such inventories.

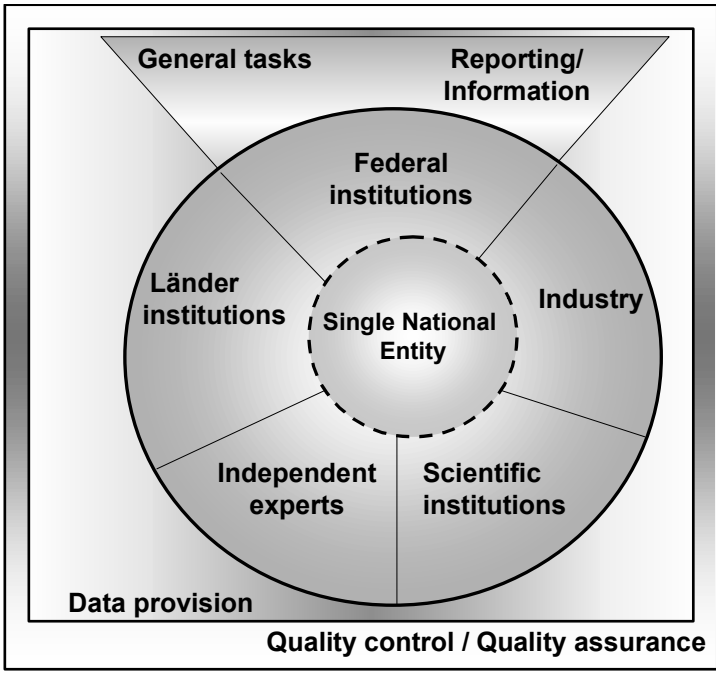



Figure 53: Functions of the National System and the institutions to be involved

### *17.1.2 Development of the National System*

In implementing provisions on establishment of a National System, the Federal Environmental Agency is receiving specialised and technical support from a research project (FKZ: 201 42 258) that will help to formulate a pertinent overall concept that makes allowance for both international requirements and the applicable national framework. The requirement areas of the National System where priority action is needed in future 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 (ÖKO-INSTITUT, 2004a).

The ***Co-ordination Agency for the National System (Single National Entity)*** is sited in the Federal Environmental Agency's Section II 5.3. It acts as a central point of contact, and it coordinates and informs all participants in the National System. During the period 2003-05, the SNE will additionally be identifying new institutional facilities to be incorporated into the National System, as well as checking and initiating the conclusion of legal agreements for ensuring data continuity for the inventories. The SNE will also be responsible for central archiving.

The National System institutions, in addition to the SNE, include the ***Quality System for Emissions Inventories*** (QSE), which is currently being established for management of quality monitoring and assurance, and the ***Central System of Emissions*** (CSE), a central, national database for emissions calculation and reporting (cf. Figure 54).

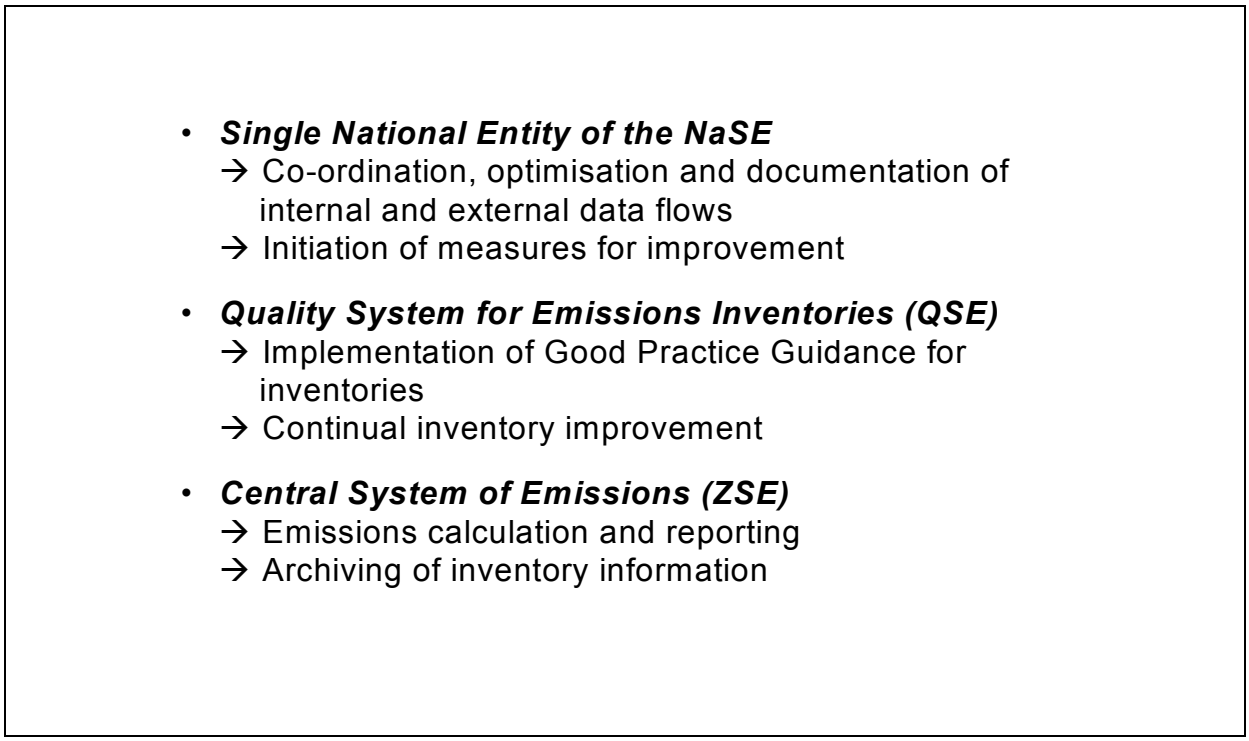



Figure 54: Institutions of the National System of Emissions Inventories

In a first step, the SNE has concentrated its efforts on initiating activities, in the Federal Environmental Agency, in support of establishment of the National System. A *Working Group on Emissions Inventories* has been set up to co-ordinate relevant work within the Federal Environmental Agency; it will incorporate all of the agency's employees who are involved in inventory preparation. Since the second half of 2002, the national co-ordination agency (SNE) has held a growing number of information events on the requirements resulting from the Framework Convention on Climate Change and the Kyoto Protocol, and in particular, on the resultant consequences for the UBA's specialised efforts. Since then, internal awareness, at the Agency, of the relevance and scope of this task has risen sharply. The Working Group is charged with facilitating participation of experts in the inventory-preparation, reporting, quality assurance and review processes, as well as with externally communicating relevant requirements via contacts with external data providers. The Working Group's members maintain bilateral contacts within the context of ongoing inventory work. In addition, the Working Group meets three times per year to inform all of its members of progress achieved and of further action required to improve the inventories.

In a second step, the national co-ordinating agency (SNE) is working to involve additional institutions in the National System. This work as well builds on existing structures.

### *17.1.3 Workshop on the National System*

In April 2004, the Federal Environmental Agency will hold a workshop on the National System of Emissions Inventories. At this workshop, participants will be informed about the status of emissions reporting on greenhouse gases, as well as about relevant requirements. The event will also discuss existing problems and weaknesses, and it will develop and identify approaches for improving inventories and inventory reporting and for solving relevant problems. The event topics will include methods in various areas and for various source categories, databases for the greenhouse-gas inventory, co-ordinating preparation of a

balanced, harmonised National Inventory Report (NIR) and overarching topics relative to inventory preparation, such as quality assurance and control, uncertainties and data secrecy.

The event is aimed at persons who currently provide, or who may provide, contributions or data to the national greenhouse-gas inventory. This group includes Federal Environmental Agency specialists involved in inventory preparation, participating departments of ministries and of their subordinate authorities, representatives of the Länder, associations, working groups, research institutions and the Federal Statistical Office (DESTATIS).

The workshop is designed to provide both overarching, general information and information about specific source categories, with regard to the current status of greenhouse-gas-emissions reporting and relevant requirements. The event's topical emphases will include:

1. The main requirements for greenhouse-gas reporting, on the basis of relevant international regulations and provisions;
2. The current status of implementation of such international requirements in Germany;
3. Specification of requirements in light of the SNE's experience with current reporting;
4. Specification of requirements on the basis of experience with, and results of, international reviews of greenhouse-gas inventories;
5. Specification of requirements in light of reporting of other countries;
6. Overarching requirements in implementation (for example, development of new data sources; ensuring provision of at least minimum data sets comprising data, uncertainties, methods and documentation; institutionalisation of data flows; data protection / secrecy, quality assurance /–control, etc..).

The workshop is divided into a general part, aimed at all participants, and sector-specific parts covering the five areas of energy, industrial processes, agriculture, forestry and land-use changes and waste. With respect to the area-specific sections, five working groups will be formed; these groups will work concurrently, during the workshop, on selected issues relative to individual source categories within the areas. The workshop results will be used directly for inventory improvement, and they will be summarised in a workshop report that is likely to be completed by the end of June.

## 17.2 German Quality System for Emissions Inventories

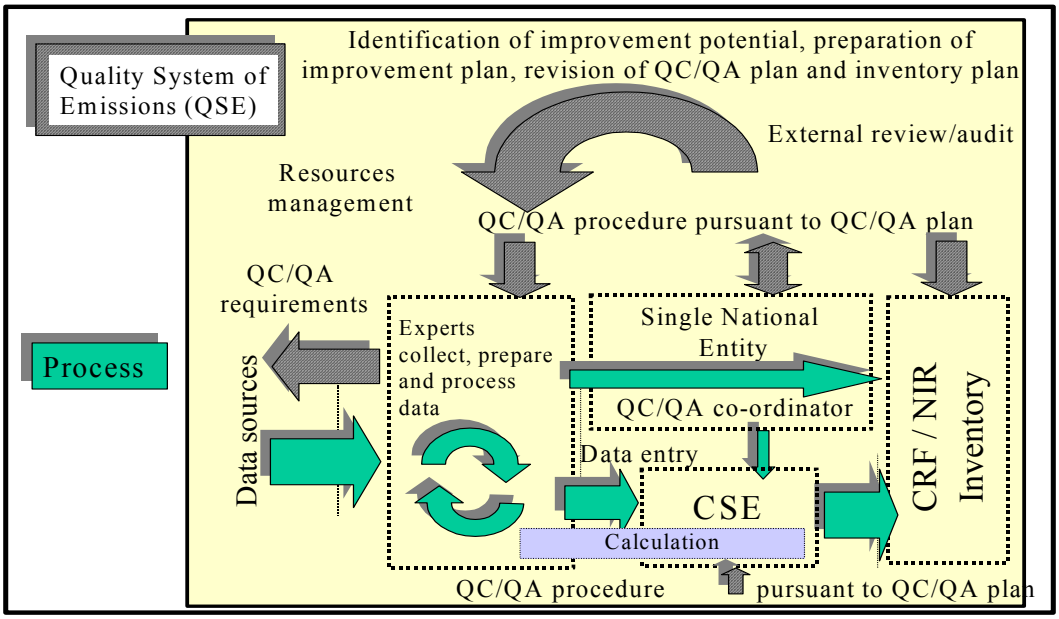
Since 2002, the national co-ordinating agency (SNE) has been working to develop and implement a QC/QA system (Quality System for Emissions Inventories - QSE). A research project is providing scientific support for the Federal Environmental Agency in implementing requirements from *Good Practice Guidance* (DREHER, 2002). The QSE should serve to meet the requirements of the IPCC, and it should make allowance for the national situation in Germany and for the internal structures and procedures of Federal Environmental Agency (UBA), the reporting institution. The QSE's procedures should be flexible enough to be able to routinely incorporate future changes in requirements. The project will develop a procedural and organisational concept that addresses identified problem areas in emissions reporting and that transparently defines responsibilities for the procedure. At the same time, the process will link inventory preparation and QC/QA measures in a manner oriented to specific target groups.

