Britta Hoem (ed.)

The Norwegian Emission Inventory

Documentation of methodologies for estimating emissions of greenhouse gases and long-range transboundary air pollutants

Statistisk sentralbyrå • Statistics Norway
Oslo–Kongsvinger

Rapporter

I denne serien publiseres statistiske analyser, metode- og modellbeskrivelser fra de enkelte forsknings- og statistikkområder. Også resultater av ulike enkeltundersøkelser publiseres her, oftest med utfyllende kommentarer og analyser.

Reports

This series contains statistical analyses and method and model descriptions from the various research and statistics areas. Results of various single surveys are also published here, usually with supplementary comments and analyses.

ISBN 82-537-6859-1 Trykt versjon
ISBN 82-537-6860-5 Elektronisk versjon
ISSN 0806-2056

Emnegruppe
01.04.10

Design: Enzo Finger Design
Trykk: Statistisk sentralbyrå/218

Standardtegn i tabeller	Symbols in tables	Symbol
Tall kan ikke forekomme	Category not applicable	.
Oppgave mangler	Data not available	..
Oppgave mangler foreløpig	Data not yet available	...
Tall kan ikke offentliggjøres	Not for publication	:
Null	Nil	-
Mindre enn 0,5 av den brukte enheten	Less than 0.5 of unit employed	0
Mindre enn 0,05 av den brukte enheten	Less than 0.05 of unit employed	0,0
Foreløpig tall	Provisional or preliminary figure	*
Brudd i den loddrette serien	Break in the homogeneity of a vertical series	—
Brudd i den vannrette serien	Break in the homogeneity of a horizontal series	I
Desimalskilletegn	Decimal punctuation mark	,(.)

Abstract

Britta Hoem (ed.)

The Norwegian Emission Inventory
Documentation of methodologies for estimating emissions of greenhouse gases and long-range transboundary air pollutants

Reports 2005/28 • Statistics Norway 2005

The Norwegian emission inventory is a joint undertaking between the Norwegian Pollution Control Authority (SFT) and Statistics Norway. The Norwegian Pollution Control Authority is responsible for the emission factors and for providing data from specific industries and sources, while emission figures are derived from models operating at Statistics Norway. Statistics Norway is responsible for developing the emission models, for the collection and development of activity data, and for the calculations. Emission data are used for a range of national applications and for international reporting.

This report document the methodologies used in the Norwegian emission inventory of greenhouse gases (GHG), acidifying pollutants, heavy metals (HM) and persistent organic pollutants (POPs). The documentation will also serve as a part of the National Inventory Report submitted by Norway to the United Nation Framework Convention on Climate Change (UNFCCC), and as documentation over the reported emissions to UNECE for the pollutants restricted by CLRTAP (Convention on Long-Range Transboundary Air Pollution).

This report replaces the previous documentations of the emission model, Rypdal (1993), Rypdal (1995b) and Flugsrud et al. (2000). The most important changes are that heavy metals and POPs have been included, text has been updated where appropriate, the structure has been changed to correspond to the nomenclature used for international reporting and information about QA/QC (Quality Assurance/ Quality Control) and uncertainties have been added.

The Norwegian Emission Inventory; Documentation of methodologies for estimating emissions of greenhouse gases and long-range transboundary air pollutants is also avable at *http://www.ssb.no.*

Acknowledgement: Statistics Norway and the Norwegian Pollution Control Authority have financed the report

Contents

List of Figures

List of Tables

Appendices

1. Introduction

1.1. Inventory documentation: Needs and Plans

Emission data are used for a range of national applications and for international reporting. Many users of emission data want to know how the data have been estimated. The emission data are based on a mix of measurements and calculations. The purpose of this report is to document the methodologies used in the Norwegian emission inventory of greenhouse gases (GHG), acidifying pollutants, heavy metals (HM) and persistent organic pollutants (POPs). The documentation will also serve as a part of the National Inventory Report (SFT 2005b) submitted by Norway to the United Nation Framework Convention on Climate Change (UNFCCC), and as documentation over the reported emissions to UNECE for the pollutants restricted by CLRTAP (Convention on Long-Range Transboundary Air Pollution).

The structure of this report is following the guidelines given by UNFCCC for structure of the National Inventory Report. Differences between the previous published National Inventory Report (SFT 2005b) and this documentation report are that the National Inventory Report only includes greenhouse gases, and that emissions from the IPCC sector 5 LULUCF (Land Use, Land Use Change and Forestry) are included in the National Inventory Report, but not here. The reasons why emissions from LULUCF are not part of the calculations in the Norwegian emission model operated by Statistics Norway, are that these calculations are not included in the national emission data presented by Statistics Norway each year.

It is planned that this documentation report will be updated annually in connection with publishing of emission data at the beginning of the year. Users of the printed version of the documentation should conesquently consult the web version (at www.ssb.no/english/subjects/01/04/10/) for possible recent updates. In general, the information in the methodology part will only be changed when appropriate, while data changed annually are given in the Appendices.

The documentation report is a further development of Rypdal (1993), Rypdal (1995b) and Flugsrud et al. (2000). The most important changes are that heavy metals and POPs have been included, text has been updated where appropriate, the structure has been changed to correspond to the nomenclature used for international reporting and information about QA/QC (Quality Assurance/ Quality Control) and uncertainties have been added.

The Division for Environmental Statistics at Statistics Norway has been publishing this report. The report has been edited by Britta Hoem, with contributions from Anne Finstad, Ketil Flugsrud, Gisle Haakonsen, Britta Hoem, Lisbet Høgset, Henning Høie, Kristin Rypdal, Trond Sandmo and Kristin Aasestad at Statistics Norway. Torgrim Asphjell, Christel Benestad, Øyvind Christophersen, Tor Færden, Eilev Gjerald, Harold Leffertstra, Sophia Mylona, Marit Viktoria Pettersen, Audun Rosland and Per Svardal at the Norwegian Pollution Control Authority have also been contributing to the report. Statistics Norway and the Norwegian Pollution Control Authority have financed the report.

1.2. Institutional arrangements

The emission inventory is produced in collaboration between Statistics Norway and the Norwegian Pollution Control Authority (SFT).

Statistics Norway is responsible for:

- collection of activity data
- operation and further development of models for emission estimation
- emission calculations
- filling in most of the tables for international reporting to UNFCCC and UNECE
- publishing national official statistics on emissions to air.

SFT is responsible for:
- overall responsibility for international reporting to UNFCCC and UNECE
- emission factors for all sources
- the quality of measured emission data from large industrial plants based on individual reports submitted to SFT on a regular basis
- submitting amounts of import and export data of HFCs, PFCs and SF_6.

Activity data[1] are collected either internally at Statistics Norway (e.g. data on energy use, industrial production, animals, etc.) or reported to Statistics Norway from external sources such as the Norwegian Petroleum Directorate (OD), the Public Road Administration (VD) and also from the Norwegian Institute on Land Inventory (NIJOS). Emission figures are derived from models operating at Statistics Norway. In the modelling activities Statistics Norway makes use of the data collected by SFT on emission factors, emissions from industrial plants and on imports and exports of HFCs, PFCs and SF_6.

SFT is responsible for quality control of the data they deliver to the Statistics Norway model, but Statistics Norway makes an additional consistency check (see Chapter 1.5). Statistics Norway is responsible for quality control of the activity data and the emission figures from the model, but SFT also participates in this quality control.

1.3. The process of inventory preparation

The Norwegian emission inventory is based on a general emission model and a series of more detailed satellite models, which cover specific emission sources (e.g. road traffic, air traffic, landfills, solvents, HFCs, SF_6, PFCs). These models are operated by Statistics Norway with only one exception; the model calculating emissions from landfills that is operated by the Norwegian Pollution Control Authority.

Data and information on point sources are recorded at the Norwegian Pollution Control Authority under the Norwegian Pollutant Release and Transfer Register (PRTR) (http://www.sft.no/bmi/). This register, nationally known as INKOSYS, was introduced in 1978 as an internal tool for the authorities. It was upgraded in 1992, and has over the last years been under continuous development in order to harmonise with the PRTR adopted by the OECD in 1996. Each polluting industrial installation or plant is subjected to licensing and is obliged to produce an annual report to the pollution control authorities. The report should provide activity data, emission figures and information about the particular source and it should address compliance with current environmental standards. SFT supplies Statistics Norway with data from INKOSYS relevant for the preparation of the national emission inventory.

1.3.1. Data collection, processing and archiving

Statistics Norway collects the majority of data necessary to run the Norwegian emission model. These are as follows: activity levels, emission factors, aggregated results from the satellite models and emission figures for point sources.

The collected data are subjected to the Quality Assurance and Quality Control (QA/QC) routines described in section 1.5 as well as source specific routines as described under each source chapter. They are subequently processed by Statistics Norway into a format appropriate to enter the emission models. The models are designed in a manner that accommodates both the estimation methodologies reflecting Norwegian conditions and those recommended internationally.

The input data used in the model runs, the versions of the models used and the model output are all stored at Statistics Norway. Relevant information including dates and procedures followed are also recorded.

1.4. Definitions and structure

The structure of this documentation follows the nomenclature used for reporting to UNFCCC in the Common Reporting Format (CRF) and to the Convention on Long Range Transport of Air Pollution (CLRTAP) as Nomenclature For Reporting (NFR).

The main sectors here are:
1A Energy combustion
1B Energy production
2 Industrial processes
3 Solvent and other product use
4 Agriculture
5 Land use change and forestry
6 Waste

Note that the classification of individual sources may differ from Flugsrud et al. (2000).

The description of the pollutants included is given in table 1.1.

Emissions of heavy metals, POPs and particulates are further described in the reports Finstad et al. (2001), Finstad et al. (2002a), Finstad and Rypdal (2003) and Finstad et al. (2003).

[1] Data on the magnitude of human activity resulting in emissions or removals taking place during a given period of time.

Table 1.1. Definition of pollutants in the Norwegian emission inventory

Class	Pollutant	Symbol	Definition
Greenhouse gases			
	Carbon dioxide	CO_2	Includes all carbon emitted, e.g. as CH_4, CO and NMVOC
	Methane	CH_4	
	Nitrous oxide	N_2O	
	Perfluorocarbons	PFCs	$CF_4 + C_2F_6$
	Hydrofluorocarbons	HFCs	
	Sulphur hexafluoride	SF_6	
Acidifying gases			
	Sulphur dioxide	SO_2	
	Nitrogen oxides	NO_x	$NO + NO_2$
	Ammonia	NH_3	
Heavy metals (HM)			
	Lead	Pb	
	Cadmium	Cd	
	Mercury	Hg	
	Arsenic	As	
	Chromium	Cr	
	Copper	Cu	
Persistent organic pollutants (POPs)			
	Polycyclic Aromatic Hydrocarbons	PAH	Emission is calculated for PAH-total, PAH-6 and PAH-4. PAH-total includes 16 components according to Norwegian Standard (NS9815). PAH-6 is OSPARs Borneff-6 and include 6 components. PAH-4 is consisting of four components used as an indicator for PAH emissions required for reporting to CLRTAP.
	Dioxins	-	Dioxin emission is given in the unit I-TEQ, which is required for reporting to CLRTAP. I-TEQ is based on the international model ("Nato-modell") and is the sum of PCDD/PCDF multiplied by the components toxicity equivalency factor (I-TEF). TEQ = sum ($PCDD_i$ * TEF_i) + sum ($PCDD_j$ * TEF_j).
Particulates			
	Total suspended particulates	TSP	
	-	PM_{10}	Particulate matter with diameter less than 10µm
	-	$PM_{2.5}$	Particulate matter with diameter less than 2.5µm
Other pollutants			
	Carbon monoxide	CO	
	Non-methane volatile organic compounds	NMVOC	

1.5. Quality Assurance and Quality Control (QA/QC)

This chapter describes general QA/QC procedures. For source specific QA/QC, see each source sector for detailed descriptions.

The QA/QC work has several dimensions. In addition to accuracy, also timeliness is essential. As these two aspects may be in conflict, the QA/QC improvements in recent years have been focusing on how to implement an effective QA/QC procedure and how to have an efficient dataflow in the inventory system.

During the past years several quality assurance and quality control procedures for the preparation of the national emission inventory have been established in Norway. Statistics Norway made its first emission inventory for some gases in 1983 for the calculation year 1973. The emission estimation methodologies and the QA/QC procedures have been developed continuously since then. Norway has not yet implemented a formal quality assurance/quality control or verification plan.

1.5.1. General QA/QC procedures

The inventory is produced in several steps

- Preliminary estimates are produced three months after the end of the inventory year (for SO_2 6 months later)[2]. These estimates are based on preliminary statistics and indicators and data that have been subjected to a less thorough quality control.
- The next update is made about one year after the inventory year. At this stage, statistics are available for more sources and emissions data from point sources have been subject to quality control.
- The "final" update is made about two years after the inventory year. At this stage, final statistics are available for all sources and also regional emission data are compiled.
- Recalculations of the inventory are performed annually caused by smaller or larger methodological changes or refinements. These recalculations are made for the entire time series.

The general QA/QC procedures are applied for all these steps.

[2] Preliminary estimates are not made for heavy metals and POPs.

1.5.1.1. Input side
In 2002, the Norwegian emission model was revised to facilitate QA/QC on input data, and not only on the emission data. Input data here includes emissions reported from large plants, activity data, emission factors and other estimation parameters.

The value of all parameters is compared with the previous year's value and to any preliminary figures. If there are large deviations, the value of the parameter is first checked for typing errors or unit errors. Changes in emissions from large plants are compared with changes in activity level. If necessary, the primary data providers are contacted for an explanation. The primary data providers will sometimes have reasons to correct the value or they provide an acceptable explanation.

The activity data are often statistical data. Statistical data go through a systematic revision process, which may be manual or, more and more frequently, computerised. Revision significantly reduces the number of errors in the statistics used as input to the inventory.

Statistics Norway and SFT verify emission data reported to SFT by plants. First SFT makes a check of the data they receive from the plants and the plants have the opportunity to submit new data when errors are discovered. Statistics Norway, where possible, then makes comparable emission calculations based on activity data sampled in official statistics and deviations are explained through contact with the plants. Internal checks of time series for all emission sources are made every year when an emission calculation for a new year is done. Changes in time series have to be explained with either change in data or in methodology.

The emission data are typically revised based on special projects focusing on particular key categories. These projects are repeated in regular intervals when new information is available. These projects often involve comparison of emission factors in the literature and a rational for choice of emission factor. More information is provided under the source specific QA/QC procedure.

When possible, estimates based on different methodologies are compared. An important example is the metal production sector where CO_2 estimates reported by the plants are compared with estimates based on the good practice methodology corrected for national circumstances. In this case, both production based and reducing agent based calculations are performed to verify the reported value. See the source sector specific description in Chapter 4.4.

When a new source is included or there have been changes in the methodology, two members of the inventory team check the new data. When there are changes in methodologies or data, the internal documentation as well as this documentation is updated.

The Norwegian inventory has a long history of taking into account completeness. However, from time to time new emission sources occur (for example a new Industrial plant) or existing sources are for the first time recognised as a source. Information about new plants is delivered by SFT and for oil and gas production activities from administrative information. Information about existing sources is collected from guideline materials and national and international literature sources.

1.5.1.2. Output side
Every year our time series of emission data is increasing with one year. Because of methodological changes and other improvements the whole time series is recalculated annually. There are two main types of checks performed on the emission data:

Comparing data with last year's calculations for the same year
The recalculated emission data for a year is compared with last year's emission data for the same year. This could for instance be to compare the 1990 CO_2 data calculated in 2004 with the 1990 CO_2 data calculated in 2005. All major differences are explained. Changes may be due to revisions in energy data, new plants, correcting for former errors, new emission methodologies or there may be caused by new errors. These checks lead to corrections and re-runs of the Norwegian Emission Model.

Comparing data for a new year with calculations for the previous year
The emission data for the last year are compared with data for the previous year. In 2004 Statistics Norway/SFT calculated 2003 emission data for the first time. These data were compared with the 2002 data to check if there were errors. Large deviations were explained. There may be large deviations that are correct, for instance caused by closedowns of large industrial plants.

The procedure of making annual estimates as well as several updates for each year gives several opportunities for detecting gross errors. Each new estimate is compared with the provisional estimate as well as with the latest estimate for the previous year. Any changes must be explained, and in this way gross errors may be detected. Findings from the QA/QC on input data are utilised, and if needed, further checks are initialised.

Finally, where alternative methodologies are available, emission estimates are often made by both methods and then compared. Such comparisons may reveal errors and suggest where methods can be improved, and they also indicate the level of uncertainty.

1.5.2. Source specific QA/QC procedures and verification

Source specific QA/QC procedures may for instance be comparing an emission estimate for a source with an estimate done by a different methodology. This is done for several sources. Such source specific QA/QC procedures are described under each source sector later in this report.

Norway has conducted a verification of national GHG emissions data in the report Statistics Norway/SFT (2000). The main goals of that work were to suggest possible statistical data to use as indicators for comparing emission figures between countries on a general basis and to test the method on the Norwegian national emission estimates. In the report we compared Norwegian emission data with national data for Canada, Sweden and New Zealand. The report concluded that no large errors in the Norwegian emission inventory were detected. The process of verification did, however, reveal several smaller reporting errors, emissions that had been reported in other categories than they should have been. These errors have been corrected in later reports to the UNFCCC. Finally, it is important to realise that this method of verification only considers consistency compared with what other countries report. It is not a verification of the scientific value of the inventory data themselves.

In 2002, a project initiated by the Nordic Council of Ministers has been completed, where the results for emissions of greenhouse gases from the agricultural sector in the national emission inventories was compared with the results using the IPCC default methodology and the IPCC default factors. The results for the Nordic countries are collected in a report (Petersen and Olesen 2002).

In 2004 the Nordic Council of Ministers initiated a new project that will be finalised in 2005. The project focuses on NMVOC, heavy metals and POPs. A final report will be published in the end of 2005 with the following elements:

- comparisons of the emission estimation methodologies and emission factors used in each country (review)
- identification of gaps in knowledge
- identification of possible "burden sharings" with respect to research areas (research taking place in one country, but used in all countries)
- discussions of the particular Nordic aspects influencing the emissions
- discussions of the possible contributions from research in the Nordic countries
- proposals for research areas
- recommendations for further work

1.5.3. Dataflow

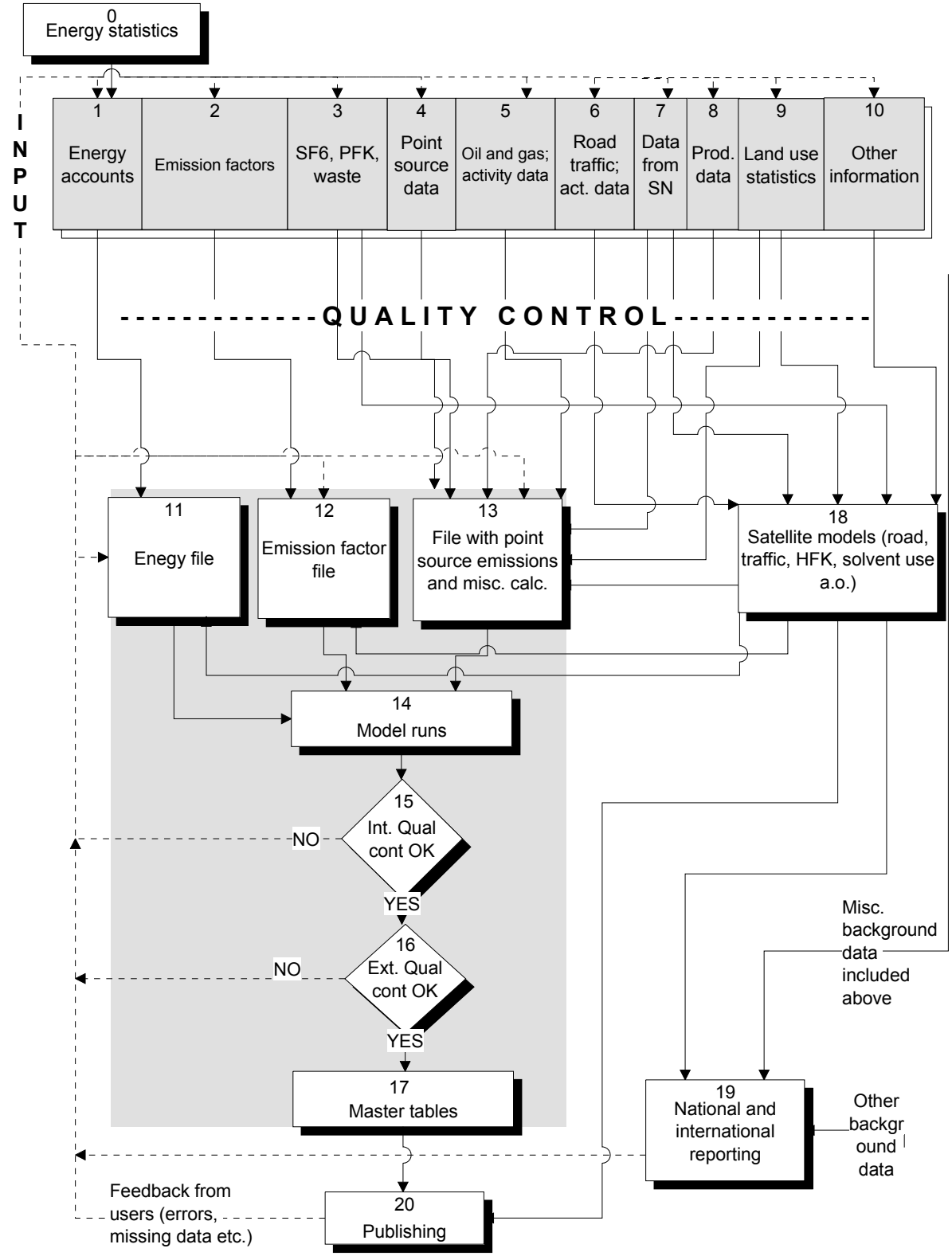
Statistics Norway has, like other institutions, been working for many years on the issue of quality of the national inventory, but the focus has traditionally been on controlling the final quality of products, not on controlling processes or input data. In 2001, Statistics Norway started a Total Quality Management project to broaden this quality concept (Haakonsen 2001). The goal was not just traditional data quality, but also taking into account the need to meet the deadlines of international reporting of emission data.

For this task a project team was established. The team had representatives from both the users of the emission inventory data, the input data providers in addition to members at different levels of the inventory team. Early in the project the team made a flow chart of the different processes involved in the inventory work (figure 1.1); from receiving all the different input data to international reporting and the publishing of the results in a press release. Based on this, "bottlenecks" (critical process variables) and connected processes were identified. The energy data for the manufacturing industry (as provided by Statistics Norway) was identified as the most critical dataset as it is essential for the results and at the same time is finished quite late compared with the need for timeliness of inventory data (with respect to deadlines for international reporting). The inventory team must therefore try to involve the key data providers closer in the inventory preparation process, give them information about the applications and invite them to try to adjust their internal deadlines to better support the essential deadlines for the inventory work.

The project team concluded that the data providers must be closer involved in the work.

- They must know that their data is important for the quality of the whole inventory.
- They must know that the Norwegian reporting to the UN Conventions can be delayed if their work is delayed.
- The data providers may be able to change their time limits to be able to deliver the data earlier.
- The inventory team must be better to inform the providers about what kind of data they need and at what time they need the data. The providers are responsible to report any delay as soon as possible.

Figure 1.1. Process diagram for the Norwegian emission inventory work within Statistics Norway



Source: Haakonsen (2001).

The team did also identify problems with the model itself. The model was not constructed to handle long time series. Doing recalculations was time consuming because the model was organised so that, for example, the emission factors were stored in annual files. Since most of the emission factors are the same every year, this led to increased possibilities for errors in addition to wasted time. In addition the model was constructed in a way that made automatic checks on input data difficult. Since the large input datasets are checked manually and not automatically, many errors will not be detected before the model run is completed and the

tables are checked in our quality control system. This led to time consuming re-runs of the model. In addition, it is often more difficult to trace errors in the results than in the input data. Therefore some errors were not detected with the "result check" method.

As a consequence of these findings Statistics Norway in 2002/2003 made a new Norwegian emission model. The model:

- makes automatic controls easy
- handles long time series better
- logs all corrections (time and responsible person)

The new Norwegian emission model is further described in Chapter 2.

1.5.4. Archiving

The national emissions inventory is a part of Statistics Norway's data archiving system. All input data to and results from the general Norwegian emission model from every publication cycle are stored and documented in this system.

Several input data are used in preliminary calculations before entering into the general Norwegian emission model. This includes satellite models such as road traffic and air traffic, as well as a number of simpler calculations that do not fit into the framework of the general model. The preliminary calculations are not included in the central archiving system, which is not suited for such a diverse collection of data. For some satellite models there is an established archiving routine where all input data and results from every calculation cycle are stored.

1.6. Uncertainties in total emissions

The uncertainty in the Norwegian emission inventory has been investigated systematically in three reports (SFT 1999a, Rypdal and Zhang 2000, 2001). The first two reports are focusing on the uncertainty in the greenhouse gas emissions, and the last report is investigating the uncertainty in the emission estimates of long-range air pollutants.

1.6.1. Greenhouse gases

The emission estimates for the greenhouse gases in the Norwegian emission model may be ranked roughly in order of increasing uncertainty as follows:

$$CO_2 \approx SF_6 < HFC < CF_4/C_2F_6 \approx CH_4 < N_2O$$

In the report Rypdal and Zhang (2000) the uncertainty in level for the total Norwegian GHG emissions in 1990 is estimated at 21 per cent. An uncertainty in level of 3 per cent was estimated for CO_2, while estimations of other gases have much higher uncertainties. Calculations of emissions of N_2O are most uncertain; the uncertainty in level is estimated to be more than 150 per cent. The estimated uncertainty in trend is 4 per cent for the period 1990 to 2000.

Using a simpler method of analysis (Good Practice Guidance Tier 1), the uncertainty in level was found to be 11-17 per cent (SFT 1999a). In the 1999 report a qualitative evaluation of the uncertainty in the Norwegian greenhouse gas inventory of each gas was carried out concerning emissions factors, activity data and direct measured emissions. Emissions of CH_4 from landfills, N_2O from agriculture and PFCs from production of aluminium are found to have the highest uncertainty. This result is in accordance with what was found by Rypdal and Zhang (2000), where uncertainties in level and trend were estimated using models based on simulations (Good Practice Guidance Tier 2).

The major elements of the most recent work on emission uncertainties in Norway (Rypdal and Zhang 2000) are summarised in the tables presented in Appendix D. These tables list the standard deviation and probability density of the activity data and emission factors found under the various IPCC source categories, as well as the estimated uncertainties in emission level and in trend for the greenhouse gases under consideration.

In 2005, a key category analysis on the greenhouse gas inventory was performed. The steps taken to find key categories with respect to level and trend were the determination of uncertainties in input parameters (AD = activity data and EF = emission factors). Uncertainty data were obtained from Rypdal and Zhang (2000) with some modifications. The highest uncertainties from Rypdal and Zhang (2000) could not be used directly, as they would have totally dominated the analysis. More information about the modifications made and the uncertainty values used in the key category analysis are given in Appendix E.

1.6.2. Acidifying substances and NMVOC

The emission estimates for long-range air pollutants in the Norwegian emission model may be ranked roughly in order of increasing uncertainty as follows:

$$SO_2 < NO_X < NH_3 \approx NMVOC$$

The sources of uncertainty in the emission estimates include sampling errors, poor relevance of emission factors or activity data, and gross errors.

Evaluation of the uncertainty in the long-range air pollutants is given in the report Rypdal and Zhang (2001). Summary tables with the results are given in Appendix D.

1.6.3. Heavy metals and POPs

The uncertainty is generally higher for HM and POPs than for other components in the Norwegian emission

model except for N_2O. There are various reasons for this high uncertainty. The most important reason is that there is limited information about emission factors and it is not clear how usable the emission factors found in international literature are on Norwegian conditions. Emission factors for some HM and POPs components are insufficient for some sources, so emission factors for similar sources have then been used. In addition it is not certain that all emission sources are known or sufficiently mapped. The industrial reporting to Norwegian Pollution Control Authority has improved in recent years. The reported figures can however vary a great deal from one year to another. For earlier years they can be insufficient and since HM and POPs are to be calculated from 1990, recalculations are necessary. These recalculations are necessary based on assumptions and knowledge of the plants. Emissions in the early 1990s are therefore more uncertain than today.

1.7. Key category analyses

For the greenhouse gases a key category analysis was performed in 2005, following the IPCC Good Practice Guidance (IPCC 2001).

For SO_2, NO_X, NMVOC, NH_3 and heavy metals (HM) and POPs no systematic key category analyses have been made.

1.7.1. Greenhouse gases

According to the IPCC definition, key categories are those that add up to 90 per cent of the total uncertainty in level and/or trend. In the Norwegian greenhouse gas emission inventory key categories are primarily identified by means of a Tier 2 method, as recommended by IPCC's Good Practice Guidance (IPCC 2001). A description of the methodology is presented in Appendix E.

A key category analysis was performed in April 2005, see table 1.2 below for identified key categories. The table lists the 24 identified key categories arranged primarily according to contribution to the uncertainty in level. It was performed at the level of IPCC source categories and each greenhouse gas from each source category was considered separately with respect to total GWP (Global Warming Potential) weighted emissions, except land-use, land-use change and forestry. The advantage in using a Tier 2 rather than the Tier 1 methodology is that uncertainties are taken into account so the ranking shows where uncertainties can be reduced. In addition, the Tier 1 method can identify categories that are not actually key categories according to Tier 2 (Flugsrud and Rypdal 2001).

Table 1.2. Summary of identified key categories for the greenhouse gases except LULUCF

IPCC Category		Gas	Level assessment		Trend assessment	Method (Tier)
			1990	2003	1990-2003	2003
4D1	Direct soil emissions	N_2O	42,56 %	40,22 %	19,50 %	Tier 1a
1A3b	Road Transportation	CO_2	8,20 %	9,75 %	3,90 %	Tier 2
4D3	Indirect emissions	N_2O	9,98 %	9,55 %	4,10 %	Tier 1a
1A1, 1A2, 1A4	Stationary Fuel Combustion, Gas	CO_2	2,99 %	5,43 %	8,64 %	Tier 2 / 3
4D2	Animal production	N_2O	5,23 %	5,16 %	1,56 %	Tier 1a
1A3b	Road Transportation	N_2O		4,01 %	13,21 %	Tier 2
6A	Solid Waste Disposal on Land	CH_4	4,59 %	3,72 %	4,47 %	Tier 2
1B2a	Oil (incl. oil refineries, gasoline distribution)	CO_2	1,95 %	2,39 %	1,24 %	Tier 2
4A1	Cattle	CH_4	1,89 %	1,74 %	1,04 %	Tier 1
2C3	Aluminium Production	PFCs	6,92 %	1,44 %	22,73 %	Tier 2
1A1, 1A2, 1A4	Stationary Fuel Combustion, Oil	CO_2	1,40 %	1,40 %		Tier 2
1A3d	Navigation	CO_2	1,04 %	1,31 %	0,76 %	Tier 2
1B2c	Venting and Flaring	CH_4		0,97 %	1,57 %	Tier 2
1A3a	Civil Aviation	CO_2	0,71 %	0,97 %	0,83 %	Tier 2
2C2	Ferroalloys Production	CO_2	1,01 %	0,85 %	0,88 %	Tier 2
2C3	Aluminium Production	CO_2		0,72 %		Tier 2
1B2c	Venting and Flaring	CO_2	0,84 %	0,70 %	0,72 %	Tier 2
2C4	SF_6 Used in Aluminium and Magnesium Foundries	SF_6			2,09 %	Tier 2
2F	Consumption of Halocarbons and Sulphur Hexafluoride	HFCs			1,88 %	Tier 2
2B2	Nitric Acid Production	N_2O	0,75 %		0,73 %	Tier 2
1B2a	Oil (incl. oil refineries, gasoline distribution)	CH_4			0,61 %	Tier 2
2A1	Cement Production*	CO_2	0.92 %	1.07 %	0.96 %	Tier 2
1B1a	Coal mining and handling**	CH_4				Tier 2
	CO_2 capture and storage***	CO_2				CS (Tier 2)***

* Identified because of large contribution to the total emissions (Tier 1).

** Key category since emission factors deviates from IPCC default emission factors.

*** No methodology or category is defined in IPCC Guidelines.

Table 1.3. Summary of identified key categories - LULUCF

IPCC Category		Gas	Level assessment		Trend assessment	Method (Tier)
			1990	2003	1990-2003	2003
5A1	Forest land remaining forest land, living biomass	CO_2	6.80 %	10.53%	20.03	Tier 3
5C1	Grassland remaining grassland, soils, histosols	CO_2	8.04	7.57	256	Tier 2**
5A1	Forest land remaining forest land, dead organic matter	CO_2	4.39	3.50	1.31	Tier 3
5A1	Forest land remaining forest land, soils, other*	CO_2	1.94	2.00	1.35	Tier 3
5A1	Forest land remaining forest land, soils, drained organic soils	CO_2	1.23	1.22	0.67	Tier 1
5B1	Cropland remaining cropland, soils, histosols	CO_2	0.89	0.85	-	Tier 2
5E1	Forest converted to settlements, living biomass	CO_2	*Tier 1 only*		-	Tier 2

* "Other" refers to all areas excluding Finnmark county and drained areas.

** Country specific emission factors.

*** No methodology or category is defined in IPCC Guidelines.

A Tier 2 key category analysis was also performed for the land-use, land-use change and forestry sector. From this analysis we identified the key categories listed in table 1.3.

1.8. Completeness

An assessment of the completeness of the emission inventory should, according to the IPCC Good Practice Guidance (IPCC 2001), address the issues of spatial, temporal and sectoral coverage along with all underlying source categories and activities. Confidentiality is an additional element of relevance.

1.8.1. Greenhouse gases

In terms of spatial coverage, the GHG emission calculated covers all activities within Norway's jurisdiction.

In the case of temporal coverage, complete set of emission figures are produced and updated every year for the years 1980, 1987 and for all years from 1989.

With regard to sectoral coverage are emissions from the IPCC sector 5 LULUCF (Land Use, Land Use Change and Forestry) not included in this documentation. The reason for this exclusion is that this sector is not part of the calculations in the Norwegian emission model operated by Statistics Norway, and it is not included in the national emission data presented by Statistics Norway each year. Norway reports emissions and removals from this sector to the UNFCCC, though. A further description of the calculations of the data Norway report for LULUCF to the UNFCCC, is given in SFT (2005b).

Otherwise the Norwegian GHG emission inventory includes estimates from all known relevant sources or sinks. There are, however, a few exceptions of minor sources/sinks, which are not covered. These are:

- Emissions of CH_4 from agricultural waste, after it is applied to soils. In the IPCC Guidelines it is written that "Agricultural soils may also emit CH_4", but no calculation methodology is proposed.
- Carbon stock change of harvested wood products. The IPCC default method is used, where harvested wood is counted as emissions the year the harvest takes places.

The reason for not including the above activities is lack of data and/or exclusion from the list of priorities in the national inventorying work because of the source's insignificant contribution to the national total.

Emissions from the use of feedstock are in accordance with Good Practice Guidance, and they are generally accounted for in the industrial processes sector in the Norwegian inventory. By-products from processes like CO gas that is sold and combusted are accounted for and reported under the energy sector.

1.8.2. Other pollutants

Norway is requested to report emissions to UNECE for the pollutants restricted by CLRTAP (Convention on Long-Range Transboundary Air Pollution). Minimum reporting request each year includes the acidifying pollutants (NO_x, SO_2, NH_3) and NMVOC, the heavy metals Pb, Cd and Hg, particulate matter (TSP, PM_{10} and $PM_{2.5}$) and CO. Norway also report, under the section "additional reporting", the heavy metals As, Cr and Cu, and the POPs dioxins and PAH.

In terms of spatial coverage, the calculated air emissions cover all activities within Norway's jurisdiction.

In the case of temporal coverage, emission figures for CO, SO_2, NO_x, NH_3 and NMVOC are produced and updated every year for the years 1980, 1987 and for all years from 1989. For HM, POPs and particles, emission figures are produced for all years from 1990.

With regard to sectoral coverage, the following sources with relevant emission amounts are not covered in the inventory even if emissions can be expected:

Energy sector:

- NH_3 emissions from Civil aviation, domestic cruise (1A3aii (ii))
- Emissions of particulate matters from clutch wear (1A3b)
- Emissions of particulate matters from use of unpaved roads (1A3b)
- Emissions of particulate matters from sand strewing (1A3b)

- Fugitive emissions of HM from solid fuel transformation (1B1b)
- Fugitive emissions of NO_X from natural gas (by land-based desulphuration) (1B2b)

Industry sector:
- Emissions of NMVOC from asphalt roofing (2A5) and NMVOC and PAH from road paving with asphalt (2A6)
- Emissions of NO_X, NMVOC and NH_3 from ammonia production (2B1)
- Emissions of NMVOC from Nitric acid production (2B2)
- Emissions of NO_X from production of NPK-fertilizers (2B5) and emissions of Cd from production of Phosphate fertilizers (2B5)
- Emissions of NMVOC from the pulp and paper industry (2D1)
- Emissions of NH_3 from refrigeration and air conditioning equipments using other products than halocarbons (2G)

Agricultural sector:
- Emissions of NMVOC from manure management (4B)
- Emissions of NMVOC from agricultural soils (4D)
- Emissions of NMVOC from field burning of agricultural wastes (4F)

Waste sector:
- Emissions of NO_X, NMVOC, NH_3 and CO from solid waste disposal on land (6A)
- Emissions of NMVOC and NH_3 from waste-water handling (6B)
- Emissions of particulate matters and POPs from burning of bonfire, emissions of POPs from burning of garden waste, and emissions of particulate matters, POPs and HM from burning of animal carcasses (6C)
- Emissions of HM and POPs in connection with fires and open burning at landfills (6C)
- Evaporation of Hg from landfills and emission of Pb by detonation of explosives (6C)
- Emissions of dioxins by smoking processes for preservation of meat and fish (6C)

The reasons for not including these emission sources are mainly lack of activity data, emission factor or known calculation methodology.

1.9. Indirect CO_2 emissions from CH_4 and NMVOC

According to the reporting guidelines to the Climate Convention all emissions of carbon from fossil compounds are to be included in the national emission inventory. When methane or NMVOC are oxidised in the atmosphere indirect CO_2 emissions are formed. The emissions of CH_4 and NMVOC from some sources will partly be of fossil origin and should therefore be included. Fossil carbon in fuels combusted are automatically included in the emission inventory due to the fact that the guidelines for calculating the emissions takes into account the fossil carbon in the fuel. These indirect CO_2 emissions are included in the Norwegian emission inventory. However, indirect CO_2 emissions from non-combustion sources originating from the fossil part of CH_4 and NMVOC are taken into account separately calculated on the basis of average carbon content.

Fossil carbon in the emissions of CH_4 and NMVOC from the following non-combustion sources are included in the Norwegian emission inventory:

- 1B1a - Coal mining
- 1B2a - Loading and storage of crude oil, oil refineries, gasoline distribution
- 1B2b - Gas terminals
- 1B2c - Venting (extraction and production drilling)
- 2B4.1 - Silicone carbide production
- 2B5.1 - Methanol production
- 2B5.4 - Plastic production
- 2C2 - Ferroalloys production (reducing agents)
- 3 - Solvent and other product use

The indirect CO_2 emissions from oxidised CH_4 and NMVOC are calculated from the content of fossil carbon in the compounds. The average amount of carbon is estimated to be 75 per cent in methane and 82 per cent in NMVOC. This leads to the emission factors 2.75 kg CO_2/kg CH_4 and 3 kg CO_2/kg NMVOC.

2. The Norwegian emission model; general description

This chapter describes the general structure of the Norwegian emission model "Kuben" ("the Cube"). The model was developed by Statistics Norway (Daasvatn et al. 1992, 1994). It was redesigned in 2003 in order to improve reporting to the UNFCCC and UNECE, and to improve QA/QC procedures.

The Norwegian emission model is organised around a general emission model called "Kuben" ("the Cube"). Several emission sources, e.g. road traffic, air traffic and solvents are covered by more detailed satellite models. Aggregated results from the side models are used as input to the general model. The satellite models are presented in the appropriate sections of chapters 3-7. This chapter describes the general emission model.

2.1. Structure of the general emission model

The general emission model is based on equation (1).

(1) Emissions (E) = Activity level (A) · Emission Factor (EF)

For emissions from *combustion*, the activity data concern energy use. In the Norwegian energy accounts, the use of different forms of energy is allocated to industries (economic sectors). In order to calculate emissions to air, energy use must also be allocated to technical sources (e.g. equipment). After energy use has been allocated in this way, the energy accounts may be viewed as a cube in which the three axes are fuels, industries, and sources.

The energy use data are combined with a corresponding matrix of emission factors. In principle, there should be one emission factor for each combination of fuel, industry, source, and pollutant. Thus, the factors may be viewed as a four-dimensional cube with pollutants as the additional dimension. However, in a matrix with a cell for each combination, most of the cells would be empty (no consumption). In addition, the same emission factor would apply to many cells.

Emissions of some pollutants from major manufacuring plants (point sources) are available from measurements or other plant-specific calculations. When such measured data are available it is possible to replace the estimated values by the measured ones:

(2) Emissions (E) = [(A - A_{PS}) · EF] + E_{PS}

where A_{PS} and E_{PS} are the activity and the measured emissions at the point sources, respectively. Emissions from activity for which no point source estimate is available (A-A_{PS}) are still estimated with the regular emission factor.

Non-combustion emissions are generally calculated in the same way, by combining appropriate activity data with emission factors. Some emissions may be obtained from current reports and investigations, and some are measured directly as described in chapters 3-7. The emissions are fitted into the general model using the parameters industry, source, and pollutant. The fuel parameter is not relevant here. The source sector categories are based on EMEP/NFR and UNFCCC/CRF categories, with further subdivisions where more detailed methods are available. An oversight of the source sector categories used is given in Appendix G.

2.2. The four axes: Pollutants, industries, sources, and fuels

The model currently includes 21 *pollutants*. They are given in table 2.1, see section 1.4.

The model uses approximately 130 *industries* (economic sectors). The classification is common with the Energy Accounts, and is almost identical to that used in the National Accounts, which is aggregated from the European NACE (rev. 1) classification (Daasvatn et al. 1994). The allocation of energy use and emissions to industries is the basis for combining inventory results with economic data in economic/ enviromental accounts (Erlandsen et al. 2002) and with economic models. The large number of sectors is an advantage in dealing with important emissions from manufacturing industries. The disadvantage is an unnecessary disaggregation of sectors with very small emissions. To make the standard sectors more appropriate for calculation of emissions, a few changes

have been made, e.g. "Private households" is defined as a sector. The list of sectors is shown in Appendix F.

The *fuels* and technical *sources* used for combustion with energy use (NFR source sector 1A) are shown in tables 2.2-2.4.

Table 2.1. Energy commodities in the Norwegian emission inventory

Energy commodity	Aggregate fuel category in CRF
Coal	Solid Fuels
Coke	Solid Fuels
Petrol coke	Liquid Fuels
Wood	Biomass
Wood waste	Biomass
Black liquor	Biomass
Wood pellets	Biomass
Wood briquettes	Biomass
Charcoal	Biomass
Natural gas	Gaseous Fuels
Refinery gas	Liquid Fuels
Blast furnace gas	Solid Fuels
Landfill gas	Biomass
Fuel gas	Liquid Fuels
LPG	Liquid Fuels
Gasoline (road transport)	Liquid Fuels
Aviation gasoline	Liquid Fuels
Kerosene (heating)	Liquid Fuels
Jet kerosene	Liquid Fuels
Autodiesel	Liquid Fuels
Marine gas oil	Liquid Fuels
Light fuel oils	Liquid Fuels
Heavy distillate	Liquid Fuels
Heavy fuel oil	Liquid Fuels
Municipal waste	Other Fuels
Special waste	Liquid Fuels

Table 2.2. Sources for energy combustion in the Norwegian emission inventory

Source	CRF/NFR
Stationary combustion	
Direct fired furnaces	1A1, 1A2
Gas turbines	1A1c, 1A3e
Boilers	1A1, 1A2, 1A4, 1A5
Small stoves	1A2, 1A4, 1A5
Flaring	1B2C, 6C
*Mobile combustion**	
Passenger car	1A3b i, 1A5b
Light duty vehicles	1A3b ii, 1A5b
Heavy duty vehicles	1A3b iii, 1A5b
Motorcycle	1A3b iv
Moped	1A3b iv
Snowscooter	1A4b, c
Railway	1A3c
Aviation jet/turboprop (0-100 m)	1A3a ii (i), 1A5b
Aviation jet/turboprop (100-1000m)	1A3a ii (i) , 1A5b
Aviation jet/turboprop (cruise)	1A3a ii (ii), 1A5b
Aviation helicopter (0-100 m)	1A3a ii (i)
Aviation helicopter (100-1000m)	1A3a ii (i)
Aviation helicopter (cruise)	1A3a ii (ii)
Aviation small craft (0-100 m)	1A3a ii (i)
Aviation small craft (100-1000m)	1A3a ii (i)
Aviation small craft (cruise)	1A3a ii (ii)
Ships	1A3d, 1A4c, 1A5b
Small boats 2 stroke	1A4b
Small boats 4 stroke	1A4b, c
Equipment 2 stroke	1A3e, 1A4c
Equipment 4 stroke, tractor	1A3e, 1A4b, c, 1A5b

* For road transport the source split is more detailed in the sub-model. See section 3.4.2.