### *17.2.1 Tasks of the Quality System of Emissions*

The national co-ordinating agency (SNE) is charged with describing, introducing, updating and documenting QC/QA procedures. Such tasks apply both to procedures for quality assurance and control within the Federal Environmental Agency and to work with external data providers and organisations in the framework of the NaSE. The key elements of a QC/QA system that meets the IPCC's minimum requirements (cf. Chapter 8.3 of *Good Practice Guidance*) include:

- The QC/QA system must have an appointed co-ordinator. The QC/QA co-ordinator is responsible for maintaining the system and implementing the QC/QA plan, and he/she serves as a contact person for all of the Federal Environmental Agency's sections and for experts working in the framework of the NaSE;
- Implementation of a start-up organisation, with clearly defined responsibilities and competences,
- Preparation and maintenance of a QC/QA plan,
- Introduction and description of the necessary overarching and source-category-specific QC measures (Tier 1 + Tier 2),
- Introduction and description of the necessary internal and external quality assurance measures reviews, audits),
- Definition of documentation, recording and reporting obligations, and introduction of a procedure for document management,
- Procedures for monitoring, assessing and modifying the QC/QA system within the meaning of continual improvement,
- System documentation, in a suitable form (manual, guide).

The aforementioned QC/QA-system elements represent a concept for an ideal, IPCC-conformal emissions-reporting process (cf. Figure 55). Such a concept has been developed in general form and is currently being tested, in the framework of partial solutions, for practical feasibility.




[B/W arrows: flow of data/text; green arrows : QC/QA elements]
Figure 55: Ideal concept for the emissions-reporting process

The QSE's scope of application comprises the entire emissions-reporting process:

- Data collection, including selection of methods and data sources
- Data preparation and emissions calculation
- Reporting

The term "data" includes figure and number data (activity data, emission factors and uncertainties, as well as material and calculation rules that can be used to obtain such data) and texts and documents, such as those that enter into the national inventory report.

The QSE is binding for all NaSE participants. In the first half of 2004, the Federal Environmental Agency will issue an internal directive / work instructions setting forth the binding nature of the QSE. Details regarding the system's binding applicability for other NaSE participants remain to be defined.

### *17.2.2 Structure of the Quality System of Emissions*

#### 17.2.2.1 Initial organisation

Within the QSE framework, a concept for an initial, start-up organisation was developed that defines binding responsibilities and the necessary QC and QA measures. The defined roles and responsibilities have the purpose of facilitating effective information exchange and directive-conformal execution of QC and QA (cf. Table 107).

Table 107: Roles and responsibilities in the QSE

| Role | Task | Responsible |
|---|---|---|
| QC/QA co-ordinator (QCC) | Overarching QC and QA throughout the entire reporting process<br>Maintenance and further development of the QSE<br>Management and updating of the QC/QA plan and QSE manual<br>Description of quality targets<br>Management and updating of the improvement plan, and management of relevant adoption in the inventory plan | An appointed staff member of the national co-ordinating agency (SNE) |
| NaSE co-ordinator | Ensuring on-time, requirements-conformal reporting<br>Initiating implementation of overarching measures from the inventory plan<br>Selection of institutions and collection of relevant informational materials, legal agreements<br>Ensuring that all inventory information is archived, carrying out central archiving of inventory information<br>Preparation of execution and post-processing of inventory reviews | An appointed staff member of the national co-ordinating agency (SNE) |
| Specialised contact person (source-category-specific) in the SNE | Facilitation of specialised and technical support (QC/QA, inventory work and reporting) | An appointed staff member of the national co-ordinating agency (SNE) |
| Contact persons in Federal Environmental Agency sections | Multipliers in sections and specialised areas with regard to the national co-ordinating agency (SNE) information's and requirements with regard to emissions reporting | An appointed member of each relevant section |
| QC/QA representative for the specialised area | QC for data and report sections delivered to the national co-ordinating agency (SNE)<br>Approval of report sections<br>Ensuring that necessary inventory work, QC measures and documentation are carried out at the operational level<br>Definition of specialised responsibilities for emissions reporting within the section in question | Heads of all affected sections |
| Specialised representative at the operational level | Data collection, entry and calculation, in keeping with the prescribed methods<br>Definition of source-category-specific quality and review criteria<br>Execution of QC measures<br>Decentralised archiving of source-category-specific inventory information | All employees appointed by the relevant section head |
| CSE Administrator (CSE Admin) | Overarching QC and QA throughout the entire inventory process<br>Approval of review criteria for the CSE<br>Ensuring the integrity of databases<br>Emissions reporting and data aggregation into report formats | An appointed staff member of the national co-ordinating agency (SNE) |
| Report co-ordinator (NIRC) | Contact person for section, for work related to the NIR<br>Coordines support (collects work from section staff and distributes it within the national co-ordinating agency (SNE)) | An appointed staff member of the national co-ordinating agency (SNE) |

#### 17.2.2.2 Procedural organisation

Procedures for QC/QA measures in the QSE are oriented to the emissions-reporting process described in Chapter 1.3. At the same time, quality management must be directly linked with the various steps in the inventory process. In future, suitable QC measures will be allocated to each step of the process; these measures will then be assigned, via the defined initial/start-up organisation, to the various relevant players.

The necessary QC reviews are currently undergoing a co-ordination process. In future, they will be sent to the involved experts, in the form of QC checklists containing data requests, and they will have to be completed throughout the course of support work. QC checks are actually defined not as checks but as quality targets; in each case, either compliance with the targets must be confirmed or non-compliance must be justified. By way of example, Table 108 shows relevant checks for definition of requirements. In a first training measure carried out in January 2004, these checks were presented, together with the draft of the concept for the QC/QA plan, to experts of the Federal Environmental Agency and the Federal Agricultural Research Institute (FAL). This work is expected to be completed by the beginning of the second quarter of this year.

| No. | Process step/ *Aspect* | Quality target | Documentation | Responsible | Tier 1/ Tier 2 | Quality target achieved | | Option for action | Option exercised | | Not applicable |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | yes | no[143] | | yes | no | |
| **1.0** | **Data collection** | | | | | | | | | | |
| **1.1** | **Definition of requirements** | | | | | | | | | | |
| 1.1.1 | | The general requirements for basic quality control (Tier 1) have been defined and documented. | QKP | QCC | 1 | | | | | | |
| 1.1.2 | | The general requirements pertaining to data and report formats (CSE and NIR) have been defined and documented. | IB | QCC, CSE Admin | 1 | | | | | | |
| 1.1.3 | | The current key sources have been defined and documented. | IB | QCC | 1 | | | | | | |
| 1.1.4 | | The existing data pertaining to the source category has been documented and made available to the responsible expert. | IB | QCC, CSE Admin | 1 | | | Where documentation of the data source is incomplete, required actions are described in the improvement plan. | | | |
| 1.1.5 | | The general requirements have been defined and documented, taking the information description in 1.1.1-1.1.5 into account. | IB | QCC | 1 | | | | | | |

Table 108: Example of QC checklist for the process step "definition of requirements"

143 Where a target is not met, the nature and extent of the required corrective measure(s), along with the name of the responsible party, the relevant time frame and any applicable restrictions, must be noted on a separate sheet.

The national co-ordinating agency (SNE) has developed a questionnaire in anticipation of introduction of the systematic quality assurance that will support inventory reporting; this questionnaire has since been used, on a trial basis for reporting in 2004, for downstream (in the workflow) quality assurance for work received for the inventory and the NIR. The questionnaire, which is presented below, shows the reviews that have been carried out.

***Emissions reporting: Quality assurance checklist***
***Source category: .....***
***CRF / NFR code: .....***
***.....***

Context / Progress / Feedback

| Reference | Responsibility | Organisation | Person processing | Date carried out | Pro-gress | Feed-back re-quired |
|---|---|---|---|---|---|---|
| AR | Responsible expert<br>*QC manager (does not yet apply)*<br>CSE entry | | | -- | -- | -- |
| EF | Responsible expert<br>*QC manager (does not yet apply)*<br>CSE entry | | | -- | -- | -- |
| National co-ordination | Technical/specialised contact person<br>QC co-ordinator | | | | | |

Data and text checks by the technical/specialised contact person

***1. Comparison with NIR of the previous year (June 2003)***

| *Data/text consistency:* | Reference | consistent | not consistent |
|---|---|---|---|
| | AR | | |
| | EF | | |
| | Text | | |

| ***Check*** | ***Description of deficiencies*** |
|---|---|
| a) Check NIR contributions with the same wording for currentness<br>b) Check new text passages for scientific / technical correctness and consistency with the overall text<br>c) If necessary, describe any deficiencies and arrange for author to make necessary changes | a)<br>b) |

***2. Comparison with synthesis and assessment report (SAR) I and II***

| *Taking account of reviewresults:* | Reference | taken into account | not taken into account |
|---|---|---|---|
| | SAR Part I | | |
| | SAR Part II | | |

| ***Check*** | ***Description of deficiencies*** |
|---|---|
| a) Compare figures with those in inventories of other Annex I countries, for highly divergent data items → correction or justification required<br>b) Data comparison for D (where possible)<br>c) Take national findings into account / check feedback of independent experts, regarding the German inventory | a)<br>b)<br>c) |

| | |
|---|---|
| c) If necessary, describe any deficiencies and arrange for author to make necessary changes | |

***3. Comparison between provided data / report and CSE data***

| | Reference | consistent | not consistent |
|---|---|---|---|
| Data consistency | | | |
| | AR | | |
| | EF | | |

| ***Check*** | ***Description of deficiencies, AR*** |
|---|---|
| a) Compare data in the NIR draft (master) and CSE data[144] (greenhouse gases)<br>b) Compare data provided for the current inventory year and the CSE data ("classical gases")<br>c) If necessary, describe any deficiencies, arrange for clarification and cross-checking by CSE and section experts and arrange for corrections by the author | ***Description of deficiencies, EF***<br>a) Gas coverage <in/complete>[145]<br>Gas present missing Combustion[146]process<br>$CO_2$<br>$CH_4$<br>HFC<br>PFC<br>$SF_6$<br>$N_2O$<br><br>b) Data delivery for the inventory <missing/present><br>Gas present missing Combustion process<br>$NO_X$<br>CO<br>NMVOC<br>$SO_2$<br>$NH_3$<br>PM |