Table 2.3. Combinations of fuels and sources in use

	Direct fired furnaces	Gas turbines	Boilers	Small stoves	Flaring	Passenger car	Light duty vehicles	Heavy duty vehicles	Motorcycle	Moped	Snowscooter	Railway	Aviation jet/turboprop	Aviation helicopter	Aviation small craft	Ships	Small boats 2 stroke	Small boats 4 stroke	Equipment 2 stroke	Equipment 4 stroke, tractor
Coal	x	..	x	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Coke	x	..	x	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Petrol coke	x	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Fuel wood	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Wood waste	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Black liquor	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Wood pellets	..	..	x	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Wood briquettes	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Charcoal	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Natural gas	x	x	x	..	x	x	..	x	..	..	..	..	..	..	..	x	..	..	..	..
Refinery gas	x	..	x	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Blast furnace gas	x	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Landfill gas	..	..	x	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Fuel gas	x	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
LPG	..	..	x	x	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Motor gasoline	..	..	..	..	..	x	x	x	x	x	x	..	..	..	..	..	x	x	x	x
Aviation gasoline	..	..	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..	..
Kerosene (heating)	..	..	x	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Jet kerosene	..	..	..	..	..	..	..	..	..	..	..	..	x	x	..	..	..	..	..	..
Auto diesel	..	..	x	..	..	x	x	x	..	..	..	x	..	..	..	..	..	x	..	x
Marine gas oil/diesel	x	x	x	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..
Light fuel oils	..	..	x	x	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	x
Heavy distillate	x	..	x	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..
Heavy fuel oil	x	..	x	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..
Municipal waste	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Special waste	x	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

The sources for non-combustion emissions and for combustion without energy use are based on EMEP/NFR and UNFCCC/CRF categories, with further subdivisions where more detailed methods are available (Appendix G).

2.3. Regions: a fifth axis

Information about the geographical distribution of emissions is useful for modelling and control purposes. The spatial distribution of emissions introduces another dimension (axis) to the general model.

2.3.1. Municipalities

The municipalities, of which there are 434 on the mainland (in 2004), have been chosen as the smallest unit for regionalisation. In addition we have included the regions Svalbard, sea areas north and south of 62°N, and air space 100-1000 m and more than 1000 m above ground level.

Emissions are allocated to geographical units *after* the national totals have been calculated. Emissions are allocated in one of three ways:

- Emissions from *point sources* are allocated directly to municipalities.
- When figures for the activity used to calculate emissions are available *directly* at municipal level, these figures are used. Examples are fuel combustion in manufacturing industries and emissions from animals.
- When the activity at the municipal level is unknown, the national emissions are allocated *indirectly* using surrogate statistical data. For example, fuel combustion in service industries is allocated using employment figures. In a number of cases the activity is known directly at the intermediate level (county), but allocation within counties uses surrogate data.

Data from several important sources, e.g. industrial statistics, are not available at the municipal level until one and a half years after the year of emissions.

2.3.2. EMEP grid squares

Emissions by EMEP 50 km x 50 km grid square are reported to the UNECE and used in models of long-range air pollution. The emissions are allocated to grid squares as follows:

- Emissions from large point sources are allocated directly to the appropriate squares.
- Emissions at sea from national sea traffic and offshore petroleum activities are allocated to squares on the basis of a detailed analysis of 1993 activity data (Flugsrud and Rypdal 1996). The 1993 emissions are projected using national emission trends for each of the categories fishing, other sea traffic, flaring, other combustion, and other emissions in the petroleum sector.
- The remaining emissions in each municipality are allocated to squares according to the proportion of the area of the municipality in each square.

The method assumes that emissions are evenly distributed within municipalities. In reality, emissions often occur only in small parts of a municipality. If a municipality is large relative to the grid squares, the emissions may be allocated wrongly. However, few municipalities measure more than 50 km across and the larger municipalities are usually sparsely populated, with small emissions. It is therefore assumed that the level of error due to the method is acceptable. The direct allocation of large point sources also reduces the potential error.

3. Energy

3.1. Overview

This chapter provides descriptions of methodologies employed to calculate emissions from the energy sector. The disposition of the chapter is following the IPCC and NFR classifications of the emission sources. In section 3.2 emission estimations from energy combustion are described. This includes combustion emissions from energy industries, manufacturing industries and construction, transport and other combustion sources. Section 3.2 also includes memo items about international bunker fuels and CO_2 emissions from biomass.

In section 3.3 a description is given for fugitive emissions from fuels. This includes fugitive emissions from coal mining and handling, and from oil and natural gas. Section 3.3 also includes a description of the CO_2 capture and storage at the oil and gas production field Sleipner West.

3.2. Energy combustion

IPCC 1A
NFR 1A
Last update: 01.09.05

3.2.1. Overview

Combustion of fossil fuels and biomass leads to emissions of greenhouse gases, acidifying pollutants, NMVOC, particulate matter, heavy metals, PAH and dioxins. Small amounts of NH_3 can also be emitted.

Emissions from energy combustion include contributions from all sources addressed in the IPCC/UNECE Guidelines. Emissions from waste incineration at district heating plants are accounted for under the energy sector, as the energy is utilised. Methane from landfills used for energy purposes is also accounted for in this sector. Emissions from flaring in the energy sectors are described in section 3.3 *Energy production*. Coal and coke used as reducing agents and gas used for production of ammonia (non-energy part) are accounted for under industrial processes. Flaring outside the energy sectors is described in Chapter 7 *Waste*. The same applies to emissions from cigarettes, accidental fires etc. Emissions from burning of crop residues and agricultural waste are accounted for under Chapter 6 *Agriculture*.

3.2.1.1. Method

Emissions from energy combustion are estimated at the sectoral level in accordance with the IPCC sectoral approach Tier 2/Tier 3. Often total fuel consumption is better known than the sectoral consumption.

The general method to estimate emissions from fuel combustion is multiplication of fuel consumption by source and sector by an appropriate emission factor. Exceptions are road and air transport where more detailed estimation models are used, involving additional activity data (see section 3.2.4.2 and 3.2.4.1 respectively). Fuel consumption figures are taken from the Norwegian energy accounts. The fuels theoretical energy content and their density are listed in table 3.1.

Table 3.1. Average energy content and density of fuels

Energy commodity	Theoretical energy content	Density
Coal	28.1 GJ/tonne	..
Coal coke	28.5 GJ/tonne	..
Petrol coke	35.0 GJ/tonne	..
Crude oil	42.3 GJ/tonne = 36.0 GJ/m³	0.85 tonne/m³
Refinery gas	48.6 GJ/tonne	..
Natural gas (2004)[2]	40.1 GJ/1000 Sm³	0.85 kg/Sm³
Liquefied propane and butane (LPG)	46.1 GJ/tonne = 24.4 GJ/m³	0.53 tonne/m³
Fuel gas	50.0 GJ/tonne	..
Petrol	43.9 GJ/tonne = 32.5 GJ/m³	0.74 tonne/m³
Kerosene	43.1 GJ/tonne = 34.9 GJ/m³	0.81 tonne/m³
Diesel oil, gas oil and light fuel oil	43.1 GJ/tonne = 36.2 GJ/m³	0.84 tonne/m³
Heavy distillate	43.1 GJ/tonne = 37.9 GJ/m³	0.88 tonne/m³
Heavy fuel oil	40.6 GJ/tonne = 39.8 GJ/m³	0.98 tonne/m³
Methane	50.2 GJ/tonne	..
Wood	16.8 GJ/tonne = 8.4 GJ/solid m³	0.5 tonne/solid m³
Wood waste (dry wt)	16.8 GJ/tonne	..
Black liquor (dry wt)	14.0 GJ/tonne	..
Waste	10.5 GJ/tonne	..

[1] The theoretical energy content of a particular energy commodity may vary. The figures therefore indicate mean values.

[2] Sm3 = standard cubic metre (at 15 ℃ and 1 atmospheric pressure).

Source: Energy statistics, Statistics Norway.

Table 3.2. Overview of estimated and reported greenhouse gases CO_2, CH_4 and N_2O for the energy combustion in 2003

	CO_2	CH_4	N_2O
A. Fuel Combustion Activities (Sectoral Approach)			
1. Energy Industries	E	E	E
a. Public Electricity and Heat Production	E/R	E	E
b. Petroleum Refining	R	E	E
c. Manufacture of Solid Fuels and Other Energy Industries	E/R	E/R	E/R
2. Manufacturing Industries and Construction			
a. Iron and Steel	E/R	E	E
b. Non-Ferrous Metals	E	E	E
c. Chemicals	E/R	E	E
d. Pulp, Paper and Print	E	E	E
e. Food Processing, Beverages and Tobacco	E	E	E
f. Other (Oil drilling, construction, other manufacturing)	E	E	E
3. Transport			
a. Civil Aviation	E	E	E
b. Road Transportation	E	E	E
c. Railways	E	E	E
d. Navigation	E	E	E
e. Other Transportation (Snow scooters, boats, motorized equipment, pipeline transport)	E	E	E
4. Other Sectors			
a. Commercial/Institutional	E	E	E
b. Residential	E	E	E
c. Agriculture/Forestry/Fisheries	E	E	E
5. Other (Military)	E	E	E

[1] R means that emission figures in the national emission inventory are based on figures reported by the plants. E means that the figures are estimated by Statistics Norway (Activity data * emission factor).

For some major manufacturing plants (in particular offshore activities, refineries, gas terminals, cement industry, production of plastics, ammonia production), emissions of one or more compounds, reported to the Norwegian Pollution Control Authority from the plants, are used instead of figures calculated as described above. In these cases, the energy consumption of the plants in question is subtracted from the total energy use before the general method is used to calculate the remaining emissions of the compound in question, in order to prevent double counting. An overview of the type of emissions (i.e. estimated and/or reported) used in the inventory for the different sectors is given in table 3.2 for the greenhouse gases CO_2, CH_4 and N_2O.

In the last years three documentation reports have been published describing the methodologies used for road traffic (SFT 1999c), aviation (Finstad et al. 2002b) and navigation (Tornsjø 2001).

3.2.1.2. Activity data

The energy consumption data used in the emission calculations are taken from the annual energy accounts, compiled by Statistics Norway. The energy accounts survey the flow of the different energy carriers within Norwegian economic activities. The energy accounts include energy carriers used as raw materials and reducing agents - these are subtracted in the data used to estimate emissions from combustion. Some emissions vary with the combustion technology; a distribution between different sources is thus required. Total use of the different oil products is based on the Norwegian sales statistics for petroleum products. For other energy carriers, the total use of each energy carrier is determined by summing up reported/estimated consumption in the different sectors. A short summary of the determination of amounts used of the main groups of energy carriers and the distribution between emission sources is given below.

Natural gas

Most of the combustion of natural gas is related to extraction of oil and gas on the Norwegian continental shelf. The amounts of gas combusted, distributed between gas turbines and flaring, are reported annually to Statistics Norway by the Norwegian Petroleum Directorate (NPD). These figures include natural gas combusted in gas turbines on the various oil and gas fields as well as on Norway's two gas terminals on shore. The data are of high quality, due to the Norwegian system of CO_2 taxation on fuel combustion. Statistics Norway's annual survey on energy use in manufacturing industries and sales figures from distributors give the remainder. Some manufacturing industries use natural gas in direct-fired furnaces; the rest is burned in boilers and, in some cases, flared.

LPG and other gases

Consumption of LPG in manufacturing industries is reported from the plants to Statistics Norway in the annual survey on energy use. Figures on use of LPG in households are based on sales figures, collected annually from the oil companies. Use in agriculture and construction is based on non-annual surveys; the figure for agriculture is held constant, whereas the figure for construction is adjusted annually, based on employment figures. Use of refinery gas is reported to Statistics Norway from the refineries. The distribution between the sources direct-fired furnaces, flaring and boilers is based on information collected from the

refineries in the early 1990's. At some industrial plants, excess gas from chemical and metallurgical industrial processes is burned, partly in direct-fired furnaces and partly in boilers. These amounts are reported to Statistics Norway. Two ferroalloy plants sell excess gas (CO gas) to some other plants, where it is combusted for energy purposes. Amounts sold are annually reported to Statistics Norway.

Oil
Total use of the different oil products is based on Statistics Norway's annual sales statistics for petroleum products. The data are considered very reliable since all major oil companies selling oil products have interest in and report to these statistics[3]. The use of sales statistics provides a given total for the use of oil products, which the use in the different sectors must sum up to. This is not the case for the other energy carriers. The method used for oil products defines use as identical to sales; in practice, there will be annual changes in consumer stocks, which not are accounted for.

Stationary use takes place in boilers and, in some manufacturing industries, in direct-fired furnaces. There is also some combustion in small ovens, mainly in private households. Mobile combustion is distributed between a number of different sources, described in more detail below. In addition to oil products included in the sales statistics, figures on use of waste oil are given in Statistics Norway's industry statistics. Statistics Norway also collects additional information directly from a few companies about the use of waste oil as a fuel source.

Coal
Use of coal, coke and petrol coke in manufacturing industries is annually reported from the plants to Statistics Norway. The statistics cover all main consumers and are of high quality. Combustion takes place partly in direct-fired furnaces, partly in boilers. Figures on some minor quantities burned in small ovens in private households are based on sales figures. In addition, an insignificant figure on use of coal in the agricultural sector has formerly been collected from the farmers. From 2002, there is no use of coal in Norwegian agriculture.

Wood, wood waste and black liquor
Use of wood waste and black liquor in manufacturing industries is taken from Statistics Norway's annual survey on energy use in these sectors. Use of wood in households is based on figures on the amount of wood burned from the annual survey on consumer expenditure. The statistics cover purchase in physical units and estimates for self-harvest. The survey figures refer to quantities *acquired*, which not necessarily correspond to *use*. The survey gathers monthly data that cover the preceding twelve months; the figure used in the emission calculations (taken from the energy accounts), is the average of the survey figures from the year in question and the following year. Figures on some minor use in agriculture and in construction are derived from earlier surveys for these sectors. Combustion takes place in boilers and in small ovens in private households. Consumption figures for wood pellets and wood briquettes are estimates, based on annual information from producers and distributors.

Waste
District heating plants and incineration plants annually report combusted amounts of waste (boilers) to Statistics Norway and the Norwegian Pollution Control Authority. There is also some combustion in manufacturing industries, reported to Statistics Norway.

According to the Norwegian Pollution Act, each incineration plant has to report emission data for SO_2, NO_X, CO, NH_3, particles, heavy metals and dioxins, and the amount of waste incinerated to the county governor. The county governor then reports this information to the Norwegian Pollution Control Authority. If emissions are not reported, the general method to estimate emissions from waste incineration is to multiply the amount of waste used by an appropriate emission factor. Normally a plant specific emission factor is made for the component in question. This factor is based on the ratio between previous emission figures and quantities of waste burned. This factor is then multiplied with the amount of waste incinerated that specific year.

3.2.1.3. Emission factors
Emission factors used for the energy sector are given in Appendix B. Emission factors for CO_2 and SO_2 are independent of technology, and emissions factors are described here. For the other emission components descriptions are given for each source sector.

CO_2
Emission factors for CO_2 are independent of technology and are based on the average carbon content of fuels used in Norway.

CH_4 and N_2O
In general, information on emission factors for CH_4 and N_2O is very limited, because, unlike those for CO_2, they depend on the source of the emissions and the sector where the emissions take place. The emission inventory mostly uses default factors from IPCC (1997b). The emission factor for methane from fuel wood is taken from SINTEF (1995). Due to lack of data, some emission factors are used for sector/source combinations other than those they have been designed for.
SO_2

[3] The statistics are corrected for direct import by other importers or companies.

The emission factors for SO_2 change yearly, in accordance with changes in the sulphur content in the products.

3.2.1.4. Uncertainties
An estimate of the uncertainty in both activity data and emission factors for all emission sources for greenhouse gases is given in the report Rypdal and Zhang (2000). An analysis of the uncertainty in the long-range air pollutants is given in the report Rypdal and Zhang (2001). Summary tables with the results are given in Appendix D.

Generally, the total energy use is less uncertain than the energy use in each sector. For some sectors (e.g. the energy and manufacturing industries) the energy use is well known, while it is more uncertain in households and the service sectors. The energy use in the most uncertain sectors has been adjusted in the official energy statistics, so that the sum of the energy use in all sectors equals the total sales.

3.2.1.5. Completeness
All known combustion with energy utilization in different industries and private households is included.

3.2.1.6. QA/QC
The emission sources in the energy sector are subjected to the QA/QC procedures described in section 1.5.1. In the last years three documentation reports have been published describing the methodologies used for road traffic (SFT 1999c), aviation (Finstad et al. 2002b) and navigation (Tornsjø 2001).

3.2.2. Energy industries

IPCC 1A1, Key category for CO_2 from gas and oil
NFR 1A1
Last update: 01.09.05

3.2.2.1. Description
Energy industries include emissions from electricity and heat generation and distribution, extraction of oil and natural gas, coal production, gas terminals and oil refineries. Norway produces electricity mainly from hydropower, so emissions from electricity production are small compared to most other countries. Due to the large production of oil and gas, the emissions from combustion in energy production are high.

3.2.2.2. Method
A general description of the method used for estimation of emissions from fuel combustion is given in section 3.2.1.1. For waste incineration also a more detailed description of the methodology for some components is given in this section.

Waste incineration
CO_2 and CH_4
We do not consider net CO_2 emissions from wood/biomass burning in the inventory, because the amount of CO_2 released during burning is the same as that absorbed by the plant during growth. Carbon emitted in compounds other than CO_2, e.g. as CO, CH_4 and NMVOC, is also included in the CO_2 emission estimates. This double counting of carbon is in accordance with the IPCC guidelines (IPCC 1997b).

N_2O and NO_x
Emissions of NO_X are reported from each plant to the Norwegian Pollution Control Authority. An estimated amount of 2.5 per cent of this NO_X is subtracted and reported to UNFCCC as N_2O (SFT 1996). Accordingly, the net NO_X emissions constitute 97.5 per cent of the emissions reported by the plants. For some years, emissions of NO_x have not been reported for a number of plants. In these cases, specific emission factors for the plants have been made, based upon earlier emissions and amounts of waste incinerated. These new factors have been used to estimate the missing figures.

Particles
Emissions of particles from district heating plants are reported to the Norwegian Pollution Control Authority. The different plants started to report particulate emissions at various points in time. Most of them started reporting from 1994. Emissions of particles in the years before reporting have been assumed to be the same as in the first year the plant reported. New control device systems (mainly wet scrubbers) were installed at the end of the 1980s at the largest plants. Around 1995 more control device systems were installed as a result of stricter emission requirements. Most plants today have fabric filter or electrofilter together with wet scrubbers. Only two plants do not have wet scrubbers.

The emission permits do not state which particle fraction that is going to be measured. It is common to measure total amount of particles. It is however presumed that the particles emitted are less than $PM_{2.5}$. TSP and PM_{10} are therefore the same as $PM_{2.5.}$

Dioxin
Emissions of dioxin from waste burning at district heating plants are reported to the Norwegian Pollution Control Authority. We have reported data for each plant from the period 1994/1995. Before 1994 we have only national totals. For estimating the emissions of dioxin for each plant before 1994 we derived an emission factor from total amount of waste burned together with the total dioxin estimate. The emissions of dioxin were estimated by multiplying the given emission factor of 20 μg/tonne waste by the amount of waste burned at each plant. This calculation was done for each of the missing years for plants that did not report emissions.

Heavy metals
The estimate of heavy metals from waste combustion at district heating plants is reported to Norwegian Pollution Control Authority. Before 1999 many emissions of heavy metals were reported together as one group. This made it difficult to use the data to estimate the emission of each component. From 1999 there are separate data for each component, but for As, Cr and Cu there are a few plants that have insufficient reporting. To calculate the emissions of heavy metals before 1999 we have estimated an emission factor for each plant with the aid of reported emission data and amount of waste burned at each plant. The emission factor derived has been used to calculate emissions for previous years by multiplying each specific emission factor with the amount burned for the corresponding year for each plant.

Every district heating plant had stricter emission requirements for particles from 1995. It is expected that the emissions of heavy metals, except for mercury, were reduced analogously. At the same time the emission of mercury was regulated from 0.1 mg/Nm^3 to 0.05 mg/Nm^3. These regulations are considered while calculating emissions for previous years.

3.2.2.3. Activity data
Electricity and heat generation and distribution
The energy producers annually report their use of different energy carriers to Statistics Norway. There is only some minor use of oil products at plants producing electricity from hydropower. Combustion of coal at Norway's only dual purpose power plant at Svalbard/Spitsbergen is of a somewhat larger size. The amount of waste combusted at district heating plants is reported annually both to Statistics Norway and the Norwegian Pollution Control Authority. The data are considered to be of high quality.

Extraction of oil and natural gas
Production of oil and natural gas is the dominating sector for emissions from combustion in the energy industries in Norway. The Norwegian Petroleum Directorate annually reports the amounts of gas combusted in turbines and diesel burned in turbines and direct-fired furnaces on the oil and gas fields. The data are of high quality due to the CO_2 tax on fuel combustion. These activity data are used for 1990-2002. From 2003, reported emission figures from the field operators are used.

Coal production
Norway's coal production takes place on Svalbard. The only coal producing company annually reports its coal consumption and some minor use of oil products.

Gas terminals
Norway has two gas terminals, where natural gas from the Norwegian continental shelf is landed, treated and distributed. Annual figures on natural gas combusted in turbines and flared are reported to the Norwegian Petroleum Directorate (figures on flaring at one plant is reported to the Norwegian Pollution Control Authority).

Oil refineries
The oil refineries annually report their use of different energy carriers to Statistics Norway. Refinery gas is most important, but there is also some use of LPG and oil products.

3.2.2.4. Emission factors
Emission factors used for the energy sector are given in Appendix B. For some industries and components more information about the derivation of the emission factors are given in this section.

3.2.2.4.1. CO_2
Waste incineration
The emission factor for combustion of waste (fossil part only) was calculated by SFT (1996).

Extraction of oil and natural gas
The CO_2 emission factor for gas combustion offshore used for all years leading up to 1998 and for all fields except one, is an average factor based upon a survey carried out in the early 1990's (OLF 1993, 1994). From 1999 onwards the emission factors employed reflect increasingly field specific conditions.

3.2.2.4.2. CH_4
Waste incineration
The emission factor for combustion of waste (fossil part only) was calculated by SFT (1996).

3.2.2.4.3. TSP, PM_{10} and $PM_{2.5}$
Electricity and heat generation
Emission factors for TSP, PM_{10} and $PM_{2.5}$ are based on emission data given in EPA (2002). EPA (2002) gives emission data based on measurements made from various boilers using different control device systems. The power plant at Svalbard is equipped with a multicyclone, and emission factors derived from measurements from boilers controlled with multicyclone device systems are used.

3.2.2.4.4. Dioxins and PAH
Electricity and heat generation
Dioxin emissions from coal combustion at the power plant at Svalbard are derived from emission factors found in literature. The emission factor used is the emission factor recommended in Bremmer et al. (1994). The same emission factor is also used in Parma et al. (1995) and Hansen (2000). Burning of coal at power plants is also expected to give particle-bound dioxin emissions, but because of the effective control device using multicyclone collector, the emissions are expected to be low.

Emission factors for PAH-4, PAH-6 and PAH-total are derived from an emission profile developed from emission measurements from boilers using different control device systems (EPA 1998).

PAH emissions from waste incineration are calculated by emission factors and amount of waste burned. The emission factor used for calculating emissions of PAH before 1995 is 2.5 g PAH/tonne waste burned. It is assumed that the emissions have been reduced by 70 per cent since then because of stricter emission requirements from 1995. The new emission factors have been identified using information from Sweden. We have no plant or country specific emission profile of PAH from waste incineration at district heating plants in Norway. Instead an emission profile from a district heating plant in Sweden, burning wood powder is used (NILU/NIVA (1995)/ Karlsson et al. (1992)).

3.2.2.4.5. Heavy metals
Electricity and heat generation
The emission factors for heavy metals used for calculating emissions from coal fired power plants are from EEA (2001). The factors are, however, not specific for coal fired power plants but standard factors recommended for calculating emissions from coal combustion in energy and transformation industries.