***4. Review of overview table for gases, methods and uncertainties in the NIR***

| Overview Information | Reference | consistent | not consistent |
|---|---|---|---|
| | EF | | |
| | EF uncertainties | | |
| | Distribution of uncertainties | | |
| | Method for EF determination | | |

| ***Check*** | ***Description of deficiencies*** |
|---|---|
| a) Check agreement of gas coverage with NIR text, CSE data and IPCC/ UN ECE requirements<br>b) Check agreement of EF uncertainties figures (including distribution) with NIR text and CSE data<br>c) Check agreement of methods used for EF determination with IPCC/ UN ECE requirements<br>c) If necessary, describe any deficiencies and arrange for author to make necessary changes | a)<br>b)<br>c) |

144 Possible approach: For the source category, retrieve or prepare a suitable enquiry in the CSE and export it as a csv file. In Excel, open the file in the csv format and format it for printing. For purposes of comparison, print out the file and compare the relevant figures.
145 Standard abbreviations: NO – not occurring; NE – not estimated
146 complete only for industrial processes

5. ***Comparison with interview records (in future: with the inventory plan)***

Taking account of removals: Reference Record <No.> (<Date>): <Topic> consistent not consistent

| ***Check*** | ***Description of deficiencies*** |
|---|---|
| a) Check whether actions with priority ++ and time frame k have been carried out. Name any affected parties.<br><br>b) For industrial processes: Check whether existing agreements regarding distribution of combustion-related and process-related emissions have been taken into account.<br><br>c) If necessary, describe any deficiencies and arrange for author to make necessary changes<br><br>d) Where new circumstances apply, the relevant interview record (later: inventory plan) is to be corrected | a)<br><(affected: ....)><br><br>b) |

***6. Checking of NIR chapters for correctness, conformity with requirements and completeness***

| Reference | Chapter present no | Chapter present yes | Description adequate no | Description adequate yes |
|---|---|---|---|---|
| NIR Chap. x.x.1:<br>Source category description: | | | | |
| NIR Chap. x.x.2: Methodological issues | | | | |
| NIR Chap. x.x.3: Time-series consistency | | | | |
| NIR Chap. x.x.3: Uncertainties | | | | |
| NIR Chap. x.x.4: Source-specific QC/QA and verification | | | | |
| NIR Chap. x.x.5: Source-specific recalculations | | | | |
| NIR Chap. x.x.6: Planned improvements | | | | |

| ***Check*** | ***Description of deficiencies*** |
|---|---|
| a) Description is adequate, if: The source-category delimitations are clearly logical (if possible, describe ZSE→ CRF aggregation rule);<br>The relevance of emitters is clear.<br>b) The description is adequate if the following holds, for AR and EF and for all methods of the entire time series:<br>The Tier used is named and jusified;<br>The Tier approach was selected in accordance with requirements (key-source analysis + Guidelines); otherwise, justification for any deviation;<br>The description of methods is scientifically | a)<br>b)<br>c)<br>d)<br>e)<br>f)<br>g) |

| | |
|---|---|
| consistent and transparent (logical).<br>c) The description is adequate if the following holds, for AR and EF and for all methods of the entire time series:<br>Any changes of methods in the time series are justified scientifically and on the basis of data availability.<br>d) The description is adequate, if the following holds, for AR and EF of the entire time series:<br>Uncertainties pursuant to Tier 1 (experts' assessment) are indicated, with information as to their size and distribution on the CSE-module level.<br>e) The description is adequate if the following holds, for AR and EF and for all methods of the entire time series:<br>Measures for scientific verification of values are described;<br>Measures for quality assurance in connection with data collection, data processing and data provision are plausibly described;<br>In the case of changes of methods: measures taken to achieve maximum time-series consistency are described.<br>f) The description is adequate if, in cases of changes of values or methods, the following holds for AR or EF in the time series:<br>Recalculation in the NIR and CRF Tables 8a and 8b is described and justified.<br>g) The description is adequate if, in connection with key sources, the schedule and work plan for dealing the following types of problems are listed:<br>Method is not requirements-conformal, or is not an equivalent country-specific method;<br>Lacking time-series consistency, or lacking QC/QA in case of methods change;<br>Lacking information regarding uncertainties;<br>Lacking or inadequate QC/QA; lacking recalculation. | |

#### 17.2.2.3 Documentation system

The QSE will be used to introduce the necessary QC/QA measures, pursuant to the IPCC, for the entire process of emissions reporting. Execution, description and documentation of QC/QA measures take place largely in conjunction with the relevant inventory contributions. To this end, a documentation system was developed that represents all such measures and related actions in an integrated manner tailoured to the specific parties and tasks concerned. The documentation system will be introduced at the Federal Environmental Agency in 2004. Figure 56 presents the interrelationships between the various elements of the system.

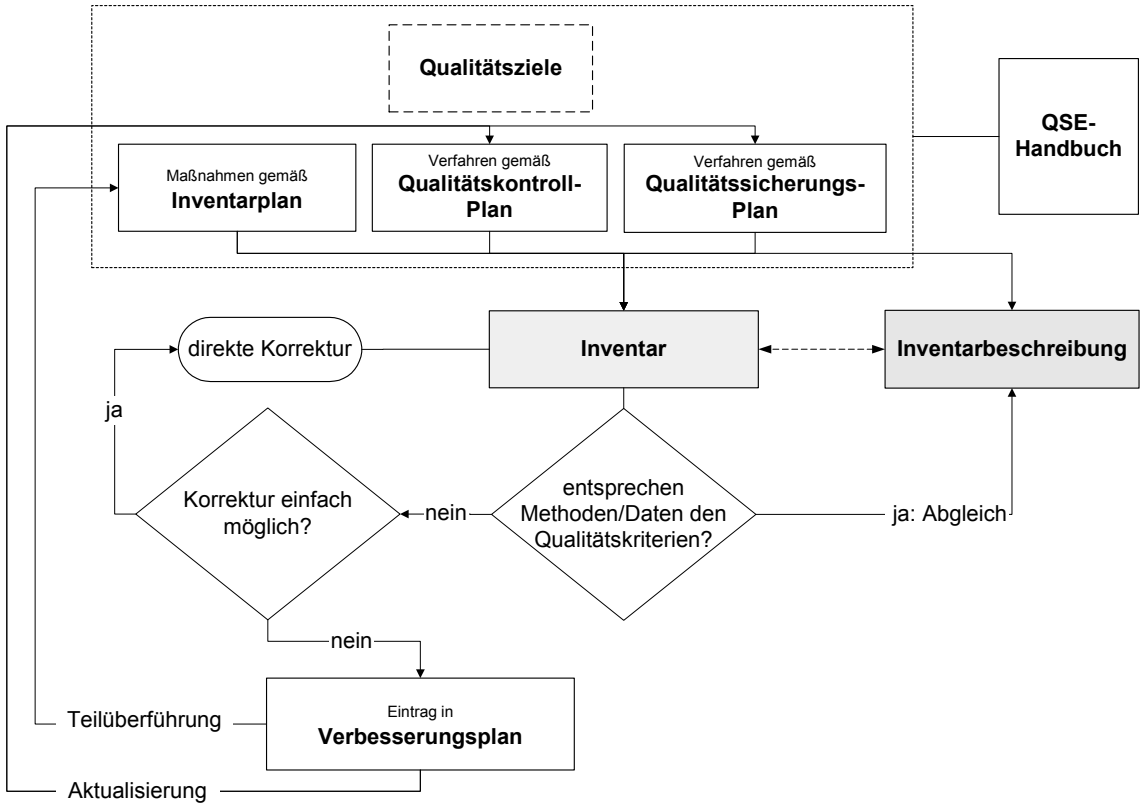



Figure 56: Interrelationship of various elements of the QSE

[From Top and from the left to the right: Quality targets; Measures pursuant to inventory plan; Procedures pursuant to quality-control plan; Procedures pursuant to quality-assurance plan; QSE Manual; Direct correction; Inventory; Inventory description; Simple correction possible?; Do methods / data conform to quality criteria?; Yes: Update; Teilüberführung = Partial transfer; Entry into improvement plan; Updating]

The ***QC plan*** describes all quality-control procedures; similarly, the ***QA plan*** describes all quality assurance procedures (including review and audit). QC/QA measures are carried out regularly. The plans are updated annually.

By carrying out QC/QA measures, the Federal Environmental Agency, along with other NaSE participants, can identify improvement measures with regard to emissions reporting and to the QSE. Where improvement measures can be carried out easily and promptly, correction takes place right away. Any more time-consuming and complex improvement measures for the inventories, and all improvement measures for the QSE, are first reported by the responsible experts to the Single National Entity, which then summarises them within the **improvement plan**.

The Single National Entity integrates improvement measures for inventories within the **inventory plan** for the following year, after setting priorities as necessary. In addition to improvement measures, this plan contains short summaries of the goals applying to inventory preparation for each of the source categories. Improvement measures from the inventory plan are published in the NIR, and correction measures in this framework become binding and subject to specific deadlines. Improvement measures affecting other ministries and departments are co-ordinated within the framework of *Working Group VI* of the $CO_2$-

*Reduction* IWG. In each case, specific procedures must be agreed for improvement measures that are to be carried out by National System participants who are not affiliated with any federal institutions. The inventory plan undergoes defined approval processes, as an attachment to the NIR and via UBA's internal co-ordination procedures and interministerial co-ordination.

**Inventory description** is a central documentation element. In such descriptions, inventory-preparation procedures are described source-category-specifically. In each case, documentation agrees with the relevant current NIR, which is always prepared on the basis of deliveries from the competent experts. Inventory description is supplemented with additional documentation – such as complex calculation models. Such description, which supports the review process, is managed by the Single National Entity, on the basis of contributions by the responsible experts.

All QSE documentation with regard to the system's initial and regular organisation is managed within the framework of the QSE manual. This manual is subject to the approval of the Federal Environmental Agency's top management.

### *17.2.3 Quality targets*

The overarching purpose of the QSE is to ensure compliance with international reporting obligations with respect to transparency, consistency, comparability, completeness and accuracy in inventory preparation (cf. Figure 57).

Figure 57: Requirements from international reporting obligations with regard to inventory preparation

**Transparency** means that the assumptions and methods used in preparation of emissions inventories must be clearly explained so that users can understand and assess the reported information. Transparency is of fundamental importance with regard to the success of an IPCC-conformal emissions-reporting process.