3.2.2.5. Uncertainties
Uncertainty estimates for greenhouse gases and long-range air pollutants are given in Appendix D. Since the energy use is well known for the energy industries, the uncertainty in the activity data is considered to be minor.

3.2.2.6. Completeness
Major missing emission sources are not likely.

3.2.2.7. Source specific QA/QC
The energy industries are subjected to the general QA/QC procedures described in section 1.5.1. For the following industries there are also made some source specific QA/QC activities.

Heat generation in district heating plants
Emissions of heavy metals and POPs from waste incineration have been subject to detailed control. The estimates are based on measurements, but the values are uncertain due to high variability. Reported emission values can vary by orders of magnitude from year to year. Each historical value has been checked in the QA/QC process, and some data have been rejected and replaced by calculated values.

Extraction of oil and natural gas
For emissions of NO_X from turbines offshore, time series over the emissions calculated with field specific emission factors have been compared with the emissions given using the earlier used average emission factor.

From 2003 field specific emission figures reported from the companies are used directly in the emission model. These emission figures are compared to calculations with field specific emission factors.

Oil refineries
The CO_2 emissions reported from the refineries are being compared with emission estimates calculated by Statistics Norway. The emissions are calculated by using activity data and emission factors for the different energy carriers used.

3.2.3. Manufacturing industries and construction

IPCC 1A2, Key category for CO_2 from gas and oil
NFR 1A2
Last update: 01.09.05

3.2.3.1. Activity data
Most of the emission figures are calculated based on activity data and emission factors. For a few plants the emission figures are based on reported figures from the plants.

Statistics Norway carries out annual surveys on energy use in manufacturing industries, which supply most of the data material for the calculation of combustion emissions in these sectors. The energy use survey covers 90 per cent of the energy use in this sector. For the remaining companies, figures are estimated based on data from the sample together with data on economic turnover, taking into account use of different energy carriers in the same industries and size groups. A change in methodology from 1998 has had minor consequences for the time series, since the energy use is mainly concentrated to a few major plants within the industry, from which data were collected both in the present and the earlier method. The data on energy use in manufacturing industries are considered to be of high quality.

Information on use of waste oil and other hazardous waste is also collected through the energy use statistics.

For the construction industry, the figures on use of the different energy carriers are partly taken from the annual sales statistics for petroleum products, partly projected from earlier surveys; the energy data are considered rather uncertain.

In some sectors autodiesel is mainly used in machinery and off-road vehicles, particularly in mining and construction. A special survey was undertaken to estimate the fraction used for off-road purposes in these sectors. The methods for calculating emissions

are discussed in section 3.2.4.7. Emissions from off-road machinery in industry are currently reported in category 1A3e. According to the guidelines, they should be included in category 1A2. In the NFR, emissions from off-road machinery in industry are specifically assigned to category 1A2f *i*.

3.2.3.2. Emission factor
Emission factors used for the energy sector are given in Appendix B.

3.2.3.3. Uncertainties
Uncertainty estimates for greenhouse gases and long-range air pollutants are given in Appendix D. The energy use is considered well known for the manufacturing industries.

3.2.3.4. Completeness
Major missing emission sources are not likely.

3.2.3.5. Source specific QA/QC
There is no specific QA/QC procedure for this source. See section 1.5.1 for the description of the general QA/QC procedure.

3.2.4. Transport
IPCC 1A3
NFR 1A3

3.2.4.1. 3.2.4.1. Aviation
IPCC 1A3a, Key category for CO_2
NFR 1A3a
Last update: 01.09.05

3.2.4.1.1. Method
The calculation methodology applied is described in Finstad et al. (2002b). According to the IPCC Good Practice Guidance the methodology used is Tier 2 based on the detailed methodology in EEA (2001). This methodology allows estimation of emissions and fuel consumption for different types of aircraft according to the average flying distance and numbers of landings and take-offs (LTO). All movements below 1000 m are included in the "Landing Take Off" (LTO) cycle. Movements over 1000 m are included in the cruise phase. All emissions from international aviation are excluded from national totals, and are reported separately (see section 3.2.6.3).

3.2.4.1.2. Activity data
Statistics Norway annually collects data on use of fuel from the air traffic companies. These data include specifications on domestic use and amounts bought in Norway and abroad. The types of fuel used in aircraft are both jet fuel (kerosene) and aviation petrol. The latter is used in small aircraft only. Emissions from the consumption of jet kerosene in domestic air traffic are based directly on these reported figures. Domestic consumption of jet kerosene has been reported to Statistics Norway by the airlines since 1993. The survey is annual, but data from the surveys for 1993 and 1994 have not been used here, as one of the largest airlines in Norway was not included. Domestic consumption prior to 1995 is estimated by extrapolation on the basis of domestic kilometres flown and is more uncertain (Finstad et al. 2002b). Sales figures are used for the minor use of aviation petrol.

3.2.4.1.3. Emission factors
Emission factors used are given in Appendix B, table B1, table B2 and tables B5-B7.

The Norwegian Petroleum Industry Association provides emission factors for CO_2 and SO_2 for the combustion of jet fuel and gasoline (Finstad et al. 2002b). The emission factor for SO_2 varies depending on the sulphur content of the fuel used. Emission factors for particles are from Brock et al. (1999) and Döpelheuer and Lecht (1998), and all particles are found to be less than $PM_{2.5}$ (Finstad et al. 2002b).

A default emission factor for N_2O for all aircraft is used (IPCC 2001) and is valid for both LTO and the cruise phase. EEA (2001) and IPCC (2001) suggest using an emission factor for CH_4, given in Olivier (1991), to be 10 per cent of total VOC. This is, however, only valid for LTO since studies indicate that only insignificant amounts of methane is emitted during the cruise phase. No methane is therefore calculated for the cruise phase and all emissions are assumed to be VOC (HC).

The NO_X, CO and VOC emission factors are aircraft specific as given in EEA (2001).

Only aggregated emission factors (kg/tonnes fuel used) are used in the Norwegian inventory. The emission factors are calculated based on total emission divided by activity data for LTO and in the cruise phase, respectively.

Recalculations have been done based on the new methodology (EEA 2001 and Finstad et al. 2002b) and this led to a change in emission factors for previous years. New emission factors back to 1989 have therefore been used in the inventory. Emission factors for 1989-1992 are based on aircraft data from 1989, while emission factors for 1993-1997 are based on aircraft data from 1995.

Emission factors for small aircraft are the same for the whole period.

3.2.4.1.4. Uncertainties
Activity data
The uncertainty in the activity data for civil aviation is estimated to be ±20 per cent of the mean, primarily due to the difficulty in separating domestic emissions

from emissions from fuel used in international transport (Rypdal and Zhang 2000). In a recent study on emissions from aircraft (Finstad et al. 2002b), fuel consumption was also estimated bottom-up and compared to the reported figures (see also section 3.2.4.1.6.*)*. The estimated and reported data differed by about 10 per cent. However, the reported data are considered most accurate and were used in the calculation. As described above, data before 1995 are more uncertain than for later years.

Emission factors
The uncertainty in the CO_2 emission factors is ±3 per cent. The uncertainty in the emission factors for CH_4 and N_2O is respectively ±69 and ±110 per cent of the mean.

3.2.4.1.5. Completeness
Major missing emission sources are not likely.

3.2.4.1.6. Source specific QA/QC
In 2002 a methodology improvement was made in the emission calculations for civil aviation (Finstad et al. 2002b). According to the IPCC Good Practice Guidance the methodology used is Tier 2 based on the detailed methodology in EEA (2001). This methodology allows estimation of emissions and fuel consumption for different types of aircraft according to the average flying distance and numbers of landings and take-offs (LTO).

3.2.4.2. 3.Road transport
IPCC 1A3b, Key category for CO_2 and N_2O
NFR 1A3b i-v
Last update: 01.09.05

3.2.4.2.1. Method
A model for estimating emissions from road traffic was developed in 1993 (SFT 1993) and revised in 1999 (SFT 1999c). The results (expressed as average aggregated emission factors) from this model have been used as input to the general emission model.

3.2.4.2.1.1. Model structure
A fuel-based model has been chosen, where the total consumption of various fuels provides the framework for determining the emissions. The emission factors depend on the kind of vehicle (type, weight, technology, age), fuel type, and driving mode. The total number of vehicle-kilometres does not enter the calculations directly. However, fractions of the total mileage are estimated for each combination of vehicle category and driving mode. These fractions are used to allocate fuel consumption to the various combinations. Emission factors may be given as emissions per vehicle-kilometre or per unit fuel consumed.

Total emissions (Q) of a pollutant (*j)* from fuel type (*k),* while driving with a warm engine may be calculated from equations (3) and (4) below:

$$(3) \quad Q_{jk} = M_k \sum_i \left(p_{ijk} \cdot \frac{l_{jk}}{\overline{l_k}} \cdot \left(\frac{T_{ik}}{T_k} \right) \right)$$

or

$$(4) \quad Q_{jk} = M_k \sum_i \left(q_{ijk} \cdot \frac{1}{\overline{l_k}} \cdot \left(\frac{T_{ik}}{T_k} \right) \right)$$

$$q_{ijk} = p_{ijk} \cdot l_{ik}$$

where

Q: Total emissions
M: Total fuel consumption
p: Emission factor, g/kg
q: Emission factor, g/km
l: Fuel consumption, kg/km
T: Vehicle-kilometres
$_k$: Fuel type
$_i$: Combination of vehicle type, fuel type, and driving mode
$_j$: Pollutant

l_k is the average consumption, kg/km, of fuel (*k)* and is determined by equation (5).

$$(5) \quad l_k = \sum_k l_{ik} \cdot \left(\frac{T_{ik}}{T_k} \right)$$

Emissions from evaporation and cold starts are added to the tailpipe emissions from warm motors.

The fuel-based model calculates changes in emissions between years from changes in M_k (total fuel consumption) and:

- The number of vehicles in the various categories
- Technologies in use
- Annual average distance (km) driven per vehicle
- Driving patterns

3.2.4.2.1.2. Model parameters
Road traffic emissions are calculated for each combination of the following parameters:

- Pollutants: the same pollutants as in the general emission model, excluding heavy metals and POPs
- Vehicle categories: there are 10 classes, which are different combinations of vehicle type, weight, and fuel, see table 3.3.
- Vehicle age (0-29 and 30+ years, 31 age classes in all)
- Driving mode: Five modes are considered:

Urban	Speed limit	30 km/h or less
Urban	"	40 and 50 km/h
Rural	"	60 and 70 km/h

Rural	"	80 km/h
Highway	"	90 km/h

Note: The names of the driving modes do not indicate where driving actually takes place: for instance, driving is classified as urban driving if the speed limit is less than 50 km/h, even outside an urban area.

The modes apply only to driving with a warm engine. Emissions from cold start and evaporation are calculated separately as described in section 3.2.4.2.4.

Table 3.3. Vehicle categories[1,2] in the emission model for road traffic

Fuel	Type	Total weight
Gasoline	Passenger car	..
"	Light duty	< 3.5 t
"	Heavy duty	> 3.5 t
"	Bus	> 3.5 t
Diesel	Passenger car	..
"	Light duty	< 3.5 t
"	Light heavy duty	3.5 - 7.5 t
"	Medium heavy duty	7.5 - 16 t
"	Heavy heavy duty	> 16 t
"	Bus	> 3.5 t

[1]Emissions from motorcycles and mopeds are calculated with a simplified method.

[2]The model may also be extended to include LPG and CNG vehicles.

3.2.4.2.2. Activity data

All activity data are, as far as possible, updated for every year of the inventory. Data are taken primarily from official registers, public statistics and surveys. However, some of the data are based on assumptions. The sources of activity data are listed below:

- Total fuel consumption: the total amounts of fuels consumed are corrected for off-road use (in boats, snow scooters, motorized equipment, etc.). These corrections are estimated either from assumptions about the number of units, annual operation time, and specific fuel consumption, or from assumptions about and investigations of the fraction of consumption used off-road in each sector. The Norwegian Petroleum Industry Association supplies the data for total fuel consumption.

- Number of vehicles: the number of vehicles in the various categories and age groups is taken from the official register of the Norwegian Directorate of Public Roads.

- Average annual mileage: most figures are determined from surveys by Statistics Norway or the Institute of Transport Economics. In some instances assumptions are needed.

- Driving modes: the Directorate of Public Roads has data on the annual number of vehicle-kilometres driven on national and county roads. The data are allocated by speed limits and vehicle size (small/large). Similar data exist for municipal roads in the ten largest cities. The same distribution is assumed to be valid for other municipal roads.

The fraction T_{ik}/T_k of the vehicle-kilometre total for each fuel is calculated using the following variables:

- Number of vehicles, by category and age
- Average annual mileage, by category
- Average annual mileage, by age and aggregate vehicle category

These fractions are used together with specific fuel consumption factors to allocate fuel used by road traffic to categories defined by the parameters vehicle type, vehicle age and driving mode.

3.2.4.2.3. Emission factors

The emission factors are based on several sources. Complete lists of sources with references are given in SFT (1999c). The most important references are listed below:

- Copert II (EEA 1997), a computer program to calculate emissions from road traffic. Both this and the following report have been used for several purposes, including warm engine emissions from light and heavy vehicles, cold start emissions and emissions from mopeds and motorcycles.
- Previous version of Copert (Eggleston et al. 1991).
- A detailed report for the German *Umweltbundesamt* (Hassel et al. 1994) based on measurements from TÜV (Technischer Überwachungs-Verein Rheinland), is used for emissions from light vehicles.
- Measurements performed by the National Institute of Technology in Norway (SFT 1993), used for emissions from light vehicles.
- Several reports from AB Svensk Bilprovning in Sweden (listed in SFT 1993), used for emissions from heavy vehicles.
- The Corinair Emission Inventory Guidebook (EEA 1996), used for evaporation.
- Results from the MEET programme (Methodologies for Estimating Air Pollution Emissions from Transport) (Sérié and Joumard 1996), are used for cold start emissions.

All factors are given by vehicle category and technology, and refer to new vehicles. Some factors also distinguish between driving modes. In addition, emission factors (hot and cold) and fuel consumption factors are corrected to take into account the change in values as the vehicles age.

The factors are listed in Appendix B.

3.2.4.2.4. Emissions from evaporation and cold starts

Emissions and fuel consumption from evaporation and cold starts are calculated separately.

Evaporation of NMVOC from gasoline vehicles is calculated using the method given in the Corinair Emission Inventory Guidebook (EEA 1996). Emissions from running losses, hot soak emissions, and diurnal emissions are included. Average emission factors have been calculated, taking Norwegian climate conditions into account. Factors are given by vehicle category and technology.

In most cases, driving with a cold engine gives higher emissions than driving with a warm one, particularly for CO and NMVOC. The extra emissions are called cold start emissions. These are calculated as an additional emission contribution per start. Factors are given by vehicle category and technology. They are mainly taken from Copert (EEA 1997) and Sérié and Joumard (1996). Detailed driving patterns and regional temperature data are used. The driving patterns are taken from a travel survey (Haukeland et al. 1999) and include trip length and time between trips. Engine temperatures are corrected for the use of engine pre-heaters.

The extra fuel consumption caused by evaporation and cold starts is subtracted from the total consumption before emissions from warm engines are calculated.

3.2.4.2.5. Uncertainties
With regard to CO_2 emissions from road transportation, the uncertainty in the activity data and emission factors is found to be ±20 per cent and ±3 per cent of the mean, respectively (Rypdal and Zhang 2000). In the case of N_2O the uncertainty in the activity data is ±20 per cent, but the uncertainty in the emission factors is as high as ±110 per cent. The uncertainty in the activity data and the emission factors for CH_4 is ±20 and ±69 per cent of the mean, respectively.

3.2.4.2.6. Completeness
Major missing emission sources are not likely.

3.2.4.2.7. Source specific QA/QC
Top down and bottom up data on fuel consumption are compared for gasoline and diesel vehicles on an annual basis. The consumption of gasoline and auto diesel for road traffic is estimated as total sales minus consumption for other uses, i.e a top down approach. The emission model for road traffic (SFT 1993; SFT1999c) also makes bottom up estimates of consumption, which can be compared with the top down data. For gasoline, the agreement is very good (difference < 5 per cent for most years). For auto diesel the agreement is poorer, with the top down estimate up to 40 per cent above the bottom up estimate. The causes are on the one hand uncertainties in the amount of non-road use and on the other hand uncertainties in mileage and specific consumption. However, the total consumption of auto diesel, and hence the CO_2 emission from this fuel, is well known. The uncertainty concerns the allocation between road and non-road use. For CH_4 and N_2O the total emission is sensitive to the allocation due to different emission factors.

3.2.4.3. Railways
IPCC 1A3c
NFR 1A3c
Last update: 01.09.05

3.2.4.3.1. Description
Railway traffic in Norway uses mainly electricity. Auto diesel is used at a small number of lines, for shunting etc.

3.2.4.3.2. Method
General estimation methodology for calculating combustion emissions from consumption figures and emission factors is used.

3.2.4.3.3. Activity data
Consumption figures for auto diesel used in locomotives are collected annually from the Norwegian State Railways.

3.2.4.3.4. Emission factors
Emission factors for NO_x, HC, CO, and PM_{10} were estimated by Bang (1993) based on a literature survey and data on Norwegian usage profiles. The HC factor of 4 g/kg was used directly for NMVOC.

The other emission factors are the same as for diesel machinery in mining and quarrying (see section 3.2.4.7.4), with the following exceptions:
- N_2O: 1.2 g/kg vs 1.3 g/kg for machinery (IPCC Guidelines)
- NH_3: 0 g/kg vs 0.005 g/kg for machinery.

3.2.4.3.5. Uncertainties
The consumption data are of high quality. Their uncertainty is estimated to be ±10 per cent of the mean. The uncertainty in the emission factors for CO_2, CH_4 and N_2O is ±3, ±69 and ±110 per cent of the mean, respectively.

3.2.4.3.6. Completeness
Major missing emission compounds are not likely.

3.2.4.3.7. Source specific QA/QC
Consumption data from the Norwegian State Railways are compared with sales to railways according to the Petroleum statistics. However, the latter includes some consumption by buses operated by the State Railways. Since 1998, the reported sales of "tax-free" auto diesel to railways have been around 20 per cent higher than the consumption data from the State Railways. Until 1997, the reported sales were around 5 per cent

higher. The reason for this discrepancy has not been checked. "Tax-free" auto diesel is only for non-road use, so consumption by buses should not be the cause.

3.2.4.4. Electric railway conductions
IPCC 1A3c
NFR 1A3c
Last update: 01.09.05

3.2.4.4.1. Method
Electric railway conductions contain copper that is emitted in contact with trains. In the inventory copper emissions are calculated by emission factors and activity data.

3.2.4.4.2. Activity data
The activity data used for calculating emissions of copper from electric wires are annual train kilometers given by the Norwegian State Railway (NSB).

3.2.4.4.3. Emission factors
According to Norwegian State Railway (Rypdal and Mykkelbost 1997) the weight of a contact wire is 0.91 kg/meters. The weight is reduced by 20 per cent after 3 million train passes. This gives an emission factor of 0.06 g/train kilometers. It is, however, uncertain how much of this is emitted to air. In the inventory it is assumed that 50 per cent is emitted to air. This gives an emission factor of 0.03 g/ train kilometer.

Table 3.4. Emission factor for electric railway conductions. g/km

	Emission factor (g/train kilometers)
Cu	0.03

3.2.4.4.4. Uncertainties
The emission factor used is uncertain. First, there is an uncertainty connected to the reduction of 20 per cent after 3 millions train passes. Secondly, there is uncertainty regarding the assumption that 50 per cent are emissions to air (Finstad and Rypdal 2003).

3.2.4.4.5. Completeness
No major components are assumed missing.

3.2.4.4.6. Source specific QA/QC
There is no specific QA/QC procedure for this source. See section 1.5.1 for the description of the general QA/QC procedure.

3.2.4.5. Navigation
IPCC 1A3d, Key category for CO_2
NFR 1A3d
Last update: 01.09.05

3.2.4.5.1. Method
According to CLRTAP and UNFCCC, Norwegian national sea traffic is defined as ships moving between two Norwegian ports. In this connection installations at the Norwegian part of the continental shelf are defined as ports.

Emissions from navigation are estimated according to the Tier 2 IPCC methodology. The levels and the spatial distribution of emissions from national sea traffic are estimated by an updated and improved methodology presented in Tornsjø (2001). The improvement is due to the collection of new data on fuel use for the different vessel categories and the registration of changes in regular coastal trade (connections/distances). Mobile drilling rigs are also included in the calculations. Emissions from international marine bunkers are excluded from the national totals and are reported separately (section 3.2.6), in accordance with the IPCC Good Practice Guidance.

Annual emissions are estimated from sales of fuel to domestic shipping and fishing, using average emission factors in the calculations. For 1993 and 1998 emissions have also been estimated based on a bottom up approach (Tornsjø 2001). Fuel consumption data were collected for all categories of ships (based on the full population of Norwegian ships in domestic transport); freight vessels (bulk and tank by size), oil loading vessels, supply/standby ships, tug boats, coastal ferries, military ships and other ships. Emissions were estimated from ship and size specific emission factors and fuel use. From this information, average emission factors were estimated for application in the annual update based on fuel sales. This approach is unfortunately too resource demanding to perform annually. Sale of fuel to domestic shipping and fishing were about 15 per cent higher, in both 1993 and 1998, than the fuel consumption estimated as described in section 3.2.4.5.2 for the same years. Some explanations may be that the sales figures also include sales to foreign vessels bunkering in Norway. Norwegian vessels bunkered abroad are not included.

3.2.4.5.2. Activity data
The annual sales statistics for petroleum products gives figures on the use of marine gas oil, heavy distillates and heavy fuel oil in domestic navigation. For fuels used in fishing vessels, figures from the sales statistics are used directly, according to the guidelines. Information on fuel used in freighters is gathered from surveys performed by Statistics Norway. In cases where information on oil related vessels is lacking, data are collected directly. Data on fuel consumed by public road ferries are available from the Directorate of Public Roads, whereas the consumption by other ferries and regular coastal trade vessels is obtained directly from the companies. The consumption figures for other types of ships and boats are mainly taken from Flugsrud and Rypdal (1996).

For marine gas oil, the sales figures are adjusted up or down when problems in balancing the overall use against the total sale of this energy carrier arise, thus introducing an element of uncertainty regarding the quality of the figures actually used in the emission estimates. The total fuel use has been verified in Tornsjø (2001), showing a deviation of about 15 per cent. This can be explained by the fact that the bottom up method does not cover all ships, but it may also be that the domestic/international distinction is not precise enough in the sales statistics. The increase in bottom up consumption and sales between 1993 and 1998 is quite similar.

3.2.4.5.3. Emission factors
Emission factors used for navigation are given in Appendix B, table B1, table B2 and tables B9-B11.

CO_2
For CO_2 the following standard emission factors based on carbon content are used:

- Marine gas oil/diesel and special distillate: 3.17 kg/kg fuel
- Heavy fuel oil: 3.20 kg/kg fuel

N_2O and CH_4
For liquid fuels the general/standard emission factors for N_2O and CH_4 used in the emission inventory are taken from IPCC/OECD: 0.23 kg CH_4/tonne fuel and 0.08 kg N_2O/tonne fuel.
In the case of oil drilling, the employed factors are as follows:

- CH_4: 0.8 kg/tonne marine gas oil/diesel; 1.9 kg/tonne heavy fuel oil
- N_2O: 0.02 kg/tonne marine gas oil/diesel

Some natural gas is combusted in ferry transportation; the CH_4 emission factor used in this case is 56.04 kg/1000 Sm^3 fuel.

SO_2
The emission factors are determined from the sulphur content of the fuel.

3.2.4.5.4. Uncertainties
The estimated bottom-up emission figures are uncertain. The most important sources of error are assumed to be estimation of fuel used by fishing vessels, delimitation of national sea traffic and the emission factors. Generally there is also uncertainty connected to cases where calculations are necessary because of the lack of data on fuel consumption. This applies particularly to large ships, as these usually use more fuel and accordingly have greater significance for the emissions. No analysis on levels of error has been made. National emission figures are generally more certain than the figures for the different vessel categories.

The uncertainty in the activity data is assessed to be ±10 per cent. For CO_2 the uncertainty in the emission factors for ships and fishing vessels is ±3 per cent of the mean, while for CH_4 it ranges between -50 and +100 per cent of the mean. For N_2O the uncertainty range is between -66 and +200 per cent of the mean (Rypdal and Zhang 2000). Uncertainties in emission factors are shown in table 3.5.

Table 3.5. Uncertainties in emission factors for ships and fishing vessels. Per cent

	Standard deviation (2σ)
CO_2	±3
CH_4	-50 to +100
N_2O	-66 to +200
SO_2	±25
NO_x	±15
NMVOC	±50

Source: Rypdal and Zhang (2000, 2001).

3.2.4.5.5. Completeness
Major missing emission sources are not likely.

3.2.4.5.6. Source specific QA/QC
In 2001, bottom-up (from surveys) and top down data (from sales) on fuel consumption were compared (Tornsjø 2001). The outcome showed that data from sales were 15 per cent higher than data from reported consumption. This can be explained by the fact that the bottom up method does not cover all ships, but it may also be that the domestic/international distinction is not specified precisely enough in the sales statistics. A similar deviation has been found for the years 1993 and 1998. In the calculations, sales figures are used, as they are assumed to be more complete and are annually available. As mentioned, emission estimates for ships have been made bottom up for 1993 and 1998 (Tornsjø 2001). These results have been compared with the annual estimates. The agreement is reasonable, given the uncertainty in the fuel data determined by both methods.

3.2.4.6. Pipeline
IPCC 1A3e
NFR 1A3e i
Last update: 01.09.05

3.2.4.6.1. Method
Emissions are estimated through the general methodology described earlier, involving consumption figures and appropriate emission factors.

3.2.4.6.2. Activity data
Figures on natural gas used in turbines for pipeline transport at two separate facilities are reported annually from the Norwegian Petroleum Directorate to Statistics Norway. Energy generation for pipeline transport also takes place at the production facilities. These emissions are reported under NFR/IPCC 1A1.

3.2.4.6.3. Emission factors
The emission factors employed are the standard factors used for turbines fired with natural gas (Appendix B, table B1 table B15 and table B17). Sources for the factors are SFT/NPD and IPCC (1997b).

3.2.4.6.4. Uncertainties
Uncertainty estimates for greenhouse gases and long-range air pollutants are given in Appendix D.

3.2.4.6.5. Completeness
Major missing emission sources are not likely.

3.2.4.6.6. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

3.2.4.7. Motorized equipment
IPCC 1A3e etc.
NFR 1A3e ii etc.
Last update: 01.09.05

3.2.4.7.1. Description
The category "motorized equipment" comprises all mobile combustion sources except road, sea, air, and railway transport. Farm and construction equipment are the most important categories. Other categories include mines and quarries, forestry, snow scooters, small boats and miscellaneous household equipment.

Emissions from motorized equipment are reported under several categories:
- Agriculture/Forestry/Fishing: NFR 1A4c-ii /IPCC 1A4c
- Households: NFR 1A4b-ii /IPCC 1A3e
- Military: NFR 1A5b /IPCC 1A5b
- Other: NFR 1A3e-ii /IPCC 1A3e

Only consumption of gasoline and auto diesel is considered. Also included is a small amount of fuel oil used for equipment in construction.

3.2.4.7.2. Method
Emissions are estimated through the general methodology described earlier, involving consumption figures and appropriate emission factors.

3.2.4.7.3. Activity data
Gasoline and auto diesel are handled differently. Consumption of *gasoline* is estimated bottom-up for each type of machinery based on data on the number of each type of equipment, usage and specific consumption.

Snow scooters: Number of equipment is obtained annually from the Norwegian Public Roads Administration. We assume a mileage of 850 km/year and a specific consumption of 0.15 l/km (TI 1991). A portion of 16 per cent of petrol consumption in agriculture is assigned to snow scooters. The remaining snow scooter fuel consumption is assigned to households.

Chainsaws and other two-stroke equipment: Only consumption in forestry is considered, based on felling data. Felling statistics are gathered by Statistics Norway. 50 per cent is supposed to be felled with use of chain saws, with a consumption of 0.33 l/m^3. Note: Consumption has been kept fixed since 1994 based on a calculation by the Institute of Technology (Bang 1996).

Lawn mowers and other four-stroke equipment: Only consumption in households considered.

Consumption of *auto diesel* is based on data from the energy accounts. A certain fraction of the consumption in a number of industries is allocated to motorized equipment, based on surveys or expert judgments.

3.2.4.7.4. Emission factors
Emission factors used are given in Appendix B.

For diesel machinery, emission factors for NO_x, HC, CO, and PM_{10} were estimated by Bang (1993), based on a literature survey and data on Norwegian usage profiles. NMVOC factors were calculated by subtracting an assumed CH_4 fraction of 0.3 g/kg diesel.

3.2.4.7.5. Uncertainties
The estimates of consumption are considered quite uncertain, particularly for gasoline. However, the total consumption of gasoline and auto diesel is well known.

3.2.4.7.6. Completeness
Major missing emission sources are not likely.

3.2.4.7.7. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

3.2.4.8. Automobile tyre and brake wear
IPCC 1A3b
NFR 1A3b vi
Last update: 01.09.05

3.2.4.8.1. Tyre wear
3.2.4.8.1.1. Description
Tyre wear is a source for emission of particles, heavy metals and persistent organic pollutants. The tyres are worn down by 10 to 20 per cent of its total weight during its lifetime. Most of the rubber is lost during acceleration and braking. All rubber lost is assumed to be particles containing heavy metals and PAH.

3.2.4.8.1.2. Method
Particles

All rubber lost is assumed to be small particles. The emissions of particles are calculated based on emission factors and annual mileage.

Heavy metals
Rubber particles contain heavy metals. Emissions of the heavy metals As, Cd, Cu, Cr, Pb and Hg are calculated based on annual mileage and emission factors.

PAH
The particles emitted from tyre wear contain PAH. Emissions are calculated based on emission factors and annual mileage.

3.2.4.8.1.3. Activity data
Annual mileage is used for calculating the emissions from tyre wear. Annual mileage is given by the road traffic model, see section 3.2.4.2.

3.2.4.8.1.4. Emission factors
Particles
The emission factors used for calculating the emission of particles are given by TNO (2002). The emission factors are based on different Dutch and British studies. It is assumed that all fine particles, PM_{10}, are emitted to air, while all particles greater than 10 µm are emitted to soil or water. This is based on Dutch expert judgement. Recommended emission factors from TNO (2002) are given in table 3.6.

Table 3.6. Emission factors for particles from tyre wear. kg/mill. km

	PM_{10}
Private cars	3.45
Van	4.5
Heavy duty vehicles	18.563
MC	1.725

Source: TNO (2002).

Heavy metals
The emission factors used for the heavy metals As, Cd, Cu, Cr and Pb are derived from a particle-heavy metal distribution given by Dutch studies (Brink 1996). The content of heavy metals in the particles, given by this distribution, is multiplied by the PM_{10} emission factor (table 3.7). This gives the emission factors for the heavy metals As, Cd, Cu, Cr and Pb from tyre wear (table 3.8).

Table 3.7. Heavy metals emission factors from tyre wear. g/mill. km

	As	Cd	Cu	Cr	Pb
Private cars	0.003	0.007	1.691	0.014	0.552
Van	0.005	0.009	2.205	0.018	0.720
Heavy duty vehicles	0.019	0.037	9.096	0.074	2.970
MC	0.002	0.003	0.845	0.007	0.276

The emission factor used for the estimation of the emissions of Hg is 0.38 g/tonn tyre. This emission factor is derived from a study of heavy metal content in tyres (Bækken 1993).

PAH
Emission factors for PAH are given in Finstad et al. (2001), but there is no information about how much of the emissions that are emitted to air, and how much that goes to soil and to water. All emissions are therefore supposed to be emitted to air. There is also no PAH profile available, so in lack of other data the same PAH profile as for burning of tyres is used (EPA 1998). PAH emission factors for tyre wear are given in table 3.8.

Table 3.8. PAH emission factors from tyre wear. kg PAH/ 1000 mill. km

	PAH
Light duty vehicles	10.4
Heavy duty vehicles	0.1

Source: Finstad et al. (2001).

3.2.4.8.1.5. Uncertainties
The calculation of emissions from tyre wear is uncertain. First, the emission factors for particles used are based on international studies and not on Norwegian conditions. There is also uncertainty concerning how much of the particles that are emitted to air. According to a Dutch judgement, all particles emitted to air are PM_{10}. This is however only a judgement, and not based on scientific research. PAH emissions have been held constant since 1998.

The heavy metal emission factors are based on the particle emission factors for PM_{10}, and since this factor is uncertain, the heavy metal emission factors will also be uncertain. The content of heavy metals in the particles emitted from tyre wear is based on a Dutch study and can therefore differ from Norwegian conditions and type of tyres used.

3.2.4.8.1.6. Completeness
Tyre wear also leads to emissions of other heavy metal components, such as zinc, nickel etc., but these components are not included in the Norwegian emission inventory.

Until 2004, different methods for calculating the emissions of heavy metals from tyre wear were used. One method was used for calculating emissions of Pb, Cd and Hg (Finstad et al. 2001) and another for calculating emissions of Cu, Cr and As (Finstad and Rypdal 2003). From 2004 the same method has been used for all the heavy metal components.

3.2.4.8.1.7. Source specific QA/QC
There is no specific QA/QC procedure for this source. See section 1.5.1 for the description of the general QA/QC procedure.

3.2.4.8.2. Brake wear
3.2.4.8.2.1. Description
Brake blocks will wear during braking and this generates dust containing various metals. In the inventory, emissions of particles and heavy metals are included from this source.

3.2.4.8.2.2. Method
Particles
Emissions of particles are calculated based on emission factors and annual mileage.

Heavy metals
Emissions of lead, copper and chromium are calculated after a method described in SLB (1998). The calculations are based on annual brake wear, driven kilometers and the brake blocks' metal content.

Brake wear, private cars and vans
To calculate emissions, brake wear first has to be estimated. It is assumed that private cars change brake blocks every fourth year. The background for this assumption is that private cars, by normal driving, change brake blocks at front after 3 000 - 4 000 thousand kilometers and at the back after 6 000-8 000 thousand kilometers. A private car drive in average 1 500 thousand kilometers each year. Assuming that the brake blocks are changed after 6 000 thousand kilometers, the car will be four years old when blocks first are changed.

The brake blocks at front weigh 0.13-0.15 kg and 0.09-0.11 kg at the back. It is assumed in the calculations that the brake blocks weigh 0.15 kg at the front and 0.11 kg at the back, that the brake blocks are worn 70 per cent before they are changed and that the front and back blocks are changed after 4 000 and 6 000 thousand kilometers, respectively. This gives equations (6) and (7):

(6) Front brake blocks (private cars):
*0.7*4*0.15/4000*driven thousand kilometer*

(7) Back brake blocks (private cars):
*0.7*4*0.11/6000*driven thousand kilometer*

The same method is used for calculating emissions from brake wear for vans and minibuses.
Brake wear, heavy duty vehicles
The number of brake blocks at a heavy duty vehicle varies with both brand and model. It is assumed that each front brake block weighs 2.5 kg and 3.5 kg at the back (SLB 1998). This means that a truck with four wheels have 12 kg of brake blocks. It is assumed that the blocks are changed after 10 000 thousand kilometers when the brake blocks are worn 70 per cent.

Metal content
The metal content in the brake blocks for new and old cars have been tested (SLB 1998). For calculating the emissions from brake blocks, annual brake wear has been multiplied by the metal content. For private cars and vans the cars are separated into new and old cars. Cars four years old or younger are accounted as new. The metal content in the brake blocks in front of the car differs from the content in the brake blocks at the back (table 3.9). For heavy duty vehicles, the metal content is independent of age or type of brake block.

Table 3.9. Metal content in brake blocks. mg/kg

	New private cars		Old private cars		Heavy duty vehicles
	Front	Back	Front	Back	Front and back
Cr	137	73.4	92	151	165
Cu	117941	92198	71990	51240	9031
Pb	9052	18655	13651	9110	457

How much of the heavy metal emissions that are emitted to air were investigated by Sternbeck et al. (2001). Tunnel experiments showed that approximately 20 per cent of the brake wear emissions were emitted to air. This result is used in the calculations of brake wear emissions.

3.2.4.8.2.3. Activity data
For calculating the emissions of particles, are annual mileage given by the road traffic model, see sector 3.2.4.2.

For calculating the emissions of heavy metals, annually driven kilometers and the ratio between new and old cars are also given by the road traffic model.

3.2.4.8.2.4. Emission factors
Particles
Emission factors recommended by TNO (2002), based on different European studies, are used (table 3.10).

Table 3.10. Particle emission factors for brake wear. kg/mill. km

	$PM_{2.5}$	PM_{10}	TSP
Private cars (BM1+DM1)	6	6	6
Van (BN1+DN1)	7.5	7.5	7.5
Heavy duty vehicles	32.25	32.25	32.25
MC	3	3	3

Source: TNO (2002).

Heavy metals
Emission factors for Cr, Cu and Pb are derived based on the above information and are given in table 3.11.

Table 3.11. Heavy metal emission factors for brake wear. g/mill. km

	New private cars and vans	Old private cars and vans	Heavy duty vehicles
Cr	0.36	0.35	14.82
Cu	342.33	203.79	303.44
Pb	38.16	38.02	40.95

3.2.4.8.2.5. Uncertainties
There is high uncertainty in different steps in the emission calculations of heavy metals from brake wear, since many assumptions have been done. For example, there is uncertainty connected to the weight and the metal content of the brake blocks, and to the number of driven kilometers before blocks are changed.

3.2.4.8.2.6. Completeness
Brake wear also leads to emissions of other heavy metal components, such as zinc, nickel etc., but these components are not included in the Norwegian emission inventory.

No other major emission components are assumed missing.

3.2.4.8.2.7. Source specific QA/QC
There is no specific QA/QC procedure for this source. See section 1.5.1 for the description of the general QA/QC procedure.

3.2.4.9. Automobile road abrasion
IPCC 1A3b
NFR 1A3bvii
Last update: 01.09.05

3.2.4.9.1. Description
Asphalt dust is emitted to air while using studded tires. The abrasion layer on asphalt roads can contain approximately 90 per cent stones (rock/minerals) and 5 per cent filler. The rest is bitumen. During studded tyre abrasion, stone materials are worn down to minor particles and will together with detached filler and bitumen whirl up and become airborne. How much dust/particles studded tires generate depends on:

- Weight of the stud
- The road surface resistance against abrasion
- Vehicle velocity
- Share of heavy vehicle
- If the road surface is dry, wet or ice coated

A great share of the dust from studded tyres will bind up to the water film when the road surface is wet. Some of it will however whirl up again when the road surface dries up. This is not included in the calculation.

Bitumen is a mixture of a great number of organic components, including PAH components. The emissions of PAH from road abrasion are calculated and included in the emission inventory. Calculated emissions of Cd are also included.

3.2.4.9.2. Method
Particles
PM_{10}
The method is prepared by TI/SINTEF and documented in SFT (1999c). For calculating average emission Q (ton/year) of PM_{10} formula (8) is used:

$$(8)\quad Q_{PM10}\,(ton/year) = \sum_{\text{All vehicle categories}} SPS * n * l * m * p * w * \alpha / 10^6$$

SPS : The specific wear of studded tyres (SPS). Gives an estimate of how much of the road surface that is worn off on one road kilometer of a vehicle with studded tyres
n: Number of cars of a vehicle category in the area
l: Annual mileage for a vehicle category in the area
m: Part of the year with studded tyres in the area (between 0 and 1)
p: Share of the vehicle category using studded tyres
w: Correction factor for wet and frozen road surface. In the calculation of w, frozen surface is given 0, wet surface 0.5 and dry surface 1. If the mileage with studded tyres on a wet and frozen surface respectively is v and x, w = (0.05*v)+(1(1-v-x))
α: Share of the road dust in air that is PM_{10}. There is no data for this factor. The share of PM_{10} on ground is used as a reference. There is very varied data for the size of this factor (Hedalen 1994). Hedalen gives a PM_{10} share of 3-4 per cent. In the calculations 3 per cent is used as a first estimate. Hedalen (1994) states further that the $PM_{2.5}$ share of total road dust is 0.5-1 per cent.

The road surface has stronger wear resistance on roads with heavy traffic than on roads with little traffic. The SPS value can therefore vary with the amount of traffic. SPS-values for different ÅDT[4]-intervals were estimated based on analysis of track depths over the years 1988-1995 (NPRA 1996).

SPS is also dependent on the weight of the studs. The studs have in the recent years become lighter. The requirement in 1988 was that the stud on light vehicles should not exceed 2.0 gram, in 1990 this was changed to 1.8 gram, and it changed again in 1992 to 1.1 gram (NPRA 1997). The so-called "light studs" has a weight on 0.7 gram. Studs used on tyres for heavy vehicles could until 1992 weigh 8.0 gram, but this demand was changed to 3.0 gram. There are also other factors influencing the SPS- values, for example the road surface wear resistance and the quality of the stone materials used.

[4] ÅDT = Average annual daily traffic

SPS-values used in the calculations are given in table 3.12. The SPS values are divided on classes of ÅDT (Evensen 1997b). In the calculations average values for SPS, weighted after the size of traffic load on roads with different ÅDT, are used. The values are given in g/km and are valid for all vehicles. To estimate how much of the emissions that originate from heavy vehicles, it is provided that heavy vehicles wear 5 times more than light vehicles. The vehicle velocity is not given as an own factor, since it is included in the calculation of SPS.

Annual traffic load (trafikkarbeid) ($n \bullet l$ in the formula) used in the calculations are based on Rideng (2001).

Use of studded tyres is forbidden in Norway from the first Monday after Easter and until 31st of October. There is an exception from this rule in the three northern counties, Nordland, Troms and Finnmark. In these counties, use of studded tyres is forbidden between 1st of May to 15th of October. It is assumed in the calculations that studded tyres are used the whole period when it is allowed. This means that m is 6.5/12 in the northern counties and 5.5/12 for rest of the country.

Shares of traffic load on studded tyres in the five largest towns in Norway are given in table 3.13. There has been a decrease in use of studded tyres in Norway during the latest years. The factor p in the formula will therefore vary from one year to another. Information regarding the share of studded tyres originates from the Norwegian Public Roads Administration. There is also national data on share of the car fleet with studded tyres. The data material is based on interviews of car drivers (NPRA 1995a, 1995b and 1998). The questionnaires were given out at daytime and caused that most of the answers were from local car drivers. Accordingly, the survey included too many car drivers with annual mileage over 20 000 km. The survey from 1997 was however done differently. In the calculation program, the studded tyre share was decided to be 0.2. This value was adjusted by the different local road administrations, based on interviews or other available knowledge. The Norwegian Public Roads Administration has decided to use these data. The data are given in table 3.14. For the period 1973-1990 is it assumed that the studded tyre share was 90 per cent.

To calculate the correction factor for humid road surface, traffic load data is used. This is divided into different road conditions after Evensen (1997a) (table 3.15). Share of wet and dry road surface will change some as a consequence of varied share of studded tyres. In the calculations for 1973-1997 a correction factor is used, based on the estimation that 80 per cent of light duty vehicles and 60 per cent of heavy duty vehicles use studded tyres.

Table 3.13. SPS values. g/km

ÅDT	1973-1980	1981-1987	1988-1992	1993-1997	2002
0-1500	22	20	20	18	16
1500-3000	20	20	18	16	14
3000-5000	16	15	14	12	10
>5000	14	12	11	10	9
Average[1]	17.1	15.6	14.7	13.1	11.6

[1] Weight after traffic load on roads with differerent ÅDT.

Source: Evensen (1997b).

Table 3.14. Use of studded tyres in five prioritized communities. Share of traffic load with studded tyres. Light duty vehicles

	1998/1999	1999/2000	2000/2001	2001/2002
Oslo	51.9	32.4	21.2	31.3
Drammen	49.6	48.7	52.1	29.3
Stavanger	38.1	31.3	26.8	29.3
Bergen	37.0	29.4	28.3	31
Trondheim	67	64.4	62.1	44.4

Source: The Norwegian Public Roads Administration.

Table 3.15. Averaged studded tyre share in Norway weighted after traffic load in the different counties

1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
0.87	0.88	0.88	0.87	0.86	0.83	0.79	0.70	0.63	0.59	0.59

Source: Statistics Norway based on data from the Norwegian Public Roads Administration.

Table 3.16. Grouping of wet, dry and icy road surface

	In the Norwegian emission inventory
Wet	Wet
Dry	Dry
Slush	Wet
Loose snow	Wet[1]
Hard snow	Hard snow/ice
Bare tracks	80 per cent dry and 20 per cent wet[2]

[1] Assumption made of NILU and Statistics Norway.

[2] Assumption made by Evensen (1997a).

TSP

Hedalen and Myran (1994) analysed road dust depots from Trondheim and found that 30 weight percentage of the particles were below PM_{10}. This gives a distribution where PM_{10} is 0.3*TSP. This distribution is used in the inventory.

Cd

Emissions of Cd are calculated based on emission factors from Bækken (1993) and annually generated road dust of $PM_{10.}$

PAH

Emissions of PAH are calculated based on emission factors from Larssen (1985) and annually generated road dust of $PM_{10.}$

3.2.4.9.3. Activity data

Cd and PAH
The activity data used for calculating the emissions of Cd and PAH are annually generated PM_{10} of road dust, see sector 3.2.4.9.2.

3.2.4.9.4. Emission factors
Particles
The emission factors can be derived from the factors given under 3.2.4.9.2. The emission figures are calculated as a product of SPS values for the given year, the number of kilometers driven, part of the cars with studded tyres, part of the year with winter season, correction for icy surface and the PM_{10} share of the emission (α).The emission factors do not reflect the whirl up of road dust. Heavy duty vehicles whirl up much more than light duty vehicles.

Cd
The Cd content in the bitumen is uncertain. According to Bækken (1993), the Cd content varies between 1.9 and 43 g Cd per ton road dust. Statistics Norway has chosen an average emission factor of 22.5 g/ton, see table 3.17.

PAH
The PAH content in the bitumen is uncertain and can vary over time. According to Larssen (1985), the PAH content in airborn dust from wet roads is 330 ppm and 75 ppm from dry roads. Statistics Norway has chosen 85 ppm. In table 3.17, the emission factor of 85 g/ton is converted to correspond to the PAH components included in NS9815. This gives an emission factor of 61.7 g/ton for PAH-total.