**Consistency** means that all elements of an emissions inventory are consistent with inventory elements from other years. An emissions inventory is consistent if the same methods are used for the base year and all subsequent years, and if consistent data records are used to calculate emissions and sinks. Under certain conditions, an emissions inventory may be considered consistent even if different emissions-calculation methods have been used, as long as relevant transparent recalculations have been carried out in conformance with the requirements of IPCC *Good Practice Guidance*. A consistent overall inventory results through avoidance of double counts in the inventory and through establishment, for all source categories, of congruency between the ways activity data and emission factors are delimited.

**Comparability** means that determined emissions and sinks may be compared across different source categories, and it means that the entire inventories of different states lend themselves to comparison. Comparability is achieved through standardised use of methods – such as that prescribed by *Good Practice Guidance*, for example. Furthermore, sub-elements must be allocated to the appropriate source categories in a standardised way.

**Completeness** means that the relevant inventory is complete with regard to the relevant gases and pollutants, as well as the relevant source categories and sinks. This also includes spatial/geographical completeness. And completeness also includes adequate documentation.

**Accuracy** refers to relative measurement of the precision of emissions and sink data. Identified emissions and sinks should neither be systematically overestimated nor be systematically underestimated. Uncertainties should be reduced as far as possible. To this end, they must first be quantified.

The special quality targets pursuant to Tier 1 are currently being prepared by the Single National Entity within the framework of development of QC checklists (cf. Chapter 17.2.2.2.). Source-category-specific / sectoral quality targets should be defined, in keeping with the above principles, by the responsible experts, in co-operation with the QC/QA co-ordinator. Targets should be derived, inter alia, from completed QC/QA measures (internal/external reviews, audits, if applicable) and documented within the inventory plan.

## 17.3 The database system for emissions – Central System of Emissions

Since 1998, the UBA has developed a central national database – the *Central System of Emissions (CSE)* – as a technical tool for inventory preparation. The CSE implements the diverse requirements pertaining to emissions calculation and reporting, and it automates essential work stages. The CSE facilitates inventory planning reporting (e.g. emissions calculation, recalculation and error analysis) as well as inventory management (e.g. archiving, annual evaluation of data) and data-level quality management (cf. UBA 2003a, Decor project manual). The CSE should make it possible to fulfill the key requirements of transparency, consistency, completeness, comparability and accuracy on the data level.

In order to ensure fulfillment of these key requirements, careful attention is given to documentation within the CSE. In the CSE, records are kept of persons responsible for processing, of data sources and calculation procedures, of uncertainties relative to time series, of the date of each last change and of the persons who use such changes. The

system has a history-management function that archives deleted entries. This facilitates tracking and reconstruction of data, thereby also enabling independent review by third parties. Supporting mechanisms are provided or developed at data level for the performance of quality assurance (e.g. system for detecting uncertainties, plausibility checks). Above all, transparency is accommodated by ensuring that data is recorded in the same structure in which it is provided, and that all processing and transformations into reporting format occur only in the CSE, in the interest of clarity. In this way, the CSE is capable of administrating detailed technology-specific activity data and emission factors that can be processed, via calculation rules (calculation methods), into aggregate, source-category-specific values for the reporting formats. Aggregation of individual CSE time series for the CRF report lines is described in Annex 3 and Chapter 14f – in each case, with regard to individual source categories. In addition to aggregation and model formation for calculations, the CSE also supports scenario and forecast calculation.

Data exchange within the framework of the national system – i.e. within the Federal Environmental Agency and with third parties – is also organised via the CSE. In addition to being input directly, aggregate figures may also be imported from existing databases via a standard interface (e.g. TREMOD, GAS-EM). The aim is for technical experts responsible for content to enter inventory data directly into the CSE wherever possible or, at least, for the CSE administrator to import such data via the import interface. This applies to in-house UBA employees as well as to external parties involved in the National System. In order to achieve this, fundamental preparations have been carried out since 2001:

- Provision of a *standardised import format for CSE* in 2002 has facilitated the direct import of data from other emissions-relevant databases.
- In September 2002, participating technical experts from the UBA were given direct access to the CSE via the UBA intranet. The relevant parties are identified via an annual survey; as a result, virtually all of the responsible experts at the Federal Environmental Agency now have such access. However, write access rights for these experts are normally confined to the database content for which they are technically responsible.
- In November 2002 and 2003, training courses in the CSE were held for relevant UBA staff members.
- Course participants were provided with a description of the database in the form of the *CSE/Point Source User Manual* (UBA, 2002c).

The CSE's operational launch in 2002 fulfilled the principal technical requirements for compliance with the Kyoto requirements for inventories; the next stage now is to bring emissions-calculation and data-collection procedures completely into line with the CSE. In 2005, the CSE will be connected to the Internet. This will enable external experts also to enter data directly into the CSE and conduct searches in it.

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

- Recording of qualitative and quantitative information abut data uncertainties,
- Complying with reporting obligations under the Geneva Convention on Long-Range Transboundary Air Pollution and EU legislation (such as the NEC directive),
- Measures-based orientation of emissions calculation to facilitate better quantification of the effectiveness of emission reduction measures in future, and

- Preparation of forecasts and scenarios to facilitate future estimates on compliance with reduction obligations and to facilitate identification of additional measures needed for target attainment.

### *17.3.1 Documentation of calculations in CalQlator*

To support transparent documentation of calculations, the Federal Environmental Agency has developed a calculation tool for the CSE; this tool, "CalQlator", went into operation at the end of 2003. CalQlator makes it possible to store complex calculation methods in a user-friendly form in the database. It supports derivation of equations for linking entered values within calculations; once a formula has been entered, all calculation steps can be traced, and single changes trigger consistent recalculation of entire time series. Via a function for definition of inequalities, CalQlator can also be used for quality assurance – for example, via definition of checking parameters for maximum deviations. In January 2004, a first group of UBA staff received an introductory training course for CalQlator.

### *17.3.2 Data transfer between the TREMOD and CSE databases*

In 1999/2000, an interface was programmed for transfer of emissions data, for the source category *road transport*, from the TREMOD (Transport Emission Estimation Model) database into the CSE database; in 2003, this interface was adapted to an upgraded version of the CSE database.

The current CSE import format is shown in Table 109 below.

Table 109: Dimensions in the CSE, and pertinent TREMOD categories

| CSE signature | Description | TREMOD categories |
|---|---|---|
| SE:Name | Structural element | Vehicle category, vehicle layer, road category |
| Ts:Name | Time-series name | Like SE:Name |
| Spatial reference:Name | Germany, old German Länder, new German Länder | Scenario, Land |
| Value type:Name | Activity rate (energy consumption), emissions | Energy, component |
| Gas:Name | For example, carbon dioxide, sulphur dioxide | Component |
| EmiGru:Name | Emitter group – e.g. municipal road transport | Road category |
| VwA:Name | Type of use: Propulsion, evaporation | Emissions category (warm-up, ignition, evaporation) |
| Material:Name | Material (input) – e.g. diesel fuel * Energy Balance | Energy, energy balance, correction factor for energy balance |
| Measure:Name | Measure: Conventional, reduction equipment | Emission standard (vehicle layer) |
| Equipment:Name | Equipment – e.g. passenger automobile | Vehicle category |
| EBZ:Name | Energy Balance source – e.g. Road transport, 95 | - |
| Unit | Units TJ, kg/TJ, t | |

The most important category in the CSE is the structure element (SE). For it to be possible to derive activity rates and emission factors from TREMOD, for structure elements, several TREMOD categories have to be combined. A structure element thus consists of

- Road categories (in CSE, as "Emigruppe")
- Vehicle categories (in CSE aggregated to some extent under the "equipment" ("Technik") category)
- Vehicle layer (in the CSE category "Measure", differentiates between "conventional" and "reduction equipment")
- Emissions categories ("warm-up" and "ignition" correspond to the CSE area "drive"; "park" and "tank ventilation" correspond to the CSE area "evaporation")
- Energy (CSE category "Material"); the "material types" biodiesel, petroleum and LP gas are currently not included in TREMOD.

Table 110: Allocation of CSE structure elements (first line) and TREMOD category (second line)

| SE:Name (ID) | **EmiGru** | Type of vehicle | **Measure** | **Area** | **Material** |
|---|---|---|---|---|---|
| **-** | **SK** | **FzKat** | Vehicle layer | Emissions category | **Energy** |
| SV LNFO KOAB | AB | LNF | KO: without regulated catalytic converter | Drive | Gasoline |
| SV LNFO KOAO | ao | LNF | KO: without regulated catalytic converter | Drive | Gasoline |
| SV LNFO KOIO | io | LNF | KO: without regulated catalytic converter | Drive | Gasoline |
| SV LNFO KOVD | io | LNF | KO: without regulated catalytic converter | Evaporation | Gasoline |
| SV LNFO MTAB | AB | LNF | MT: with regulated catalytic converter | Drive | Gasoline |
| SV LNFO MTAO | ao | LNF | MT: with regulated catalytic converter | Drive | Gasoline |
| SV LNFO MTIO | io | LNF | MT: with regulated catalytic converter | Drive | Gasoline |
| SV LNFO MTVD | io | LNF | MT: with regulated catalytic converter | Evaporation | Gasoline |
| SV MOPED | io | KKR | KO: All | Drive | Gasoline |
| SV MOPED VD | io | KKR | KO: All | Evaporation | Gasoline |
| SV MRAD KOAB | AB | KR | KO: before EURO1 | Drive | Gasoline |
| SV MRAD KOAO | ao | KR | KO: before EURO1 | Drive | Gasoline |
| SV MRAD KOIO | io | KR | KO: before EURO1 | Drive | Gasoline |
| SV MRAD KOVD | io | KR | KO: before EURO1 | Evaporation | Gasoline |
| SV MRAD MTAB | AB | KR | MT: as of Euro 1 | Drive | Gasoline |
| SV MRAD MTAO | ao | KR | MT: as of Euro 1 | Drive | Gasoline |
| SV MRAD MTIO | io | KR | MT: as of Euro 1 | Drive | Gasoline |
| SV MRAD MTVD | io | KR | MT: as of Euro 1 | Evaporation | Gasoline |
| SV PKWO KOAB | AB | Automobile | KO: without regulated catalytic converter | Drive | Gasoline |