Table 3.17. PAH and Cd emission factors from road dust[1]. g/ton PM_{10} of road dust

	Emission factor (g/ton PM_{10} from road dust
Norwegian standard (PAH-total)	61.7
PAH-6	24.7
PAH-4	5.5
Cd	22.5

[1] Dry road surface.

Source: Finstad et al. (2001).

3.2.4.9.5. Uncertainties
Particle distribution of road dust has also been investigated by others than Hedalen and Myran, among them the Norwegain Institute for Air Research (NILU). The results from these measurements show another distribution than Hedalen and Myran, with a PM_{10}-fraction much lower than 30 weight percentage. In the calculation of PM_{10}, data from Hedalen and Myran (1994) are used, and for consistency reasons the same source is used for estimating TSP, despite the uncertainty and the discrepancy with NILUs estimations.

The value of α (PM_{10} share in road dust) is very uncertain. An average velocity is assumed in the calculations. This is further complicated when road surface on roads with high velocities have another wear resistance than other road surfaces.

The emission factor used for calculating Cd emissions is uncertain since it is based on two measurements.

The estimation of the PAH content in road dust from Larssen (1985) is very uncertain, since it is based on only one measurement in Oslo, but it is the only estimate available, and is used in lack of other data.

3.2.4.9.6. Completeness
Major missing emission sources are not likely.

3.2.4.9.7. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

3.2.5. Other sectors
IPCC 1A4, Key category for CO_2 from gas and oil /1A5
NFR 1A4/1A5
Last update: 01.09.05

3.2.5.1. Description
"Other sectors" includes *all* military combustion, *stationary* combustion in agriculture, forestry, fishing, commercial and institutional sectors and households, and also motorized equipment and snow scooters in agriculture and forestry, and ships and boats in fishing.

Methodology to estimate emissions from the fishing fleet is described in section 3.2.4.5 Navigation. Also military sources are described according to source (shipping, aviation etc.) to increase transparency.
3.2.5.2. Activity data

Motorized equipment is described in section 3.2.4.7.

Fishing is described under *Navigation* in section 3.2.4.5.

Households
Statistics Norway's annual survey on consumer expenditure gives figures on use of wood in households. Figures on use of coal and coal coke are derived from information from the main importer. Formerly, Norway's only coal producing company had figures on coal sold for residential heating in Norway. From about 2000, this sale was replaced by imports from abroad. Figures for LPG are collected from the suppliers. Heavy fuel oil is taken from the sales statistics for petroleum products. As the consumption of each energy carrier shall balance against the total sales in the sales statistics, use of fuel oil, kerosene and heavy distillates in households is given as the residual after consumption in all other sectors has been assessed.

Agriculture
Data on energy use in hothouses are collected in surveys performed regularly. Sales figures are used to project the figures for consumption of oil products in the years between, while bio fuels and LPG are kept constant. The Agricultural Budgeting Board has figures on the use of gasoline, auto diesel and fuel oil in agriculture excluding hothouses. A figure for the minor use of coal is collected annually from the only consumer.

Military
Figures on fuel oil are annually collected directly from the military administration, while figures from the sales statistics for petroleum products are used for other energy carriers.

3.2.5.3. Emission factor
Emission factors used are given in Appendix B.

3.2.5.4. Uncertainties
The method used for finding the use of fuel oil, kerosene and heavy distillates in households implies a great deal of uncertainty regarding the quality of these figures, particularly for fuel oil, which is the most important of these three energy carriers. Since the late 1990s it also has been necessary to adjust figures for other sectors in order to get consumption figures for households that look reasonable. Hopefully, new surveys will improve the quality of these figures in the future.

3.2.5.5. Completeness
Major missing emission sources are not likely.

3.2.5.6. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

3.2.6. International bunkers
IPCC - memo item
NFR - memo item
Last update: 01.09.05

3.2.6.1. Desription
Emissions from international bunkers (marine and aviation) have been estimated and reported separately from national estimates, in accordance with the IPCC Guidelines. Differences between the IEA (International Energy Agency) data and the data reported to UNFCCC in sectoral data for marine shipping and aviation are due to the fact that different definitions of domestic use are employed. In the Norwegian inventory, domestic consumption is based on a census in accordance with the IPCC good practice guidance. On the other hand, the IEA makes its own assessment with respect to the split between the domestic and the international market.

3.2.6.2. Shipping
3.2.6.2.1. Method
Emission figures are calculated using sales statistics and the emission factors used for domestic shipping.

3.2.6.2.2. Activity data
Sales figures for international sea transport from Statistics Norway's sales statistics for petroleum products are used for marine gas oil, heavy distillates and heavy fuel oil.

3.2.6.2.3. Emission factor
Emission factors used for *Shipping* are described under *Navigation* in section 3.2.4.5.

3.2.6.3. Aviation
3.2.6.3.1. Method
The consumption of aviation bunker fuel in Norway is estimated as the difference between total purchases of jet kerosene in Norway for civil aviation and reported domestic consumption. Figures on total aviation fuel consumption are derived from sales data reported to Statistics Norway from the oil companies. These data do not distinguish between national and international uses. Data on domestic fuel purchase and consumption are therefore collected by Statistics Norway from all airline companies operating domestic traffic in Norway. The figures on domestic consumption from airlines are deducted from the total sales of jet kerosene to arrive at the total fuel sales for international aviation. The bottom-up approach of Norway is the detailed Tier2 CORINAIR methodology. The methodology is based on detailed information on types of aircraft and number of LTOs, as well as cruise distances.

3.2.6.3.2. Activity data
Statistics Norway annually collects data on use of fuel from the air traffic companies, including specifications on domestic use and purchases of fuel in Norway and abroad.

3.2.6.3.3. Emission factor
Emission factors used for *Aviation* are described under *Aviation* in section 3.2.4.1.

3.2.7. CO_2 emissions from biomass
IPCC - memo item

Emissions are estimated from figures in the energy accounts on use of wood, wood waste and black liquor. According to the guidelines, these CO_2 emissions are not included in the national total in the Norwegian emission inventory.

3.3. Energy production (fugitive emissions from fuels)

IPCC 1B
NFR 1B
Last update: 01.09.05

3.3.1. Overview

Emission sources included in the inventory from the sector Fugitive emissions from fuels are fugitive emissions from coal mining and handling, and from oil and natural gas.

Fugitive emissions from oil and natural gas include emissions from loading and refining of oil, gasoline distribution, and fugitive emissions from the gas terminals on shore. There are also fugitive emissions in connection to venting and flaring offshore.

3.3.2. Fugitive emissions from coal mining and handling

IPCC 1B1 a
NFR 1B1
Last update: 01.09.05

3.3.2.1. Description

There are today two coal mines at Spitsbergen (the largest island in the Svalbard archipelago) operated by a Norwegian company. They opened the second mine in 2001. Emissions from all activities at Svalbard should, according to official definitions, be included in the Norwegian GHG inventory. This means that also emissions from the Russian coal production in Barentsburg should be estimated. The production at Barentsburg is at present considerably smaller than the Norwegian production. Due to lack of data this has so far not been done, but, hopefully, figures will be included in the Norwegian emission inventory in 2006. From 1990 to 1998 there were two coal mines at Svalbard operated by the Russians and thereafter it is one.

At Svalbard there is a smouldering fire in an abandoned coalmine. This mine was operated by the Russians and was closed down in 1998. Due to lack of data, emissions from this fire are not estimated. However, Norwegian authorities assume that these emissions are limited.

3.3.2.2. Method

CO_2

Indirect CO_2 emissions from methane oxidized in the atmosphere are calculated by multiplying the calculated CH_4 emission with the factor 2.74 tonne CO_2 per tonne CH_4. (See Chapter 1.9 for more information on indirect CO_2).

CH_4

Emissions of methane from coal mining in Norway are calculated by multiplying the amount of coal extracted with a country specific emission factor (Tier 2). The calculations are performed by Statistics Norway.

3.3.2.3. Activity data

Production figures are reported by the plant to Statistics Norway.

3.3.2.4. Emission factor

CH_4

A country specific emission factor of CH_4 from extraction of coal was determined in 2000 in two separate studies performed by (IMC 2000) and (Bergfald & Co as 2000).

The emissions of methane from coal mining were in the study measured in two steps. First, coal was sampled and the methane content in coal was analysed (IMC 2000). The sampling process started after a long period (a week) of continuous production. Small samples of coal were removed directly from the coalface as soon as possible after a cut was taken. This was to minimise degassing losses in the samples if the face or heading had been standing for a long time.

The samples yielded an estimate of seam gas content of 0.535-1.325 m^3 methane per tonne coal derived from an average content of 0.79 m^3 per tonne. This factor includes the total possible methane emissions from coal mining, loading and transport on shore and on sea. The factor also includes the possible emission from handling and crushing of coal at the coal power plant.

Secondly, the methane content in ventilation air from the underground coal mines at Spitsbergen was measured (Bergfald & Co as 2000). From the Norwegian mines the methane content in the ventilation air was measured to 0.1-0.4 m^3 methane per tonne coal.

Considering the measurements it was therefore decided to use 0.54 kg methane per tonne coal as emission factor when calculating methane emissions from coal mining in Norway.

According to IPCC`s Good Practice Guidance, the Norwegian mines at Spitsbergen have characteristics that should define the mines as underground mines, whereas the emission factor we use is more characteristic for surface mines. The low content of methane is explained with the mine's location 300-400 metres *above* sea level. Furthermore, the rock at Spitsbergen is porous and therefore methane has been aired through many years.

3.3.2.5. Uncertainties

3.3.2.5.1. Activity data

The uncertainty in the activity data is regarded as being low.

3.3.2.5.2. Emission factor
Today, a country specific factor based on measurements is used in the calculations. We assume that the uncertainty in the emission factor is much lower than reported in Rypdal and Zhang (2000), when an IPCC default emission factor was used. In Rypdal and Zhang (2000) the uncertainty in the emission factor was estimated by expert judgments to as much as -50 to +100 per cent.

The emission factor we use is an average of the measurement of methane in coal sampled in the study (IMC 2000). This average emission factor is two to eight times higher than the methane content measured in ventilation air by (Bergfald & Co as 2000). This should indicate that the chosen emission factor is rather conservative.

3.3.2.6. Completeness
Emissions from Russian coal extraction on Svalbard have so far not been included in the Norwegian emission calculations; hopefully, these will be included in the 2006 inventory. Other major missing emission sources are not likely.

3.3.2.7. Source specific QA/QC
Independent methods to estimate the emission factor used in the calculations are described above in this chapter.

Statistics Norway and the Norwegian Pollution Control Authority carry out internal checks of the emission time-series and corrections are made when errors are detected; see Chapter 1.5.1 for general QA/QC procedures.

3.3.3. Oil and natural gas

IPCC 1B2, 1B2a are key category for CO_2 and 1B2c for CO_2 and CH_4
NFR 1B2

3.3.3.1. Description
1B2a covers emissions from loading and storage of crude oil, refining of oil and distribution of gasoline. Loading, unloading and storage of crude oil on the oil fields off shore and at oil terminals on shore causes emissions of CH_4 and NMVOC and indirect emissions of CO_2. Non-combustion emissions from Norway's two oil refineries (a third was closed down in 2000) include CO_2, CH_4, NO_x, NMVOC, SO_2 and particulates. Gasoline distribution causes emissions of NMVOC, which lead to indirect CO_2 emissions.

1B2b covers fugitive emissions of CH_4 and NMVOC and indirect emissions of CO_2 from the two Norwegian gas terminals on shore.

1B2c covers fugitive emissions from venting and flaring. Venting emissions include emissions of CO_2, CH_4 and NMVOC from exploration and production drilling of gas and oil, and reinjection of CO_2 at one oil field (Sleipner). The major source is cold vent and leakage of CH_4 and NMVOC from production drilling and hence indirect CO_2 emissions. CO_2 emissions vented to the atmosphere when the injection of CO_2 has to stop for maintenance etc. are reported in this sector. See section 3.3.4 "CO_2 capture and storage at the oil and gas production field Sleipner West" for further description of this source.

Most of the emissions in *1B2c* come from flaring of natural gas off shore (during both well testing, extraction and pipeline transport) and at gas terminals and flaring of refinery gas at the refineries. This flaring causes emissions of CO_2, CH_4, N_2O, NO_X, NMVOC, SO_2, CO, particulates, PAH and dioxins. There is also some flaring of oil in connection with well testing - amounts flared and emissions are reported to NPD (the Norwegian Petroleum Directorate) and the Norwegian Pollution Control Authority.

The major source in sector 1B2 is flaring of natural gas on the Norwegian continental shelf.

Table 3.18 gives an overview over the calculations of the fugitive emissions of CO_2, CH_4, N_2O and NMVOC.

Table 3.18. Fugitive emissions from oil and natural gas. Emission sources, compounds, methods, emission factors and activity data included in the Norwegian GHG Inventory

B Fugitive emissions from fuels	CO_2	CH_4	N_2O	NMVOC	Method	Emission factor	Activity data
1.B.2.a Oil							
i. Exploration	IE	IE	NO	IE	Tier II	CS	PS
ii. Production	IE	IE	NO	IE	Tier II	CS	PS
iii. Transport	E	E	NO	E	Tier II	CS	PS
iv. Refining/Storage	E	E	NO	E	Tier I/II	CS	PS
v. Distribution of oil products	E	NE	NO	E	Tier I	Corinair/CS	PS/CS
vi. Other	NO	NO	NO	NO			
1.B.2.b Natural gas							
Exploration	IE	IE	NO	IE	IE	IE	IE
i. Production/Processing	IE	IE	NO	IE	IE	IE	IE
ii. Transmission	IE	IE	NO	IE	IE	IE	IE
Distribution	IE	IE	NO	IE	Tier II	CS	PS
iii. Other leakage	E	E	NO	E	Tier II	CS	PS
at industrial plants and power stations	E	E	NO	E	Tier II	CS	PS
1.B.2.c							
Venting							
i. Oil	IE	IE	NO	IE	Tier II	CS	PS
ii. Gas	IE	IE	NO	IE	Tier II	CS	PS
iii. Combined	E	E	NO	E	Tier II	CS	PS
Flaring							
i. Oil (well testing)	E	NE	NE	E	Tier II	CS	PS
ii. Gas							
Gas and oil fields	E	E	E	E	Tier II	CS	PS
Gas terminals	E	E	E	E	Tier I	CS	CS
Refineries	E	E	E	E	Tier I	CS	CS
iii. Combined	IE	IE	IE	IE	Tier I	CS	CS

IE = Emissions are calculated by Statistics Norway or reported by the plants, IE = Included elsewhere, NO = Not occurring, CS = Country specific, PS = Plant specific, Tier = the qualitative level of the methodology used.

3.3.3.2. Method

Loading and storage of crude oil off shore and on shore CH_4 and NMVOC

From 2003, emission of CH_4 and NMVOC from loading and storage of crude oil on shuttle tankers included in the GHG Inventory are based on reported emission figures from the oil companies.

For earlier years the reported emissions is calculated by Statistics Norway. The calculation was based on the field specific amounts of crude oil loaded and stored multiplied with field specific emission factors. Field specific activity data and emission factors (the latter only to the Norwegian Pollution Control Authority) used in the calculation are annually reported by the field operators to Statistics Norway and the Norwegian Pollution Control Authority. Since year 2000 some shuttle tankers have had installed vapour recovery units (VRU), and emissions from loading of crude oil on shuttle tankers with and without VRU are calculated separately for each field. In addition emission figures were annually reported to the Norwegian Pollution Control Authority and used in the QC of the calculated emission figures.

Only the Norwegian part of oil production at fields with oil loading is included. For the two Norwegian oil terminals on shore, the emissions from loading of crude oil are reported annually from the terminals to the Norwegian Pollution Control Authority. At one of the terminals VRU for recovering NMVOC was installed in 1996. The calculation of the emissions of CH_4 and NMVOC at both terminals is based upon the amount of crude oil loaded and oil specific emission factor dependent of the origin of the crude oil loaded.

Indirect CO_2 emissions from the oxidation of CH_4 and NMVOC for this source category are calculated by Statistics Norway.

Oil refineries

CO_2, CH_4, NO_x, NMVOC, SO_2 and particulates

Emission figures from the oil refineries are reported to the Norwegian Pollution Control Authority and are after QA/QC procedures used in the emission inventory.

The CO_2 emissions originate from the coke on the catalyst that is burned off and from the coke calcining kilns. The CO_2 emissions from catalytic cracker and calcining kilns are calculated from the formula (9):

*(9) tonne CO_2 per year = ((Nm^3 RG per year * volume% CO_2) / 100 *(molar weight of CO_2 / 22.4)) / 1000*

- the amount of stack gas (RG) is measured continously
- the density of the stack gas is 1.31 kg/Nm^3
- volume percentage of CO_2 is based on continuosly measurements. However, if the refinery can document that the volume percentage of CO_2 is not fluctuating more than 2 per cent from last years report it is not mandatory to have continuos measurements.

Both CH_4 and NMVOC emissions are based on measurement carried out by Spectracyne latest in 2002.

The indirect CO_2 from oxidized CH_4 and NMVOC is calculated by Statistics Norway.

Gasoline distribution
NMVOC
Emissions from gasoline distribution are calculated from figures on amounts of gasoline sold and emission factors for, respectively, loading of tanker at gasoline depot, loading of tanks at gasoline stations and loading of cars.

Gas terminals
CH_4 and NMVOC
Fugitive emissions of CH_4 and NMVOC from gas terminals are annually reported from the terminals to the Norwegian Pollution Control Authority.

The emissions are calculated based on the number of sealed and leaky equipment units that is recorded through the measuring and maintenance program for reducing the leakage. The number of sealed and leaky equipment units is collected two times a year and the average number of the countings is used in the calculation. It is assumed in the calculation that a leakage has a lasted the whole year if not the opposite is documented.

Measurement of the total emissions was carried out in 2002 and 2003.

Venting
CH_4 and NMVOC
Emissions of CH_4 and NMVOC from cold venting and diffuse emissions for each field are reported annually to the Norwegian Pollution Control Authority from the field operator. The emissions are mostly calculated by multiplying the amount of gas produced with an emission factor for each emission source identified at the field. The indirect CO_2 emissions are calculated by Statistics Norway.

The vented CO_2 at Sleipner West is measured.

Flaring
CO_2, CH_4, N_2O, NO_X, NMVOC, SO_2, CO, particulates, PAH and dioxins
Emissions from flaring of natural gas off shore are calculated by Statistics Norway on the basis of field specific gas consumption data and country specific emission factors. For CO_2, CH_4, NO_X, NMVOC and SO_2, calculated emissions are used in the inventory for the years until 2002. From 2003, emissions of these components from flaring offshore reported by the oil companies to NPD and the Norwegian Pollution Control Authority are used in the inventory. The same metod is used in the calculation of emission from flaring by well testing.

Emissions of CO_2 from flaring from one of the two gas terminals are reported from the plant. All other emissions from the gas terminals are based on activity data and emission factors.

The refineries report annually CO_2 emissions from flaring to the Norwegian Pollution Control Authority. The emissions are calculated by multiplying the amount of gas flared with plant specific emission factors.

3.3.3.3. Activity data
Loading and storage of crude oil off shore and on shore
The amount of oil buoy loaded and oil loaded from storage tankers that the oil companies emission calculations is based on is annually reported to the Norwegian Pollution Control Authority and Norwegian Petroleum Directorate (NPD). The amount of oil loaded on shuttle tankers with or without VRU is separated in the report.

For the years before 2003, Statistics Norway gathered data on amounts of crude oil loaded at shuttle tankers and stored at storage vessels from the NPD. The data from each field are reported monthly by the field operators to NPD on both a mass and a volume basis. The allocation of the amount of crude oil loaded at shuttle tankers and stored at storage vessels with or without VRU is from the annually report the field operators are committed to deliver to the Norwegian Pollution Control Authority and NPD.

The amount of oil loaded at on shore oil terminals is also reported to the Norwegian Pollution Control Authority and NPD.

Gasoline distribution
Gasoline sold is annually collected in Statistics Norway's sales statistics for petroleum products.

Gas terminals
Activity data that the terminals use in their emission calculations are sampled through the terminals measuring and maintenance program which aim is to reduce leakage.

Venting
Amounts of gas produced or handled at the platform are reported from NPD and used in the QC of the reported emissions.

Flaring
Amounts of gas flared at offshore oil and gas installations are monthly reported by the operators to the Norwegian Petroleum Directorate (NPD). Amounts flared at the two gas terminals are reported to NPD

and the Norwegian Pollution Control Authority. Amounts of refinery gas flared are found by distributing the total amounts between different combustion technologies by using an old distribution key, based on data collected from the refineries in the early 1990s. This distribution is confirmed in 2003.

3.3.3.4. Emission factor

Loading and storage of crude oil off shore and on shore

For the years before 2003, emission factors used in the calculation of CH_4 and NMVOC emissions offshore are field specific and were reported to the Norwegian Pollution Control Authority and NPD in an annual report. the Norwegian Pollution Control Authority forwarded the emission factors to Statistics Norway. From 2003 the emission figures reported by the field operators are used in the inventory.

The evaporation rate varies from field to field and over time, and the emission factors are dependent on the composition of the crude oil as indicated by density and Reid vapour pressure (RVP). The VOC evaporation emission factors are obtained from measurements, which include emissions from loading and washing of shuttle tankers. For some fields the emission factors are not measured, only estimated. The CH_4 content of the VOC evaporated is also measured so that total emissions of VOC are split between CH_4 and NMVOC.

The emission factors that the field operators use in their calculations is reported to the Norwegian Pollution Control Authority and NPD. They report emissions factor with and without VRU and the split beteen CH_4 and NMVOC.

Loading on shore: The emission factors are considerably lower at one of Norway's two oil terminals than at the other, because the oil is transported by ship and therefore the lightest fractions have already evaporated. At the other terminal the oil is delivered by pipeline. The latter terminal has installed VRU, which may reduce NMVOC emissions from loading of ships at the terminal by about 90 per cent. NMVOC emissions at this terminal are estimated to be more than 50 per cent lower than they would have been without VRU. However, the VRU technology is not designed to reduce methane and ethane emissions.

Gasoline distribution

Emission factor for NMVOC from filling gasoline to cars used in the calculations are from (EEA 2001) and is 1.48 kg NMVOC/tonne gasoline.

Venting

The emission factors used are listed in table 3.19.

Table 3.19. Emission factors for cold vents and leakage at gas fields off shore

	NMVOC Emission factor	CH_4 Emission factor	Calculation method
Emission source	[g/Sm3]	[g/Sm3]	
Glycol regeneration	0.065	0.27	
Gas dissolved in liquid from K.O. Drum	0.004	0.00	
Gas from produced water system	0.03	0.03	
Seal oil systems	0.015	0.01	
Leaks through dry compressor gaskets	0.0014	0.00	
Start gas for turbines[1]	0.4	0.36	Tonne per start up
Depressurisation of equipment	0.005	0.02	
Instrument flushing and sampling	0.00021	0.00	
Purge and blanket gas [1]	0.032	0.02	
Extinguished flare	0.014	0.02	
Leaks in process	0.007	0.02	
Depressurisation of annulus	0.0000005	0.00	
Drilling	0.55	0.25	Tonne per well

[1] The gas source is standard fuel gas.

Source: Aker Engineering (1992).