| | | | | | |
|---|---|---|---|---|---|
| SV PKWO KOAO | ao | Automobile | KO: without regulated catalytic converter | Drive | Gasoline |
| SV PKWO KOIO | io | Automobile | KO: without regulated catalytic converter | Drive | Gasoline, LP gas |
| SV PKWO KOVD | io | Automobile | KO: without regulated catalytic converter | Evaporation | Gasoline |
| SV PKWO MTAB | AB | Automobile | MT: with regulated catalytic converter | Drive | Gasoline |
| SV PKWO MTAO | ao | Automobile | MT: with regulated catalytic converter | Drive | Gasoline |
| SV PKWO MTIO | io | Automobile | MT: with regulated catalytic converter | Drive | Gasoline |
| SV PKWO MTVD | io | Automobile | MT: with regulated catalytic converter | Evaporation | Gasoline |
| SV BUS KOAB | AB | RBus, LBus | KO: before EURO1 | Drive | Diesel, biodiesel |
| SV BUS KOAO | ao | RBus, LBus | KO: before EURO1 | Drive | Diesel, biodiesel, petroleum |
| SV BUS KOIO | io | RBus, LBus | KO: before EURO1 | Drive | Diesel, biodiesel |
| SV BUS MTAB | AB | RBus, LBus | MT: as of Euro 1 | Drive | Diesel, biodiesel |
| SV BUS MTAO | ao | RBus, LBus | MT: as of Euro 1 | Drive | Diesel, biodiesel, petroleum |
| SV BUS MTIO | io | RBus, LBus | MT: as of Euro 1 | Drive | Diesel, biodiesel |
| SV LNFD KOAB | AB | LNF | KO: before EURO1 | Drive | Diesel, biodiesel |
| SV LNFD KOAO | ao | LNF | KO: before EURO1 | Drive | Diesel, biodiesel |
| SV LNFD KOIO | io | LNF | KO: before EURO1 | Drive | Diesel, biodiesel |
| SV LNFD MTAB | AB | LNF | MT: as of Euro 1 | Drive | Diesel, biodiesel |
| SV LNFD MTAO | ao | LNF | MT: as of Euro 1 | Drive | Diesel, biodiesel |
| SV LNFD MTIO | io | LNF | MT: as of Euro 1 | Drive | Diesel, biodiesel |
| SV PKWD KOAB | AB | Automobile | KO: before EURO1 | Drive | Diesel, biodiesel |
| SV PKWD KOAO | ao | Automobile | KO: before EURO1 | Drive | Diesel, biodiesel |
| SV PKWD KOIO | io | Automobile | KO: before EURO1 | Drive | Diesel, biodiesel |
| SV PKWD MTAB | AB | Automobile | MT: as of Euro 1 | Drive | Diesel, biodiesel |
| SV PKWD MTAO | ao | Automobile | MT: as of Euro 1 | Drive | Diesel, biodiesel |
| SV PKWD MTIO | io | Automobile | MT: as of Euro 1 | Drive | Diesel, biodiesel |
| SV SNF KOAB | AB | LKW, LZ, SZ | KO: before | Drive | Diesel, biodiesel |

| | | | | | |
|---|---|---|---|---|---|
| | | | EURO1 | | |
| SV SNF KOAO | ao | LKW, LZ, SZ | KO: before EURO1 | Drive | Diesel, biodiesel |
| SV SNF KOIO | io | LKW, LZ, SZ | KO: before EURO1 | Drive | Diesel, biodiesel |
| SV SNF MTAB | AB | LKW, LZ, SZ | MT: as of Euro 1 | Drive | Diesel, biodiesel |
| SV SNF MTAO | ao | LKW, LZ, SZ | MT: as of Euro 1 | Drive | Diesel, biodiesel |
| SV SNF MTIO | io | LKW, LZ, SZ | MT: as of Euro 1 | Drive | Diesel, biodiesel |
| Remarks: FzKat: Vehicle category, SK: Road category, Material: cursive components not included in TREMOD; LKW = Truck | | | | | |

### *17.3.3 Next steps*

The interface that has been developed is tailoured to the structure and data of TREMOD version 3.0 of 31 October 2002. TREMOD is currently being redesigned and expanded under commission to the Federal Highway Research Institute (BaSt) (IFEU, 2003b). In addition, integration of the new structures and results of the manual "Emissions factors for road transports" (Emissionsfaktoren des Straßenverkehrs) (INFRAS, 2003) is planned. This work will also require the the CSE interface to be adapted.

It currently seems that the manual's new vehicle-layer definitions will necessitate at least a simple updating of the CSE interface. This adaptation will not require a complicated procedure for updating TREMOD.

In future, the fuels biodiesel, petroleum, LP gas and natural gas should be integrated into the TREMOD model. As part of TREMOD enhancement under commission to BASt, by mid-2004 suitable structures will be added to TREMOD that can accept suitable basic data and deliver results to CSE.

The 1994 data was broken down, in a simple manner, into data for the old and new German Länder; this procedure is to be supplanted by differentiation of input data (stocks, mileage) in the TREMOD database, to permit production of plausible time series for emissions of western and eastern Germany.

These changes are to be carried out as concurrently as possible with the updating process based on the new manual, since the emission factors in the new manual will nearly all be changed (changes will include retroactive changes).

## 17.4 The Web-based German Emission Factor Database (GEREF)

In the GEREF (GERman Emission Factor Database), the Federal Environmental Agency will present all emission factors for Germany that are being used to fulfill reporting obligations to the Secretariat of the Framework Convention on Climate and to the European Union. This database comprises the emission factors for Germany's national reporting.

To enhance the transparency and clarity of German emissions data, the UBA publishes these emission factors in the Internet, and it permits external experts (organisations, industry, research institutions) to submit (to the UBA) and publicise new emission factors and metadata. This will enable the UBA to house a national database for emission factors that includes both emission factors for national reports and other emission factors that are collected. This will facilitate identification and discussion of differences to other emission factors, such as the international emission factors of the Emission Factors Database (EFDB),

which the IPCC manages, along with supplementary information. GEREF includes an interface for transmission of German emission factors to the EFDB. Export of selected emission factors to the international EFDB will be managed by the Federal Environmental Agency.

GEREF has been implemented by the firm of Seven2one GmbH, using MESAP, a standard application. GEREF has an Internet Web client (browser) that will enable the public to read-access emission factors. Registered users can also enter new emission factors and their meta-information, including technical data and literature references. Such entry can be carried out either manually, via the Web client, or automatically, via an Internet upload function.

The GEREF Web application, based on an MESAP solution:

- Is a database for administrating and documenting emission factors in Germany
- Provides Internet access to emission factors
- Enables visitors to search for and research emission factors
- Enables users (registered users) to enter new emission factors
- Is compatible with Federal Environmental Agency's existing databases
- Can easily be expanded to include indirect greenhouse gases and other air pollutants
- Supports data export to EFDB

# 18 ANNEX 7: TABLES 6.1 AND 6.2 OF THE IPCC GOOD PRACTICE GUIDANCE

Research project 202 42 266 (UBA, 2004) calls for determining uncertainties pursuant to Tier 1 and Tier 2, in keeping with Chap. 6 of GPGAUM[147)]. Not all of the uncertainties for German greenhouse-gas inventories have been determined. Efforts in this area have begun with determination of uncertainties pursuant to Tier 1; they are being carried out by data-supplying experts of Federal Environmental Agency departments and by external institutions. Systematic and complete experts' assessments are being hampered by the following issues, however:

- The fact that most activity rates are taken from data sources that are outside the Federal Environmental Agency (DESTATIS, industry associations or other statistics) complicates determination of uncertainties. Experts' assessments must be carried out either by experts outside of UBA, or the data-supplying institutions' own uncertainty figures must be used.
- Furthermore many activity rates are determined through a process in which UBA carries out a variety calculations, for purposes of adaptation, on an external database (Examples include BEU, TREMOD, etc..). The question arises as to how changes in uncertainties resulting from such calculations, some of which are quite complex, can be determined.
- Furthermore, in some cases no further use of current emission factors and activity rates is planned (for example, CRF 6). It thus must be asked whether it is at all useful to determine uncertainties for such values, which are badly in need of revision, or whether remodeling of calculation procedures has advanced enough to produce EF and AR for which uncertainties can be estimated.

At present, in light of the current status of relevant work, it is not yet possible to prepare Tables 6.1 and 6.2 of the IPCC Good Practice Guidance. Consequently, the following section presents results already obtained.

## 18.1 Status of work

Default values based on international experience were first used to obtain a first estimate of uncertainties and to prepare a Monte-Carlo simulation for uncertainties calculation, pursuant to Tier 2 and in keeping with Chap. 6 of GPGAUM. The database for this work consisted of information from the literature and national inventory reports of other Annex 1 countries.

For uncertainties determination pursuant to Tier 1, in October 2003 a first sample experts' assessment was carried out for fugitive emissions from liquid and gaseous fuels. On the basis of this experience, a guide to experts' assessments of uncertainties was developed; this guide conforms to the IPCC requirements set forth in Chapter 6 of GPGAUM, and it takes Germany's specific national circumstances, and the Federal Environmental Agency's organisational structure, into account. This guide, together with the pertinent time series for the source categories as they are listed in the CSE, was presented to data-supplying departments of UBA. The status of the relevant results is shown in Table 111.

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Table 111: Source-category-specific determination of uncertainties pursuant to Tier 1

| CRF | Sub-category | Fuel | Value type | Gas | Downward deviation, 1990 [%] | Upward deviation, 1990 [%] | Distribution 1990 | Downward deviation, 2002 [%] | Upward deviation, 2002 [%] | Distribution 2002 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1A1 | Gas turbines | Liquid fuels | EF | $CH_4$ | -90% | 10% | L | -50% | 50% | U |
| 1A1 | Gas turbines | Natural gas | EF | $CH_4$ | -10% | 600% | L | -50% | 50% | U |
| 1A1 | Boiler combustion systems subject to Ord. on Large Combustion Plants (GFA) | Industrial waste | EF | $CH_4$ | -75% | 75% | U | NE | NE | |
| 1A1 | Boiler combustion systems subject to Ord. on Large Combustion Plants (GFA) | Fuel gas | EF | $CH_4$ | -75% | 75% | U | NE | NE | |
| 1A1 | Boiler combustion systems subject to Ord. on Large Combustion Plants (GFA) | Lignite briquettes | EF | $CH_4$ | -10% | 150% | L | -50% | 50% | U |
| 1A1 | Boiler combustion systems subject to Ord. on Large Combustion Plants (GFA) | Other fuels | EF | $CH_4$ | -50% | 50% | U | -50% | 50% | U |
| 1A1 | Waste incineration | Household waste / municipal waste | EF | $CH_4$ | -5% | 5% | N | 0% | 0% | N |
| 1A1 | Refinery process combustion | | EF | $CH_4$ | -75% | 75% | U | -75% | 75% | U |
| 1A1 | Boiler combustion systems subject to TA Luft | Solid and liquid fuels | EF | $CH_4$ | -50% | 50% | U | -50% | 50% | U |
| 1A1 | Boiler combustion systems subject to TA Luft Luft | Solid fuels | EF | $CH_4$ | -90% | 10% | L | -50% | 50% | U |
| 1A1, 1A2f | Engines | Gas from sewage treatment, landfills | EF | $CH_4$ | -90% | 125% | L | -90% | 125% | L |
| 1A1, 1A2f | Engines | Liquid fuels | EF | $CH_4$ | -90% | 10% | L | -90% | 10% | L |
| 1A1, 1A2f | Engines | Natural gas | EF | $CH_4$ | -75% | 125% | L | -75% | 125% | L |
| 1A1, 1A2f | Other process combustion | | EF | $CH_4$ | missing | missing | | missing | missing | |
| 1A2a | | | EF | $CH_4$ | -10% | 10% | T | -10% | 10% | T |
| 1A2b | Production of non-ferrous heavy metals (process combustion) | | EF | $CH_4$ | missing | missing | | missing | missing | |
| 1A2e | Sugar manufacturing (process combustion) | | EF | $CH_4$ | missing | missing | | missing | missing | |
| 1A2f | Gas turbines | | EF | $CH_4$ | -10% | 600% | L | -50% | 50% | U |
| 1A2f | Boiler combustion systems subject to Ord. on Large Combustion Plants (GFA) | Industrial waste | EF | $CH_4$ | -75% | 75% | U | NE | NE | |
| 1A2f | Boiler combustion systems subject to Ord. on Large Combustion Plants (GFA) | Light heating oil | EF | $CH_4$ | -60% | 30% | L | -50% | 50% | U |
| 1A2f | Boiler combustion systems subject to Ord. on Large Combustion Plants (GFA) | Fuel gas | EF | $CH_4$ | -75% | 75% | U | NE | NE | |
| 1A2f | Boiler combustion systems subject to Ord. on Large Combustion Plants (GFA) | Other liquid and gaseous fuels | EF | $CH_4$ | -50% | 50% | U | -50% | 50% | U |
| 1A2f | Boiler combustion systems subject to Ord. | Other solid fuels | EF | $CH_4$ | -50% | 50% | U | -50% | 50% | U |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | on Large Combustion Plants (GFA) | | | | | | | | | |
| 1A2f | Calcium carbide production (process combustion) | | EF | $CH_4$ | missing | missing | | missing | missing | |
| 1A2f | Glass production (process combustion) | | EF | $CH_4$ | missing | missing | | missing | missing | |
| 1A2f | Manufacturing of coarse ceramics (process combustion) | | EF | $CH_4$ | missing | missing | | missing | missing | |
| 1A2f | Lime production (process combustion) | | EF | $CH_4$ | missing | missing | | missing | missing | |

Table 111: Source-category-specific determination of uncertainties pursuant to Tier 1

| CRF | Sub-category | Fuel | Value type | Gas | Downward deviation, 1990 [%] | Upward deviation, 1990 [%] | Distribution 1990 | Downward deviation, 2002 [%] | Upward deviation, 2002 [%] | Distribution 2002 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1A2f | Cement production (process combustion) | | EF | $CH_4$ | missing | missing | | missing | missing | |
| 1A2f | Small combustion plants | LP gas | EF | $CH_4$ | NE | NE | | -75% | 200% | L |
| 1A2f | Small combustion plants | Natural gas | EF | $CH_4$ | NE | NE | | -75% | 200% | L |
| 1A2f | Waste incineration | Industrial waste | EF | $CH_4$ | -5% | 5% | N | 0% | 0% | N |
| 1A2f | Waste incineration | Waste sulphite liquor | EF | $CH_4$ | missing | missing | | missing | missing | |
| 1A2f | Boiler combustion systems subject to TA Luft | Hard-coal coke | EF | $CH_4$ | -5% | 600% | L | -50% | 50% | U |
| 1A2f | Boiler combustion systems subject to TA Luft | Petroleum | EF | $CH_4$ | -75% | 75% | U | NE | NE | |
| 1A2f | Boiler combustion systems subject to TA Luft | Coke-oven / city gas | EF | $CH_4$ | -75% | 75% | U | NE | NE | |
| 1A2f | Boiler combustion systems subject to TA Luft | Industrial waste | EF | $CH_4$ | -75% | 75% | U | NE | NE | |
| 1A2f | Boiler combustion systems subject to TA Luft | Firewood | EF | $CH_4$ | -75% | 75% | U | NE | NE | |
| 1A2f | Boiler combustion systems subject to TA Luft | Fuel gas | EF | $CH_4$ | -75% | 75% | U | NE | NE | |
| 1A2f | Boiler combustion systems subject to TA Luft | Other liquid and gaseous fuels | EF | $CH_4$ | -50% | 50% | U | -50% | 50% | U |
| 1A2f | Boiler combustion systems subject to TA Luft | Other solid fuels | EF | $CH_4$ | -90% | 10% | L | -50% | 50% | U |
| 1A3a | | | EF | $CH_4$ | missing | missing | | missing | missing | |
| 1A3b | | | EF | $CH_4$ | missing | missing | | missing | missing | |
| 1A3c | | | EF | $CH_4$ | missing | missing | | missing | missing | |
| 1A3d | | | EF | $CH_4$ | missing | missing | | missing | missing | |
| 1A3e | Gas turbines in natural gas compressor stations | | EF | $CH_4$ | -10% | 600% | L | -50% | 50% | U |
| 1A3e | Mobile sources | | EF | $CH_4$ | missing | missing | | missing | missing | |
| 1A4 | Stationary combustion, TA Luft plants | Hard-coal coke | EF | $CH_4$ | -75% | 4000% | L | -50% | 100% | L |
| 1A4 | Stationary combustion, TA Luft plants | Hard coal | EF | $CH_4$ | -90% | 150% | L | -50% | 100% | L |
| 1A4 | Stationary combustion, TA Luft plants | Crude lignite | EF | $CH_4$ | NE | NE | | -75% | 150% | L |
| 1A4 | Stationary combustion, TA Luft plants | Lignite tar | EF | $CH_4$ | -75% | 2000% | L | NE | NE | |
| 1A4 | Stationary combustion, TA Luft plants | Lignite briquettes | EF | $CH_4$ | -75% | 2000% | L | -50% | 100% | L |
| 1A4, 1A5 | Mobile sources | | EF | $CH_4$ | missing | missing | | missing | missing | |
| 1A4, 1A5 | Stationary combustion | Gaseous (not including LP gas) | EF | $CH_4$ | -75% | 200% | L | -50% | 100% | L |
| 1A4, 1A5 | Stationary combustion | LP gas | EF | $CH_4$ | -75% | 200% | L | -75% | 200% | L |

| CRF | Sub-category | Fuel | Value type | Gas | Downward deviation, 1990 [%] | Upward deviation, 1990 [%] | Distribution 1990 | Downward deviation, 2002 [%] | Upward deviation, 2002 [%] | Distribution 2002 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1A4, 1A5 | Stationary combustion | Liquid (not including LP gas) | EF | $CH_4$ | -99% | 99% | N | -25% | 50% | L |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), households | Crude lignite | EF | $CH_4$ | -75% | 100% | L | -90% | 150% | L |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), households | Peat | EF | $CH_4$ | -75% | 100% | L | -75% | 150% | L |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), households | Other solid fuels | EF | $CH_4$ | -75% | 100% | L | -50% | 100% | L |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), agriculture and horticulture | Hard-coal coke | EF | $CH_4$ | -75% | 4000% | L | NE | NE | |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), agriculture and horticulture | Hard coal | EF | $CH_4$ | -75% | 100% | L | -50% | 100% | L |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), agriculture and horticulture | Crude lignite | EF | $CH_4$ | -75% | 4000% | L | NE | NE | |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), agriculture and horticulture | Firewood, untreated | EF | $CH_4$ | NE | NE | | -50% | 100% | L |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), agriculture and horticulture | Lignite briquettes | EF | $CH_4$ | -75% | 2000% | L | -50% | 100% | L |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), other small consumers | Hard-coal coke | EF | $CH_4$ | -75% | 4000% | L | -50% | 100% | L |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), other small consumers | Hard-coal briquettes | EF | $CH_4$ | -75% | 2000% | L | -50% | 100% | L |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), other small consumers | Hard coal | EF | $CH_4$ | -75% | 100% | L | -50% | 100% | L |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), other small consumers | Dust / dry coal | EF | $CH_4$ | -75% | 2000% | L | -90% | 150% | L |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), other small consumers | Crude lignite | EF | $CH_4$ | -75% | 4000% | L | -75% | 150% | L |
| 1A4, 1A5 | Stationary combustion subject to Ord. on | Waste wood (residue | EF | $CH_4$ | NE | NE | | -50% | 100% | L |

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|---|---|---|---|---|---|---|---|---|---|---|
| | small combustion plants (KFA), other small consumers | wood) | | | | | | | | |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), other small consumers | Hard lignite | EF | $CH_4$ | NE | NE | | -90% | 150% | L |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), other small consumers | Peat | EF | $CH_4$ | NE | NE | | -90% | 150% | L |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), other small consumers | Firewood | EF | $CH_4$ | -75% | 100% | L | NE | NE | |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), other small consumers | Lignite coke | EF | $CH_4$ | -75% | 2000% | L | -90% | 150% | L |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), other small consumers | Lignite briquettes | EF | $CH_4$ | -75% | 2000% | L | -50% | 100% | L |
| 1A5 | Stationary combustion, TA Luft plants | Hard-coal coke | EF | $CH_4$ | -75% | 1000% | L | NE | NE | |
| 1A5 | Stationary combustion, TA Luft plants | Hard coal | EF | $CH_4$ | -90% | 100% | L | -50% | 100% | L |