Flaring

From 2003, CO_2 emission figures reported by the oil companies to the the Norwegian Pollution Control Authority and NPD are used in the inventory. For earlier years, average emission factors, based on field specific factors, are used, except for one field, for which a field specific factor is used for all years. In table 3.20, the CO_2 emission factors for flaring off shore and at one gas terminal are shown. The other gas terminal used 2.72 tonne CO_2/tonne gas.

Emmission factors used in the calculations for well testing are shown in table 3.21.

Table 3.20. Emission factors for flaring of natural gas at off shore oil fields and one gas terminal

	Average content of CO_2 in gas flared at one gas terminal t CO_2 /t gas	Average content of CO_2 in gas flared off shore kg CO_2 / Sm^3 gas
2003	2.70	2.41
2002	2.70	2.47
2001	2.70	2.42
2000	2.70	2.52
1999	2.70	2.48
1998	2.70	2.34
1997	2.70	2.34
1996	2.70	2.34
1995	2.70	2.42
1994	2.70	2.34
1993	2.70	2.34
1992	2.70	2.34
1991	2.70	2.34
1990	2.70	2.34

Source: The Norwegian Pollution Control Authority/ Norwegian Petroleum Directorate.

Table 3.21. Emission factors for flaring in connection with well testing

Compounds (unit)	unit/tonnes flared oil	Source	unit/kSm3 flared natural gas	Source
CO_2 (tonnes)	3.2	SFT (1990)	2.34	SFT (1990)
CH_4 (tonnes)	NE		0.00024	IPCC (1997b)
N_2O (tonnes)	NE		0.00006	
NO_x (tonnes)	0.0037	OLF (2004)	0.012	OLF (2004)
NMVOC (tonnes)	0.0033	OLF (2004)	0.00002	
CO (tonnes)	0.0018		0.0015	OLF (2004)
TSP (tonnes)	0.025	Measurements (OLF[1])	2.0E-06	EPA (2002)
PM_{10} (tonnes)	0.0215	Use the same distribution as	2.0E-06	EPA (2002)
$PM_{2.5}$ (tonnes)	0.014	for combustion of heavy fuel oil in industry (EPA 2002)	2.0E-06	EPA (2002)
PAH (kg)	0.012	OLF (1991)	0	
PAH-OSPAR (kg)	0.0024	Use the same distribution as	0	
PAH-4 (kg)	0.00024	for combustion of heavy fuel oil in industry (EPA 1998)	0	
Dioxin (mg)	0.01	Measurements (OLF)	0	

[1]The Norwegian Oil Industry Association (OLF).

3.3.3.5. Uncertainties

The uncertainty in the emission factors of methane (Rypdal and Zhang 2000) and NMVOC (Rypdal and Zhang 2001) from *oil loading* is estimated to be ± 40 per cent and in the activity data ± 3 per cent.

The uncertainty in the amount of gas flared is in (Rypdal and Zhang 2000) regarded as being low, ±3 per cent, due to that there is a tax on gas flared and there is requirement by law that the gas volume flared is measured (NPD 2001). The uncertainty in the CO_2 emission factor for flaring is ±10 (Rypdal and Zhang 2000).

The uncertainty in CH_4 and NMVOC emissions from venting and, hence, in the indirect emissions of CO_2, is much higher than for flaring.

3.3.3.6. Source-specific QA/QC and verification

Statistics Norway gathers activity data on oil and gas activities from the Norwegian Petroleum Directorate (NPD). The figures are quality controlled by comparing them with the figures reported in the field operators' annual report to the Norwegian Pollution Control Authority and NPD. The calculated emissions are compared with the emission data the field operators report to the Norwegian Pollution Control Authority and NPD. From 2003, Statistics Norway estimate emission based on activity data that the field operators monthly report to NPD, and reported emission factors. When discrepancies are found between the two sets of data these are investigated and corrections are made if appropriate. If errors are found, the Norwegian Pollution Control Authority contacts the plant to discuss the reported data and changes are made if necessary.

The reported emissions from the gas terminals are compared with previous years' emissions.

Statistics Norway collects the activity data used for venting and flaring in the calculation from the NPD. The figures are quality controlled by comparing them with the figures reported in the field operators annual report to the Norwegian Pollution Control Authority and NPD and time series are checked.

The calculated emissions are compared with the emission data the field operators report to the Norwegian Pollution Control Authority and NPD, before 2003. From 2003 reported emissions is checked by the Norwegian Pollution Control Authority and Statistics Norway. Statistics Norway calculates emissions from reported emission factors and activity data collected monthly by the office of statistics in NPD. When discrepancies are found between the two sets of data this is investigated and corrections are made if appropriate. If errors are found the Norwegian Pollution Control Authority contacts the plant to discuss the reported data and changes are made if necessary.

Statistics Norway and the Norwegian Pollution Control Authority perform internal checks of the reported data for venting from the field operators. Some errors in the time-series are usually found and the field operators are contacted and changes are made. The same procedure is followed to check the amount of gas reported as flared. The quality of the activity data is considered to be high, due to the fact that there is a tax on gas flared offshore. NPD has a thorough control of the amount of gas reported as flared.

3.3.4. CO_2 capture and storage at the oil and gas production field Sleipner West

IPCC 1B2c
NFR-
Last update: 01.09.05

3.3.4.1. Description

The natural gas in the Sleipner West offshore gas-condensate field contains about 9 per cent CO_2. The CO_2 content has to be reduced to about 3 per cent before transported to the consumers onshore. The CO_2 to be removed amounts about 1 million tonnes per year.

When this North Sea field was planned around 1990 the considerations were influenced by the discussions about strategies to reduce greenhouse gas emissions

and a possible national tax on CO_2-emissons (introduced in 1991 and extended in 1996). It was therefore decided that the removed CO_2 should be injected for permanent storage into a geological reservoir. The selection of an appropriate reservoir is essential for the success of geological storage of CO_2. In their search for a suitable reservoir the companies were looking for a saline aquifer with reasonable high porosity and a capture rock above to prevent leakage. Furthermore the CO_2 should be stored under high pressure - preferably more than 800 meters below the surface. Under these conditions CO_2 is buoyant and less likely to move upwards than CO_2 in gaseous form. The chosen reservoir is the Utsira formation, which is a sandstone saline aquifer 1,000 metres beneath the seabed. The reservoir was characterised by reservoir information such as seismic surveys and information from core drillings. The field and the injection program have been in operation since 1996. Statoil monitors the injected CO_2 with respect to leakages.
Investigations carried out so far show that the injected CO_2 has been kept in place without leaking out. In case unexpected CO_2 movements take place beyond the capture rock in the future it can be registered by the monitoring technics. Table 3.22 gives the amount of CO_2 injected in the Utsira formation since the project started in 1996.

When the injection has to stop for maintenance etc. the CO_2 is vented to the atmosphere. The amount vented to the atmosphere is included in the greenhouse gas inventory reported under 1B2c - see section 3.3.3. In 2003 this emission amounted to 23 909 tonnes CO_2. The figure for the other years is given in table 3.23.

3.3.4.2. Method
The reported data covers emissions to the atmosphere e.g. when the injection system is out of operation. These emissions are measured by continuous metering of the gas stream by VCONE-meter. The reported amounts of CO_2 which are injected in the Utsira formation are based on continuous metering of the gas stream by orifice meter.

The Sleipner CO_2-injection project is considered as the first industrial-scale, environmentally driven CO_2-injection project in the world. In order to document what happens with the CO_2 a European research project initially called SACS ("The saline aquifer carbon dioxide storage project") was organized around it. The SACS project ended in 2002 and was succeeded by the ongoing the EU-cofunded CO2STORE. The projects have run parallel to the development of Sleipner West and have special focus on monitoring and simulation. Research institutes and energy companies from several countries participate in the projects. The core of the projects has been to arrive at a reasoned view of whether carbon dioxide remains in the Utsira sand and whether developments in this formation can be monitored. The spread of carbon dioxide through the aquifer is recorded by seismic surveys. Baseline 3D seismic data were acquired in 1994, prior to injection, and the first repeat survey was acquired in 1999, when some 2.28 mill ton of CO_2 had been injected into the reservoir. This was followed by seismic surveys in 1999, 2001, 2002 and 2004. Results from the projects are given in several reports and articles such as: "Final Tecnical Report of the SACS2 project – EU project NNE-1999-00521, issued 30. Aug. 2002", "Recent time-lapse seismic data show no indication of leakage at the Sleipner CO_2-injection site" published at 7th Greenhouse Gas Control Technologies Conference (GHGT7),Vancouver 2004 and "4D seismic imaging of an injected CO_2 plume at the Sleipner field, central North Sea" (under publishing in the Geological Society of London Memoir). The project has confirmed that sound waves reflect differently from carbon dioxide and salt water. Comparing seismic data collected before and after injection started has allowed researchers to show how CO_2 deep inside the Utsira formation migrates. It is held under the layer of shale cap rock, 80 metres thick, which covers the whole formation. This extends for several hundred kilometres in length and about 150 kilometres in width.

The time-lapse seismic data clearly image the CO_2 within the reservoir, both as high amplitude reflections and as a pronounced velocity pushdown. The data also resolve a vertical

CO_2 chimney, which is regarded the primary feeder of CO_2 in the upper part of the bubble. There are no seismic indications of faults within the upper part of the reservoir, and no indications of leakage into the capture rock.

Table 3.22. CO_2 from the Sleipner field injected in the Utsira-formation, 1000 tonnes

	1996	1997	1998	1999	2000	2001	2002	2003	2004
CO_2 (ktonnes)	70	665	842	971	933	1 009	955	914	750

Source: The Norwegian Pollution Control Authority.

Table 3.23. Emissions of CO_2 from the Sleipner CO_2-injection plant due to inaccessibility of the injection facilities, tonnes

	1996	1997	1998	1999	2000	2001	2002	2003	2004
CO2 (tonnes)	..	29	4.195	9.150	8.318	3.050	7.567	23.909	21.377

Source: The Norwegian Pollution Control Authority.

The time-lapse seismic images clearly show the development of the CO_2 plume, and also have been used to calculate the amount of CO_2 in the reservoir. The volume calculated from the observed reflectivity and velocity pushdown is consistent with the injected volume.

3.3.4.3. Uncertainties

The reported data covers emissions to the atmosphere e.g. when the injection system is out of operation. The accuracy in these measurements made by VCONE-meter is $^{+}$/- 5 per cent. The orifice meter used to meter the amount of CO_2 injected in the Utsira formation have $^{+}$/- 3 per cent accuracy. So far there have not been detected any leakage from the storage. We expect to have more information from the SACS/CO2STORE-projects and the monitoring program as the Sleipner project develops – see QA/QC below.

3.3.4.4. Source specific QA/QC

The results are promising and so far it looks that the injected gas remains in place rather than leaking out. However, it remains to see how permanent the storage is. In Norway storage projects like Sleipner have to apply for a permit after the Pollution control Act. The storage of CO_2 is included in the emission licence for the Sleipner West field. According to the license Statoil is obliged to draw up a proposal for a monitoring program of the CO_2-storage. Furthermore Statoil reports the amount of CO_2 emitted and the amount injected every year to the Norwegian Pollution Control Authority. The monitoring program will give a system for QA. So far the monitoring is included in the SACS/CO2STORE projects and when these detailed projects are finalized a decision will be taken about a further monitoring program for the Sleipner injection project. The injected CO_2 is believed to be removed from the atmosphere and hence it is not reported as in the emission inventory. When the injection have to stop for maintenance etc. Statoil have to pay a CO_2-tax for the emissions. These emissions are reported to the Norwegian Petroleum Directorate. In this national emissions inventory these fugitive emissions are reported under 1B2c.

4. Industrial processes

IPCC 2
NFR 2
Last update: 01.09.05

4.1. Overview

This chapter provides descriptions of the methodologies employed to calculate emissions of greenhouse gases and long-range transboundary air pollutions from industrial processes. Only non-combustion emissions are included in this chapter. Emissions from fuel combustion in the manufacturing industry are reported in Chapter 3 Energy. Emission figures are either reported by plants to the Norwegian Pollution Control Authority or calculated based on emission factors and activity data by Statistics Norway. The emission factors are collected from different sources, while the activity data mainly is from official statistics collected by Statistics Norway.

4.2. Mineral products

IPCC 2A
NFR 2A
Last update: 01.09.05

The sector category Mineral products in the Norwegian inventory include emissions from thirteen different products (see table 4.1). CO_2, SO_2, NH_3, particles, heavy metals and dioxin are components that are emitted during the production of mineral products and included in the inventory. Table 4.1 shows the various components emitted from the different activities, and for which components the emission figures in the national inventory are based on figures reported by the plants (R) and for which the figures are estimated by Statistics Norway (E).

4.2.1. Cement production

IPCC 2A1
NFR 2A1
Last update: 01.09.05

4.2.1.1. Description

Two plants in Norway produce cement. Cement is produced from the raw material calcium carbonate ($CaCO_3$). During the calcination of $CaCO_3$, calcium oxide (CaO) is produced. The calcium oxide is heated to form clinker. The clinker is then crushed to form cement. Production of cement gives rise to both non-combustion and combustion emissions of CO_2. The non-combustion emissions originate mainly from the calcination of the raw material calcium carbonate ($CaCO_3$).

(10) $CaCO_3 + heat \rightarrow CaO + CO_2$

Table 4.2. Mineral products. Components emitted and included in the Norwegian inventory[1]

Mineral products	CO_2	SO_2	NH_3	Particles	Heavy metals	Dioxin
-- Cement production	E	R	NA	R	R	R
-- Lime production	R	NA	NA	R	R	NA
-- Limestone and dolomite use	R	NA	NA	NA	NA	NA
-- Concrete pumice stone	NA	R	NA	R	NA	NA
-- Rock wool production	NA	R	R	R	R	NA
-- Glass and glass fibre	NA	NA	R	R	R	NA
-- Ore mines	NA	R	NA	R	NA	R
-- Mining and extraction of stones and minerals	NA	NA	NA	R	NA	NA
-- Production of mineral white	NA	NA	NA	R	R	NA
-- Construction /repairing of vessels - Sandblasting	NA	NA	NA	R	NA	NA
-- Sandpit and rock-chrushing plants	NA	NA	NA	E	NA	NA
-- Construction and building	NA	NA	NA	E	NA	NA
-- Leather preparing	NA	NA	R	NA	NA	NA

[1] R means that emission figures in the national emission inventory are based on figures reported by the plants. E means that the figures are estimated by Statistics Norway (Activity data * emission factor). NA = Not Applicable.

SO_2 from cement production is emitted from sulphur in the fuel (reported under Energy) and in the raw materials and especially pyrite in limestone. Only the SO_2 from the raw materials should be counted as non-combustion emissions. Particles as well as heavy metals are emitted during the production process. More than 90 per cent of the emission of mercury is due to mercury in the limestone while the emissions of Pb, Cd, Cu, Cr and As originate both from process and combustion of fuel. Emissions of dioxin are due to the thermal process in the clinker production.

4.2.1.2. Method
CO_2
Statistics Norway calculates emissions of CO_2 on the bases of the annually clinker production data and country specific emission factors (SINTEF 1998a) and this is regarded as a Tier II metod.

SO_2
The plants annually report emissions of SO_2 to the Norwegian Pollution Control Authority. Figures are based on measurements at the plants.

Particles
Emissions have been reported to the Norwegian Pollution Control Authority since 1991 and 1992 respectively. It is believed that the reported figures also include emissions from combustion. Therefore emissions from combustion of coal, coke and waste oil used in cement production are not calculated, to avoid double counting. The plants have installed particle filter.

Particle size distribution for emitted particles from cement production is found in TNO (2002). In the Norwegian emission inventory PM_{10} is assumed to be 85 per cent of TSP and $PM_{2.5}$ is 30 per cent of TSP.

Heavy metals and POPs
Emission figures for heavy metals are reported to the Norwegian Pollution Control Authority. It is believed that these figures also include emissions from combustion. Therefore emissions from combustion of coal, coke and waste oil used in cement production are not calculated, to avoid double counting.

Dioxin figures are reported to the Norwegian Pollution Control Authority. It is also here assumed that the reported figures include emissions from fuel combustion, therefore emissions from combustion are not calculated.

4.2.1.3. Activity data
CO_2
The activity data used in the calculation of the CO_2 emissions is clinker production. The plants annually report the data to Statistics Norway.

4.2.1.4. Emission factors
CO_2
The emission factors used are recommended by SINTEF (1998a) and based on the actual composition of the raw materials used. These emission factors are calculated particularly for the two Norwegian factories and are 0.520 and 0.541 tonne CO_2 per tonne clinker respectively. The IPCC default emission factor is 0.5071 tonne CO_2/tonne clinker.

4.2.1.5. Uncertainties
Uncertainty estimates for greenhouse gases and long-range transboundary air pollutants are given in Appendix D.

Reported emission figures for particles have varied a great deal as a result of changes the plants have undergone to reduce emissions. There are also uncertain measurements due to the variation from one year to another.

Regarding the heavy metals, it has varied when the two plants started reporting the various components, and therefore estimations have been necessary for the years when reporting have been insufficient. The reported figures also vary from a year to another due to process technical conditions, variations in the metal content in the limestone used and uncertain measurements.

4.2.1.6. Completeness
Major missing emission components are not likely.

4.2.1.7. Source specific QA/QC
The emission figures for CO_2 calculated by Statistics Norway are compared to emission figures reported by the plants to the Norwegian Pollution Control Authority. The calculated emission figures agree quite well with emissions figures reported by the plants.

4.2.2. Lime production
IPCC 2A2
NFR 2A2
Last update: 01.09.05

4.2.2.1. Description
One plant produces lime in Norway. CO_2 and particles are emitted from the production process of lime. For earlier years also emissions of Pb and Cd have been reported.

4.2.2.2. Method
CO_2
The plant calculates the emissions of CO_2 based on actual production volumes of lime and plant specific emission factors for CO_2 from limestone and dolomite respectively. The emissions are reported to the Norwegian Pollution Control Authority.

Particles
Emission figures for particles have been reported to the Norwegian Pollution Control Authority since 1990. Emission figures from 1990 to 1995 are based on calculations using emission factors and production volume. Since 1996, the figures are a result of measurements at the plant. The plant has installed particle filter.

In the inventory, a particle size distribution suggested by TNO (2002) is used. PM_{10} is 0.4*TSP while $PM_{2.5}$ is 0.08*TSP.

Heavy metals
Emissions of Pb and Cd have been reported for the years from 1990 until 2000.

4.2.2.3. Uncertainties
The particle distribution used is not specified for the plants, and the particles emitted might therefore have another distribution than the one suggested from TNO (2002).

4.2.2.4. Completeness
Major missing emission components are not likely.

4.2.2.5. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

4.2.3. Limestone and Dolomite Use
IPCC 2A3
NFR 2A3
Last update: 01.09.05

4.2.3.1. Description
One plant in Norway neutralizes sulphuric acid waste with limestone and fly ash. During the neutralization prosess CO_2 is produced. The use of fly ash decreases the CO_2 emissions compared with when limestone is used.

4.2.3.2. Method
The plant reports emission figures for CO_2 to the Norwegian Pollution Control Authority.

4.2.3.3. Emission factors
An emission factor of 0.45 tonnes CO_2 per tonne sulphuric acid is used by the plant, calculated from the reaction equation.

4.2.3.4. Uncertainties
No source specific uncertainty is known.

4.2.3.5. Completeness
Major missing emission components are not likely.

4.2.3.6. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

4.2.4. Concrete pumice stone
IPCC 2A7
NFR 2A7iii
Last update: 01.09.05

4.2.4.1. Description
Three factories producing concrete pumice stone are included in the inventory. Two of them report emissions of SO_2 and particles while the third one only reports emissions of particle to the Norwegian Pollution Control Authority. Non-combustion emissions of SO_2 originate from the clay used in the production process.

4.2.4.2. Method
SO_2
Emission figures for SO_2 are reported to the Norwegian Pollution Control Authority, based on measurements at the two manufacturing plants in Norway. The plants have installed flue gas desulphurisation equipment.

Particles
Two of the plants have reported emission of particles to the Norwegian Pollution Control Authority since 1990, while a third one only has reported since 2000. It is assumed that the reported figures include both process- and combustion emissions, so emission calculations from fuel combustion are not done for these two plants. The plants have installed particle filters.

No information concerning particle size is found in national or international literature, but the Norwegian Pollution Control Authority assumes that most of the particles emitted from these plants are smaller than PM_{10}. Statistics Norway has decided to use the same particle size distribution for production of cement as given in TNO (2002). PM_{10} is therefore assumed to be 0.85*TSP and $PM_{2.5}$ is 0.3*TSP.

4.2.4.3. Uncertainties
The particle size distribution used is not specific for production of concrete pumice stone, but used due to lack of specific size distribution data for this source. The particle size distribution can therefore only be seen as an estimate.

4.2.4.4. Completeness
Particles often contain heavy metals, but type of metals and volumes will depend on the origin of the particles. Metals might therefore be emitted during production of concrete pumice stone. Statistics Norway/ Norwegian Pollution Control Authority have however

no data available for calculating emission of heavy metals from this source.

4.2.4.5. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

4.2.5. Rock wool production

IPCC -
NFR 2A7iii
Last update: 01.09.05

4.2.5.1. Description
Three plants in Norway produced rock wool until 2002 when one of them was closed down. In the inventory, emission figures for NH_3, particles and heavy metals are included. For earlier years also some non-combustion emissions of SO_2 are included. Particles originate from the cutting of the mineral wool and from fuel used in the production. The emission of heavy metals is partly due to use of coal/coke, but mainly due to the stone used in the production. Emissions of dioxin and PAHs are not reported nor calculated since emissions of these components are minor or not occurring.

4.2.5.2. Method
SO_2
Until 1991, all the three plants reported to the Norwegian Pollution Control Authority some non-combustion emissions of SO_2 that are included in the inventory for those years.

NH_3
Emission figures are reported to the Norwegian Pollution Control Authority. Figures exist from 1992. It is assumed in the inventory that emission figures for 1990 and 1991 are the same as the reported figure in 1992.

Particles
Emission figures are reported to the Norwegian Pollution Control Authority. Most of the emissions come from the spin chamber, and the particle size is assumed to be less than 1 µm. Particles emitted from the fabric filter are also assumed to be smaller than 1 µm. All emissions are therefore set to be smaller than $PM_{2.5}$. All assumptions are made by the Norwegian Pollution Control Authority in accordance with the industry.

It is assumed that the reported figures include both non-combustion and combustion emissions. Combustion emissions of particles are therefore not calculated.

Heavy metals and POPs
Emission figures for Pb, Cd, As and Cr have been reported annually from one of the plants to the Norwegian Pollution Control Authority since 1999. The figures are based on measurements. It is assumed that the reported figures include combustion emissions, and emission calculations from fuel combustion are not done for these heavy metals. Statistics Norway has calculated the emission figures for missing years (1990-1998) based on reported figures in 1999 and production rate for previous years. For the two plants not reporting, Statistics Norway calculates emissions based on derived emission factors from the one plant that reports and production volumes at each plant.

4.2.5.3. Activity data
Production volumes of rock wool are annually reported from the plants to the Norwegian Pollution Control Authority.

4.2.5.4. Emission factors
Heavy metals
A default emission factor is derived for each component (Pb, Cd, As and Cr) based on the annually reported emission figures and production rates from the one plant reporting. The derived emission factors are used to calculate emissions from the two other plants (one of these were closed down in 2002) (table 4.3).