| CRF | Sub-category | Fuel | Value type | Gas | Downward deviation, 1990 [%] | Upward deviation, 1990 [%] | Distribution 1990 | Downward deviation, 2002 [%] | Upward deviation, 2002 [%] | Distribution 2002 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1A1 | Other GFA boiler combustion plants | Crude lignite, hard coal | EF | $N_2O$ | -75% | 75% | U | -50% | 50% | U |
| 1A1 | Gas turbines | | EF | $N_2O$ | -75% | 75% | U | -50% | 50% | U |
| 1A1 | GFA lignite mining | Crude lignite | EF | $N_2O$ | -10% | 150% | L | -50% | 50% | U |
| 1A1 | Boiler combustion systems subject to Ord. on Large Combustion Plants (GFA) | Petrol coke | EF | $N_2O$ | -90% | 10% | L | -50% | 50% | U |
| 1A1 | Boiler combustion systems subject to Ord. on Large Combustion Plants (GFA) | Industrial waste | EF | $N_2O$ | -75% | 75% | U | NE | NE | |
| 1A1 | Boiler combustion systems subject to Ord. on Large Combustion Plants (GFA) | Light heating oil | EF | $N_2O$ | -60% | 30% | L | -50% | 50% | U |
| 1A1 | Boiler combustion systems subject to Ord. on Large Combustion Plants (GFA) | Fuel gas | EF | $N_2O$ | -75% | 75% | U | NE | NE | |
| 1A1 | Boiler combustion systems subject to Ord. on Large Combustion Plants (GFA) | Lignite derivatives | EF | $N_2O$ | -50% | 50% | U | -50% | 50% | U |
| 1A1 | Boiler combustion systems subject to Ord. on Large Combustion Plants (GFA) | Other petroleum products | EF | $N_2O$ | -75% | 75% | U | -50% | 50% | U |
| 1A1 | Boiler combustion systems subject to Ord. on Large Combustion Plants (GFA) | Other liquid and solid fuels | EF | $N_2O$ | -90% | 10% | L | -50% | 50% | U |
| 1A1 | Engines | Other fuels | EF | $N_2O$ | -86% | 122% | L | -71% | 112% | L |
| 1A1 | Engines | Light heating oil | EF | $N_2O$ | -86% | 122% | L | -71% | 122% | L |
| 1A1 | Engines | Gas from sewage treatment | EF | $N_2O$ | -78% | 104% | L | -90% | 103% | L |
| 1A1 | Engines | Natural gas | EF | $N_2O$ | -86% | 122% | L | -65% | 115% | L |
| 1A1 | Waste incineration | Household waste / municipal waste | EF | $N_2O$ | -20% | 20% | N | -20% | 20% | N |
| 1A1 | Refinery process combustion | | EF | $N_2O$ | -75% | 75% | U | -75% | 75% | U |
| 1A1 | TA Luft | LP gas | EF | $N_2O$ | -75% | 75% | U | -50% | 50% | U |
| 1A1 | TA Luft | Solid fuels | EF | $N_2O$ | -75% | 75% | U | -50% | 50% | U |
| 1A1 | TA Luft | Other liquid and gaseous fuels | EF | $N_2O$ | -60% | 30% | L | -50% | 50% | U |
| 1A1, 1A2f | Other process combustion | | EF | $N_2O$ | missing | missing | | missing | missing | |
| 1A2a | | | EF | $N_2O$ | -10% | 10% | T | -10% | 10% | T |
| 1A2b | Production of non-ferrous heavy metals (process combustion) | | EF | $N_2O$ | missing | missing | | missing | missing | |
| 1A2e | Sugar manufacturing (process combustion) | | EF | $N_2O$ | missing | missing | | missing | missing | |
| 1A2f | Gas turbines | | EF | $N_2O$ | -50% | 50% | U | -50% | 50% | U |

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|---|---|---|---|---|---|---|---|---|---|---|
| 1A2f | Boiler combustion systems subject to Ord. on Large Combustion Plants (GFA) | Hard coal, hard-coal coke | EF | $N_2O$ | -50% | 300% | L | -50% | 50% | U |
| 1A2f | Boiler combustion systems subject to Ord. on Large Combustion Plants (GFA) | Heavy heating oil | EF | $N_2O$ | -90% | 10% | L | -50% | 50% | U |
| 1A2f | Boiler combustion systems subject to Ord. on Large Combustion Plants (GFA) | Light heating oil | EF | $N_2O$ | -60% | 30% | L | -50% | 50% | U |
| 1A2f | Boiler combustion systems subject to Ord. on Large Combustion Plants (GFA) | Fuel gas | EF | $N_2O$ | -75% | 75% | U | NE | NE | |
| 1A2f | Boiler combustion systems subject to Ord. on Large Combustion Plants (GFA) | Other gaseous fuels | EF | $N_2O$ | -90% | 10% | L | -50% | 50% | U |
| 1A2f | Boiler combustion systems subject to Ord. on Large Combustion Plants (GFA) | Other solid fuels | EF | $N_2O$ | -75% | 75% | U | -50% | 50% | U |
| 1A2f | Calcium carbide production (process combustion) | | EF | $N_2O$ | missing | missing | | missing | missing | |
| 1A2f | Glass production (process combustion) | | EF | $N_2O$ | missing | missing | | missing | missing | |
| 1A2f | Manufacturing of coarse ceramics (process combustion) | | EF | $N_2O$ | missing | missing | | missing | missing | |
| 1A2f | Lime production (process combustion) | | EF | $N_2O$ | missing | missing | | missing | missing | |
| 1A2f | Cement production (process combustion) | | EF | $N_2O$ | missing | missing | | missing | missing | |
| 1A2f | Small combustion plants | LP gas | EF | $N_2O$ | NE | NE | | -70% | 70% | N |
| 1A2f | Small combustion plants | Natural gas | EF | $N_2O$ | NE | NE | | -70% | 70% | N |
| 1A2f | Engines | Other fuels | EF | $N_2O$ | -86% | 122% | L | -71% | 112% | L |
| 1A2f | Engines | Natural gas | EF | $N_2O$ | -86% | 122% | L | -71% | 112% | L |
| 1A2f | Waste incineration | Industrial waste | EF | $N_2O$ | -60% | 5% | L | -60% | 5% | L |
| 1A2f | Waste incineration | Waste sulphite liquor | EF | $N_2O$ | missing | missing | | missing | missing | |
| 1A2f | Boiler combustion systems subject to TA Luft | Hard coal, hard-coal coke | EF | $N_2O$ | -50% | 300% | L | -50% | 50% | U |
| 1A2f | Boiler combustion systems subject to TA Luft | Petroleum | EF | $N_2O$ | -75% | 75% | U | NE | NE | |
| 1A2f | Boiler combustion systems subject to TA Luft | Coke-oven / city gas | EF | $N_2O$ | -75% | 75% | U | NE | NE | |
| 1A2f | Boiler combustion systems subject to TA Luft | Natural gas, petroleum gas | EF | $N_2O$ | -60% | 30% | L | -50% | 50% | U |
| 1A2f | Boiler combustion systems subject to TA Luft | Firewood | EF | $N_2O$ | -75% | 75% | U | NE | NE | |
| 1A2f | Boiler combustion systems subject to TA Luft | Fuel gas | EF | $N_2O$ | -75% | 75% | U | NE | NE | |
| 1A2f | Boiler combustion systems subject to TA Luft | Other gases | EF | $N_2O$ | -90% | 10% | L | -50% | 50% | U |
| 1A2f | Boiler combustion systems subject to TA Luft | Other liquid fuels | EF | $N_2O$ | -60% | 30% | L | -50% | 50% | U |

| CRF | Sub-category | Fuel | Value type | Gas | Downward deviation, 1990 [%] | Upward deviation, 1990 [%] | Distribution 1990 | Downward deviation, 2002 [%] | Upward deviation, 2002 [%] | Distribution 2002 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1A2f | Boiler combustion systems subject to TA Luft | Other solid fuels | EF | $N_2O$ | -75% | 75% | U | -50% | 50% | U |
| 1A3a | | | EF | $N_2O$ | missing | missing | | missing | missing | |
| 1A3b | | | EF | $N_2O$ | missing | missing | | missing | missing | |
| 1A3c | | | EF | $N_2O$ | missing | missing | | missing | missing | |
| 1A3d | | | EF | $N_2O$ | missing | missing | | missing | missing | |
| 1A3e | Gas turbines in natural gas compressor stations | | EF | $N_2O$ | -50% | 50% | U | -50% | 50% | U |
| 1A3e | Mobile sources | | EF | $N_2O$ | missing | missing | | missing | missing | |
| 1A4 | Stationary combustion, TA Luft plants | Hard-coal coke | EF | $N_2O$ | -90% | 100% | L | -50% | 50% | N |
| 1A4 | Stationary combustion, TA Luft plants | Hard coal | EF | $N_2O$ | -75% | 100% | L | -50% | 50% | N |
| 1A4 | Stationary combustion, TA Luft plants | Crude lignite | EF | $N_2O$ | NE | NE | | -75% | 100% | L |
| 1A4 | Stationary combustion, TA Luft plants | Lignite tar | EF | $N_2O$ | -90% | 150% | L | NE | NE | |
| 1A4 | Stationary combustion, TA Luft plants | Lignite briquettes | EF | $N_2O$ | -75% | 150% | L | -50% | 50% | N |
| 1A4, 1A5 | Mobile sources | | EF | $N_2O$ | missing | missing | | missing | missing | |
| 1A4, 1A5 | Stationary combustion | Gaseous (not including LP gas) | EF | $N_2O$ | -70% | 70% | N | -35% | 35% | N |
| 1A4, 1A5 | Stationary combustion | LP gas | EF | $N_2O$ | -70% | 70% | N | -70% | 70% | N |
| 1A4, 1A5 | Stationary combustion | Liquid (not including LP gas) | EF | $N_2O$ | -70% | 70% | N | -35% | 35% | N |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), households | Hard-coal coke | EF | $N_2O$ | -90% | 50% | L | -50% | 50% | N |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), households | Hard-coal briquettes | EF | $N_2O$ | -75% | 150% | L | -50% | 50% | N |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), households | Crude lignite | EF | $N_2O$ | -75% | 150% | L | -90% | 100% | L |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), households | Peat | EF | $N_2O$ | -75% | 150% | L | -90% | 100% | L |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), households | Firewood | EF | $N_2O$ | -75% | 100% | L | NE | NE | |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), households | Other solid fuels | EF | $N_2O$ | -75% | 150% | L | -50% | 50% | N |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), agriculture | Hard-coal coke | EF | $N_2O$ | -90% | 50% | L | NE | NE | |

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|---|---|---|---|---|---|---|---|---|---|---|
| | and horticulture | | | | | | | | | |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), agriculture and horticulture | Hard coal | EF | $N_2O$ | -75% | 75% | L | -50% | 50% | N |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), agriculture and horticulture | Crude lignite | EF | $N_2O$ | -90% | 150% | L | NE | NE | |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), agriculture and horticulture | Firewood, untreated | EF | $N_2O$ | NE | NE | | -50% | 50% | N |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), agriculture and horticulture | Lignite briquettes | EF | $N_2O$ | -90% | 100% | L | -50% | 50% | N |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), other small consumers | Hard-coal coke | EF | $N_2O$ | -90% | 50% | L | -50% | 50% | N |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), other small consumers | Hard-coal briquettes | EF | $N_2O$ | -75% | 150% | L | -50% | 50% | N |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), other small consumers | Hard coal | EF | $N_2O$ | -75% | 75% | L | -50% | 50% | N |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), other small consumers | Dust / dry coal | EF | $N_2O$ | -90% | 150% | L | -75% | 100% | L |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), other small consumers | Crude lignite | EF | $N_2O$ | -90% | 150% | L | -75% | 150% | L |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), other small consumers | Waste wood (residue wood) | EF | $N_2O$ | NE | NE | | -50% | 50% | N |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), other small consumers | Hard lignite | EF | $N_2O$ | NE | NE | | -75% | 150% | L |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), other small consumers | Peat | EF | $N_2O$ | NE | NE | | -75% | 150% | L |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), other small consumers | Firewood | EF | $N_2O$ | -90% | 100% | L | NE | NE | |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), other small consumers | Lignite coke | EF | $N_2O$ | -90% | 150% | L | -75% | 100% | L |
| 1A4, 1A5 | Stationary combustion subject to Ord. on small combustion plants (KFA), other small consumers | Lignite briquettes | EF | $N_2O$ | -90% | 150% | L | -50% | 50% | N |

| CRF | Sub-category | Fuel | Value type | Gas | Downward deviation, 1990 [%] | Upward deviation, 1990 [%] | Distribution 1990 | Downward deviation, 2002 [%] | Upward deviation, 2002 [%] | Distribution 2002 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1A5 | Stationary combustion, TA Luft plants | Hard-coal coke | EF | $N_2O$ | -90% | 100% | L | NE | NE | |
| 1A5 | Stationary combustion, TA Luft plants | Hard coal | EF | $N_2O$ | -75% | 100% | L | -50% | 50% | N |
| 1A1a | | | EF | $CO_2$ | missing | missing | | -3% | 3% | T |
| 1A1b | | | EF | $CO_2$ | missing | missing | | -1% | 1% | missing |
| 1A1c | | | EF | $CO_2$ | missing | missing | | -5% | 5% | missing |
| 1A2 | | | EF | $CO_2$ | missing | missing | | missing | missing | |
| 1A3 | | | EF | $CO_2$ | missing | missing | | missing | missing | |
| 1A4 | | | EF | $CO_2$ | missing | missing | | missing | missing | |
| 1A5 | | | EF | $CO_2$ | missing | missing | | missing | missing | |
| 2A1. | Cement production | | EF | $CO_2$ | missing | missing | | -20% | 20% | missing |
| 2A2 | Lime production | | EF | $CO_2$ | -10% | 10% | T | -30% | 10% | L |
| 2A3 | Dolomite and lime production | | NE | NE | NE | NE | NE | NE | NE | NE |
| 2A4 | Soda ash production | | EF | $CO_2$ | missing | missing | | missing | missing | |
| 2A5 | Asphalt mixing plants | | EF | NE | | | | | | |
| 2A6 | Road paving with asphalt | | NE | NE | NE | NE | NE | NE | NE | NE |

| CRF | Sub-category | Fuel | Value type | Gas | Downward deviation, 1990 [%] | Upward deviation, 1990 [%] | Distribution 1990 | Downward deviation, 2002 [%] | Upward deviation, 2002 [%] | Distribution 2002 |
|---|---|---|---|---|---|---|---|---|---|---|
| 2A7 | Glass production | | EF | $CO_2$ | missing | missing | | missing | missing | |
| 2C1 | Foundries: iron and steel casting (including malleable casting) | | EF | $CH_4$ | -10% | 10% | T | -10% | 10% | T |
| 2C1 | Raw steel production | | EF | $CO_2$ | -10% | 10% | T | -10% | 10% | T |
| 2C3 | Aluminium production: primary aluminium | | EF | $CO_2$ | -15% | 15% | N | -15% | 15% | N |
| 2C3 | Aluminium production: primary aluminium | | EF | PFC | - | - | - | -15% | 15% | N |
| 2C4 | $SF_6$ used in aluminium and magnesium foundries | | EF | $SF_6$ | - | - | - | missing | missing | |
| 4A | | | EF | | missing | missing | | missing | missing | |
| 4B1 | SNAP 10 05 01 | | EF | $N_2O$ | Reference to CORINAIR B1010-19, to $NH_3$, $N_2O$, NO, VOC | | | | | |
| 4B1 | SNAP 10 05 02 | | EF | $N_2O$ | Reference to CORINAIR B1010-19, to $NH_3$, $N_2O$, NO, VOC | | | | | |
| 4B3 | SNAP 10 05 05 | | EF | $N_2O$ | Reference to CORINAIR B1010-19, to $NH_3$, $N_2O$, NO, VOC | | | | | |
| 4B6 | SNAP 10 05 06 | | EF | $N_2O$ | Reference to CORINAIR B1010-19, to $NH_3$, $N_2O$, NO, VOC | | | | | |
| 4B9 | SNAP 10 05 07 | | EF | $N_2O$ | Reference to CORINAIR B1010-19, to NH3, N2O, NO, VOC | | | | | |
| 4B9 | SNAP 10 05 08 | | EF | $N_2O$ | Reference to CORINAIR B1010-19, to NH3, N2O, NO, VOC | | | | | |
| 4B9 | SNAP 10 05 09 | | EF | $N_2O$ | Reference to CORINAIR B1010-19, to NH3, N2O, NO, VOC | | | | | |

| CRF | Sub-category | Fuel | Value type | Gas | Downward deviation, 1990 [%] | Upward deviation, 1990 [%] | Distribution 1990 | Downward deviation, 2002 [%] | Upward deviation, 2002 [%] | Distribution 2002 |
|---|---|---|---|---|---|---|---|---|---|---|
| 4D | SNAP 10 01 00 | | EF | $N_2O$ | Reference to CORINAIR B1010-19, to $NH_3$, $N_2O$, NO, VOC | | | | | |
| 4D | SNAP 10 02 00 | | EF | $N_2O$ | Reference to CORINAIR B1010-19, to $NH_3$, $N_2O$, NO, VOC | | | | | |
| 4D | SNAP 10 03 00 | | EF | $N_2O$ | Reference to CORINAIR B1010-19, to $NH_3$, $N_2O$, NO, VOC | | | | | |
| 4A1 | SNAP 10 04 01 | | AR | | missing | missing | | -10% | 10% | missing |
| 4A1 | SNAP 10 04 02 | | AR | | missing | missing | | -10% | 10% | missing |
| 4A3 | SNAP 10 04 03 | | AR | | missing | missing | | -10% | 10% | missing |
| 4A6 | SNAP 10 04 05 | | AR | | missing | missing | | -10% | 10% | missing |
| 4A9 | SNAP 10 04 08 | | AR | | missing | missing | | -10% | 10% | missing |
| 4A9 | SNAP 10 04 09 | | AR | | missing | missing | | -10% | 10% | missing |
| 4A9 | SNAP 10 04 10 | | AR | | missing | missing | | -10% | 10% | missing |
| 4B | | | AR | | missing | missing | | missing | missing | |
| 4D | | | AR | | missing | missing | | missing | missing | |
| 5A | | | AR | | missing | missing | | -10% | 10% | missing |
| 5B | | | AR | | missing | missing | | missing | missing | |
| 5C | | | AR | | missing | missing | | missing | missing | |
| 5D | | | AR | | missing | missing | | missing | missing | |

## 18.2 Further procedure for determining uncertainties pursuant to Tier 1

In further determination of uncertainties pursuant to Tier 1, in keeping with Chapter 6 of GPGAUM, plans call for treating the source categories energy, transport and agriculture separately.

The uncertainties for activity rates in the source category Energy (CRF 1) are being estimated by experts of the Working Group on Energy Balances (AG Energiebilanzen). The uncertainties for emission factors for $CO_2$ are being estimated by experts in the Federal Environmental Agency's section (FG) I 2.5.

Uncertainties for activity rates in the source category Transport (primarily CRF 1 A 3) are also being estimated by experts of the Working Group on Energy Balances. The uncertainties in the emission factors for $CH_4$ and $N_2O$ are being estimated by experts in the Federal Environmental Agency's sections I 3.1 and I 3.2.

Uncertainties in the source category Agriculture (CRF 4) are being estimated by experts in the Federal Ministry of Consumer Protection, Food and Agriculture (BMVEL) and in the Federal Agricultural Research Institute (FAL).

Uncertainties for other source categories are being determined successively within the framework of UBA departments' data deliveries for current emissions reporting. At the same time, guideline-supported experts' assessments are being continued especially in those source categories in which very little or no uncertainties information has been provided in the framework of contributions/support.

## 18.3 Uncertainties calculation pursuant to Tier 2, in keeping with Chapter 6 of GPGAUM

Two different versions of the Monte-Carlo simulation for uncertainties calculation are used in preparation of national emissions inventories. One version appears on the lowest aggregation level (*structure elements in the CSE*), in calculation of emissions as the product of activity rate (AR) and emission factor (EF). The other version is used in aggregation of individual processes, to form source categories and source-category areas, as well as in aggregation covering the various relevant gases, using GWP values[148]. The aggregation level on which Monte-Carlo simulation is actually used depends on the database and available resources in the case in question.

The basis for uncertainties calculation is the source-category structure as specified by the IPCC and already used in the CSE in the form of time-series views. Monte-Carlo simulation should be carried out both for emissions calculation (starting level) and for emissions aggregation in Excel, with the help of a suitable programme (such as Crystal Ball).

An MS Excel®-based report form, which is to be integrated in the MESAP Explorer, will be used for practical management of uncertainties calculation. This will then provide a direct link with the CSE. All data required for calculation will then be taken from the relevant CSE time series.

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### *18.3.1 Status of uncertainties calculation pursuant to Tier 2*

Uncertainties spreads and types of distribution are specified in the CSE. The upper and lower boundaries of the 95% confidence interval are set as hypotheses (MAX and MIN), and the distribution type is set in the field *Distribution_shape* of the *Parameter quality* documentation component.

Since the CSE does not yet contain any uncertainties values, the existing report form uses default uncertainties taken from the literature. The default uncertainties are entered into the report form in such a manner that they are used only if the CSE contains no relevant values. As soon as the relevant hypotheses in the CSE are filled, these values receive preference.

In adoption of uncertainties from the literature, the different aggregation levels of the source categories had to be taken into account. In the energy sector, the uncertainties for emission factors and activity rates were determined per fuel / emissions combination and then transferred to all identical combinations149 (cf. RYPDAL et al, 2000, CHARLES et al, 1998 and WINIWARTER et al, 2000).

As to distribution types, in cases with uncertainties < 60% a normal distribution was assumed. In cases with uncertainties ≥ 60%, a log-normal distribution was used (CHARLES et al, 1998, DECISIONEERING INC., 2001).

### *18.3.2 Status of technical implementation*

The general structure of the report form has been completed. The table structure, and the structures of the individual table sheets, have also been completed, although not all table sheets have been filled with the relevant CSE data. For this to be possible, the missing time-series views must first be prepared.

Currently, the following tasks being carried out automatically via programming:

- Definition of assumptions and predictions in Crystal Ball
- Starting of simulation and definition of relevant parameters
- Aggregation of results at the table-sheet level
- Calculation of uncertainties for calculated emissions
- Filling of summary tables, and calculation of uncertainties for aggregated emissions.

The time-series views still lacking in the CSE remain to be prepared, and the report form must be filled with the relevant data. Only then will complete uncertainties calculation pursuant to Tier 2 be possible. In the framework of automation of uncertainties calculation, the procedures for automatic filling of *summary* tables, and suitable checking procedures for quality assurance, remain to be completed. Once such programming has been completed, and all available data has been incorporated in the CSE, the report form will be tested under various parameters.

149 The same uncertainty was used for the emission factor of the same gas ($CO_2$, $CH_4$, etc.) in two modules with the same material (= fuel), for example.