Table 4.3. Emission factors for Pb, Cd, As and Cr from production of rock wool. g/tonne produced rock wool

Component	Emission factors (g/tonne produced rock wool)
Lead (Pb)	0.164
Cadmium (Cd)	0.001
Arsenic (As)	0.031
Chromium (Cr)	0.703

Source: The Norwegian Pollution Control Authority and calculations at Statistics Norway.

4.2.5.5. Uncertainties

Activity data
The activity data is assumed to be of good quality since this is production rates reported from each plant to the Norwegian Pollution Control Authority.

Emission factors
Several conditions influence the emission of heavy metals as production rates and raw materials, and these factors can vary from one plant to another. To derive an emission factor based on one plant's reported emission figures and production volume and use these factors to estimate emissions at other plants are therefore quite uncertain.

4.2.5.6. Completeness
Major missing emission components are not likely.

4.2.5.7. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

4.2.6. Glass and glass fibre production
IPCC -
NFR 2A7iii
Last update: 01.09.05

4.2.6.1. Description
Four plants producing glass or glass fibre are included in the emission inventory, based on emission reports to the Norwegian Pollution Control Authority. A fifth plant also reports emissions of particles to the Norwegian Pollution Control Authority but these emissions are very small and are therefore not included in the inventory. PAH and dioxin emissions are neither calculated nor measured, however, glass production might be a dioxin source (see completeness section 4.2.6.4).

4.2.6.2. Method
NH_3
The two glass fibre producing plants annually report emission figures for NH_3 to the Norwegian Pollution Control Authority (SFT). The emission figures are based on measurements.

Particles
The two plants producing glass fibre have reported emission figures since 1990 to the Norwegian Pollution Control Authority. The one glass-producer with particle emissions has reported since 1995. Emission figures from 1990 to 1994 were therefore assumed to be the same as reported figures in 1995. This plant was however closed down in 1999.

TNO (2002) suggests using a particle size distribution of the emissions where $PM_{2.5}$ is 80 per cent of TSP and PM_{10} is 90 per cent of TSP and this size distribution is used in the Norwegian inventory.

Heavy metals and POPs
Emission of lead has been reported from two glass-producers to the Norwegian Pollution Control Authority. One of them was closed down in 1999. The emission of lead is due to the lead content in the raw material used. Emission of arsenic was reported only in the early nineties when one of the plants used raw material containing arsenic. Emissions of other heavy metals are not reported, so we assume there are not significant emissions.

4.2.6.3. Uncertainties
For the years where reported emission figures for particles do not exist, Statistics Norway has assumed that emissions are in the same order as the first year of reporting. This is uncertain and only an estimate, since it does not consider annual changes in raw materials, production rates, nor possible cleaning devices.

4.2.6.4. Completeness
Production of glass can be a source for dioxin emissions, but no reported figures are available. Emission factors are found in literature, but since activity data (production rate) is not available and it is assumed that the emission factor is dependent on type of glass produced, emissions are not calculated.

Emissions of particles are also reported from three other glass-producers in Norway, but annual emissions are so low (less than 1 tonne) so they are not included in the inventory.

4.2.6.5. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

4.2.7. Ore mines
IPCC -
NFR 2A7i
Last update: 01.09.05

4.2.7.1. Description
Three ore mines are included in the Norwegian Inventory but one of the mines was closed down in 1996. Emission figures of SO_2, particles and dioxin are included. The treatment of ore generates emissions of SO_2, and particles are also emitted. Dioxin emissions are due to the thermal process during the pellet production. The ore mine, closed down in 1996, had large dioxin emissions due to the thermal process during the pellet production.

4.2.7.2. Method
SO_2
The ore mine, which was closed down in 1996, reported emission figures for SO_2 to the Norwegian Pollution Control Authority. None of the two other ore mines report any non-combustion SO_2 emissions.

Particles
All the three ore mines report emission figures for particles to the Norwegian Pollution Control Authority. Emissions for the two existing ore mines are reported from respectively 1994 and 1996 and it is assumed by Statistics Norway, in accordance with the Norwegian Pollution Control Authority, that emissions for previous years have been in the same order of size.

The Norwegian Pollution Control Authority assumes that the particles emitted from ore mining are larger than PM_{10}. The size distribution used in the Norwegian inventory is according to TNO (2002) (table 4.4).

Table 4.4. Particle size distribution for particles emitted from ore mining. Ratio X[1]/TSP

Component	Particle size distribution (ratio)
TSP	1
PM_{10}	0.49
$PM_{2.5}$	0.07

[1] X is either $PM_{2.5}$, PM_{10} or TSP.

Source: TNO (2002).

Dioxin
Emission figures were first reported to the Norwegian Pollution Control Authority in 1994 and emissions for previous year have been assumed by Statistics Norway, in accordance with the Norwegian Pollution Control Authority, to be in the same order as reported figure in 1994.

4.2.7.3. Uncertainties
For years where reported emission figures do not exist for particles and dioxins, Statistics Norway has assumed, in accordance with the Norwegian Pollution Control Authority, that the emissions are in the same order as the first year of reporting. This is uncertain and a result of lack of better data. The size of the particles emitted from ore mining will also depend on the type of ore and production process. The particle size distribution used in the inventory does not consider these differences.

4.2.7.4. Completeness
SO_2 emissions are only included in the inventory for the ore mine that was closed down in 1996. The SO_2 emissions from the two other ore mines are not included in the inventory.

4.2.7.5. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

4.2.8. Mining and extraction of stones and minerals

IPCC -
NFR 2A7i
Last update: 01.09.05

4.2.8.1. Description
Mining and extraction of stones and minerals are done by several plants. Particles are emitted during these processes.

4.2.8.2. Method
Particles
Emission figures are reported to the Norwegian Pollution Control Authority (SFT). Reported figures exist from 1992. Emission figures for 1990 and 1991 are assumed by Statistics Norway, in accordance with the Norwegian Pollution Control Authority, to be the same as reported figures in 1992. An exception is one plant, which only reported emissions for 1992. For this plant, Statistics Norway has calculated emissions based on production rates for previous and later years.

It is given for most plants that they use fabric filter or textile fibre to clean their particle emissions. It is assumed by the Norwegian Pollution Control Authority that the particles emitted are larger than PM_{10}. The Norwegian inventory uses the size distribution recommended by TNO (2002) (table 4.4).

4.2.8.3. Uncertainties
For years where reported emission figures do not exist, Statistics Norway has assumed that emissions are in the same order as the first year of reporting. This is uncertain and a result of lack of better data. The size of the particles emitted from mining and extraction will also depend on the type of stone/mineral and production process. The particle size distribution used in the inventory does not consider these differences.

4.2.8.4. Completeness
Emission of particles is often a source of heavy metal emissions since particles often contain heavy metals. Type of metals will however depend on the origin of the particles. Metals might therefore be emitted during mining and extraction of stones and minerals. There are however no data available for calculating emissions of heavy metals.

4.2.8.5. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

4.2.9. Production of mineral white (plaster)

IPCC -
NFR 2A7iii
Last update: 01.09.05

4.2.9.1. Description
Two plants producing mineral white in Norway are included in the inventory with their emissions of mercury and particles. The mercury content in the raw materials leads to emission of mercury, and during the production process, particles are emitted.

4.2.9.2. Method
Particles
Emission figures are reported to the Norwegian Pollution Control Authority. Reported emission figures exist since 1992 and figures for 1990 and 1991 are assumed by Statistics Norway, in accordance with the Norwegian Pollution Control Authority, to be the same as the figures reported in 1992. The particles are purified through a fabric filter, and it is assumed by the Norwegian Pollution Control Authority that the size of the particles emitted after the filter are smaller than PM_{10}.

According to TNO (2002), $PM_{2.5}$ is 30 per cent of TSP, while PM_{10} is assumed to be the same as TSP. The Norwegian inventory uses this distribution.

Heavy metals
The plants have reported emission figures to the Norwegian Pollution Control Authority since 2000. For one of the plants, historical emissions are based on reported figure in 2000 and production volumes. For the other plant, emission figures for 1990-1999 are assumed to be the same as reported figure in 2000, due to lack of production data for previous years. Annual emission is assumed to be low.

4.2.9.3. Activity data
Production volumes for calculation of historical emissions of mercury for one of the plants are reported to the Norwegian Pollution Control Authority.

4.2.9.4. Emission factors
Emission factors for mercury are derived for historical calculations for one plant based on reported figure first year of reporting and production volumes.

4.2.9.5. Uncertainties
Historical emissions of mercury for both plants are uncertain. For one plant, the emission figures are based on a derived emission factor and production volumes and do not take into account changes in raw materials and possible cleaning devices. For the other plant, it is assumed, due to lack of historical production data, that the historical emissions are the same as reported figure in 2000. This is just an estimate and does not consider annual changes in raw materials, production rates, nor possible cleaning devices.

The particle size distribution used in the inventory is not specific for the plants. The particles emitted might therefore have another distribution than the one suggested by TNO and used in the inventory.

4.2.9.6. Completeness
Major missing emission components are not likely.

4.2.9.7. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

4.2.10. Construction and repairing of vessels - Sandblasting

IPCC -
NFR 2A7iii
Last update: 01.09.05

4.2.10.1. Description
Five plants constructing and repairing vessels are included in the inventory with their particle emissions. One of the plants was closed down in 2000. Emission of particles is due to the different processes during construction and repairing of vessels, but most of the particles are emitted from sandblasting.

4.2.10.2. Method
Particles
Emission figures are reported to the Norwegian Pollution Control Authority.

For four of the five plants, there are no information regarding cleaning device, but it is assumed by the Norwegian Pollution Control Authority that they have fabric filter and/or wet washer. For the last one, particle emissions are purified in cyclones, and the size of the particles emitted is larger than PM_{10}.

It is difficult to decide particle size of the particles emitted based on the above information. It is however assumed by the Norwegian Pollution Control Authority that most of the particles are larger than PM_{10} and therefore all particles are assumed to be TSP.

4.2.10.3. Uncertainties
The size of the particles emitted is uncertain and will depend on the cleaning device used at each plant. The different activities during construction and repairing can also result in emission of particles of different sizes.

4.2.10.4. Completeness
Emission of particles is often a source of heavy metal emissions since particles often contain heavy metals. Type of metals will however depend on the origin of the particles. Metals might therefore be emitted during sandblasting and repairing/construction of vessels. There are however no data available for calculating emissions of heavy metals.

4.2.10.5. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

4.2.11. Sandpit and rock-crushing plant

IPCC -
NFR 2A7iii
Last update: 01.09.05

4.2.11.1. Method
Particles will be emitted during crushing of rocks and at sandpits. In the inventory, emissions are estimated based on the production of sand- and crushed stone from the production statistics at Statistics Norway, and emissions factors recommended by Fontelle (2002).

4.2.11.2. Activity data
The production of sand and crushed stone is annually given by the production statistics (PRODCOM) at

Statistics Norway and includes PRODCOM code 14.21.11 and 14.21.12.

4.2.11.3. Emission factors
The emission factors used are based on Fontelle (2002) (table 4.5).

Table 4.5. Particle emission factors for sandpits and rock-crushing plants. Ratio X[1]/TSP

Component	g/tonne produced
TSP	160
PM_{10}	60
$PM_{2.5}$	0

[1] X is either $PM_{2.5}$, PM_{10} or TSP.
Source: Fontelle (2002).

4.2.11.4. Uncertainties
This emission source is highly uncertain since the emissions will vary from one place to another depending on the different processes in use, type of raw materials and of course the activity level. Little information is available in the literature. The emission factors used are only based on one source and are uncertain. In addition, there is uncertainty regarding the activity data. The PRODCOM codes used include total production of sand and crushed stone in Norway, but some of it might not be relevant for these calculations.

4.2.11.5. Completeness
Emission of particles is often a source of heavy metal emissions since particles often contain heavy metals. Type of metals will however depend on the origin of the particles. Metals might therefore be emitted during crushing at sandpits and rock-crushing plants. There are however no data available for calculating emission of heavy metals.

4.2.11.6. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

4.2.12. Construction and building

IPCC -
NFR 2A7ii
Last update: 01.09.05

4.2.12.1. Description
Construction and building includes a lot of different activities that will generate particle emissions.

4.2.12.2. Method
Particles
Emission factors and activity data are used to estimate the Norwegian emissions.

4.2.12.3. Emission factors
The emission factors used are based on an evaluation the French institute CITEPA made of different emission factors from this source and their calculation of average emission factors for TSP, PM_{10} and $PM_{2.5}$ (table 4.6).

Table 4.6. Particle emission factors for building and construction. Tonne/hectare/year

Component	Tonne/hectare/year
TSP	9.79
PM_{10}	1.52
$PM_{2.5}$	0.52

Source: Fontelle (2002).

4.2.12.4. Activity data
The activity data used is the annual area of completed buildings from the building statistics at Statistics Norway.

4.2.12.5. Uncertainties
The particle emissions depend on climate conditions as well as building traditions and building materials. Since the emission factors used are based on surveys in other countries than Norway, these factors might not be ideal for Norwegian conditions.

4.2.12.6. Completeness
Building of roads, railways, tunnels and demolition of buildings is also a source of particle emissions, but no emission factors are found in the literature, and therefore not included in the inventory.

4.2.12.7. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

4.2.13. Leather preparing

IPCC -
NFR 2A7iii
Last update: 01.09.05

4.2.13.1. Method
NH_3
NH_3 is used to adjust the pH level in the fattening and colouring process. This means that NH_3 is dissolved in an aqueous solution to feed fatty substances to leather. One plant reports emission figures for NH_3 to the Norwegian Pollution Control Authority. Emission figures are available from 1994. Emissions for the years 1990-1993 are assumed by Statistics Norway and the Norwegian Pollution Control Authority to be the same as reported figure in 1994. The emission of NH_3 reported by the plant is equal to the consumption of NH_3.

Table 4.7. Chemical industry. Components emitted and included in the Norwegian inventory

	CO_2	CO	N_2O	NO_x	CH_4	NMVOC	SO_2	NH_3	PM	HM	POP
Production of:											
Ammonia	R	NA	NA	IE[1]	NA	NA	NA	NA	NA	NA	NA
Nitric acid	NA	NA	R	R	NA	NA	NA	R	R	NA	NA
Other fertilizers	NA	NA	NA	R	NA	NA	NA	R	NA	NA	NA
Silicon carbide	R+E	E	NA	NA	E	NA	R	NA	R	R	R
Calcium carbide	R	NA	NA	R	NA	R	NA	NA	R	R	NA
Methanol	E	NA	NA	NA	R	R	NA	NA	NA	NA	NA
Titanium dioxide	NA	NA	NA	NA	NA	NA	R	NA	R	R	NA
Sulphuric acid	NA	NA	NA	NA	NA	NA	R	NA	NA	NA	NA
Plastic	R+E	NA	NA	NA	R	R	NA	R	R	NA	R
Explosives	NA	NA	NA	R	NA	NA	NA	NA	NA	NA	NA
Chloralkali	NA	NA	NA	NA	NA	NA	NA	NA	NA	R	NA
Pigments	NA	NA	NA	NA	NA	NA	NA	NA	NA	R	NA
Soap	NA	NA	NA	NA	NA	NA	NA	NA	R	NA	NA
Paint and varnish	NA	NA	NA	NA	NA	NA	NA	NA	R	NA	NA

E = Figures estimated by Statistics Norway.

R = Figures reported by the plant to the Norwegian Pollution Control Authority.

NA = Not Applicable.

IE = Included Elsewhere.

[1] Included in reported figures for nitric acid and other fertilizers.

4.2.13.2. Uncertainties
It is not clear if it is correct to assume that all NH_3 consumed is emitted to air. This assumption has to be revised.

4.2.13.3. Completeness
Major missing emission components are not likely.

4.2.13.4. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

4.3. Chemical Industry

IPCC 2B
NFR 2B
Last update: 01.09.05

In the Norwegian emission inventory, there are 14 different activities included under chemical industry. Most of the emission figures are reported from the plant to the Norwegian Pollution Control Authority. Only CO and CH_4 emissions from silicon carbide are estimated figures calculated by Statistics Norway. Production of carbides causes emission of many components, but most of the other activities within the sector chemical industry cause only emissions of one or two components (table 4.7).

4.3.1. Production of fertilizers

4.3.1.1. Ammonia Production
IPCC 2B1
NFR -
Last update: 01.09.05

4.3.1.1.1. Description
In Norway, ammonia is produced by catalytic steam reforming of wet fuel gas (containing ethane, propane and some buthane). This is one of the steps during fertilizer production. Hydrogen is needed to produce ammonia, and wet fuel gas is the basis for the production of hydrogen.

4.3.1.1.2. Method
CO_2
The CO_2 emission figures in the Norwegian emission model are based on emission reports from the plants. The plant calculates the emissions by multiplying the amount of each gas used with a gas specific emission factor. The plant has reported consistent figures back to 1990. A part of the CO_2, which is generated during the production process, is captured and sold to other objectives (soft drinks etc.), and therefore deducted from the emission figures for this source and reported in IPCC sector 2D2, as described in section 4.5.2.2. Some of the captured CO_2 is exported to other countries. These emissions are not included in the Norwegian emission inventory, but are the responsibility of the importer country.

NO_X
During the production of ammonia there are some non-combustion emission of NO_X. These emission figures are included in the reported NO_X emission from nitric acid production and production of other fertilizers.

4.3.1.1.3. Emission factors
CO_2
The plant emission factors used in the calculations of emissions are based on carbon content in the gases consumed.

4.3.1.1.4. Uncertainties
There are believed to be limited uncertainties in the figures reported by the plant. Uncertainty estimates are given in Appendix D.

4.3.1.1.5. Completeness
Major missing emission components are not likely.
4.3.1.1.6. Source specific QA/QC
The plants annually report the total amount of gas consumed to Statistics Norway. The emission figures reported from the plant are compared to calculations done by Statistics Norway based on total amount of gas consumed and an emission factor of 3 tonnes CO_2/tonne LPG recommended by IPCC (1997b). The calculated emission figures agree quite well with emission figures reported by the plant.

4.3.1.2. Production of nitric acid
IPCC 2B2
NFR 2B2
Last update: 01.09.05

4.3.1.2.1. Description
There are two plants where nitric acid is produced in Norway. Nitric acid is used as a raw material in the manufacture of nitrogenous-based fertilizer. The production of nitric acid (HNO_3) generates nitrous oxide (N_2O) and NO_x as by products of high temperature catalytic oxidation of ammonia (NH_3). The production of nitrogenous-based fertilizer also leads to emissions of particles.

4.3.1.2.2. Method
NO_2 and NO_x
The two plants report the emissions of N_2O and NO_X to the Norwegian Pollution Control Authority. At one plant, the emissions are measured continuously, whereas at the other the figures are calculated from monthly measurements.

NH_3
Emission figures for NH_3 are annually reported to the Norwegian Pollution Control Authority.

Particles
Both plants report emission figures to the Norwegian Pollution Control Authority and have done so since 1990 and 1992. One of the plants has also reported emissions from combustion, but since it is only 1 per cent of the non-combustion emissions, these figures are included together with the non-combustion emissions. For this plant, there is no information regarding cleaning devices and size of the particles emitted, but the Norwegian Pollution Control Authority assumes the particles are smaller than PM_{10}. For the other plant, a fabric filter was installed in the beginning of the 1990s.

In lack of plant specific information regarding particle size distribution of the emitted particles, Statistics Norway uses the distribution given by TNO (2002) for production of nitrogenous-based fertilizers where PM_{10} is 0.8*TSP and $PM_{2.5}$ is 0.6*TSP.

4.3.1.2.3. Uncertainties
Uncertainty estimates for greenhouse gases and long-range transboundary air pollutants are given in Appendix D.

There is uncertainty regarding the size of the particles emitted since there is no plant specific information available. The distribution recommended by TNO is used in lack of other data.

4.3.1.2.4. Completeness
Major missing emission components are not likely.

4.3.1.2.5. Source specific QA/QC
The plants report the production of HNO_3 to the Norwegian Pollution Control Authority. They compare the trends in the production data with the trend in N_2O emission and use this as a quality check.

There is no other source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

4.3.1.3. Other fertilizers
IPCC -
NFR 2B2
Last update: 01.09.05

4.3.1.3.1. Description
One plant produces calcium nitrate and fertilizers.

4.3.1.3.2. Method
NO_X and NH_3
Emission figures for NO_X and NH_3 from the plant are reported to the Norwegian Pollution Control Authority.

4.3.1.3.3. Uncertainties
No source specific uncertainty is known.

4.3.1.3.4. Completeness
Major missing emission components are not likely.

4.3.1.3.5. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

4.3.2. Carbide production
IPCC 2B4
NFR 2B4
Last update: 01.09.05

4.3.2.1. Description
Silicon carbide is produced at three plants and calcium carbide at one plant. The calcium carbide plant was closed down in 2003.

4.3.2.2. Silicon carbide
4.3.2.2.1. Description
Silicon carbide (SiC) is produced by reduction of quartz (SiO_2) with petrol coke as a reducing agent.

(11) $SiO_2 + 3C \rightarrow SiC + 2CO$

$CO \xrightarrow{O_2} CO_2$

In the production of silicon carbide, CO_2 and CO are released as by-products from the reaction between quartz and carbon. CH_4 may be emitted from petrol coke during parts of the process, and sulphur originates from the petrol coke. Particles are also emitted during the production process as well as heavy metals and PAH.

4.3.2.2.2. Method
CO_2
Emission figures are reported to the Norwegian Pollution Control Authority by the plants. The CO_2 emissions are estimated from the consumption of petrol coke in dry weight multiplied with an emission factor for one plant. For the other two plants emissions are estimated by multiplying the amount of silicon carbide produced with an emission factor. Indirect emissions of CO_2 are calculated based on the emission of CH_4, see Chapter 1.9.

CH_4
The IPCC default method is used for the calculations. Emissions are calculated by Statistics Norway using a default emission factor recommended by IPCC (1997b) and consumption of petrol coke.

CO
The emissions of CO are calculated by Statistics Norway from the consumption of petrol coke and an emission factor in accordance with the IPCC Guidelines (IPCC 1997b).

SO_2
Emission figures are reported to the Norwegian Pollution Control Authority by the plants. The emissions are calculated from the consumption of petrol coke in dry weight and the sulphur content in the coke. It is assumed that 3 per cent of the sulphur is left in the product or as wastage.

Particles
Emission figures for particles are reported to the Norwegian Pollution Control Authority. Two of the plants have reported since 1990 while the third has reported since 1991. Emission figures for 1990 for this plant are assumed by Statistics Norway and the Norwegian Pollution Control Authority to be the same as reported figure for 1991. For one of the plants, reported figures have not been used in the inventory for 1990-1993, since the plant means these emission figures are not representative, but a result of different measurement- and calculation methods. For this plant, reported emission figures for 1994 have been used for 1990-1993.

There is no detailed information about the particle size distribution for the emissions from silicon carbide production. The Norwegian Pollution Control Authority assumes the emissions are in the same order as emission of particles from production of ferroalloys, where all particles are expected to be smaller than $PM_{2.5}$. This is however an uncertain estimate. This leads to a distribution where $TSP=PM_{10}=PM_{2.5}$.

Heavy metals
Emission figures are reported to the Norwegian Pollution Control Authority since 1999/2000. For Pb, Hg and Cd, historical emissions are based on emission factors derived from reported figures first year of reporting and production rate that year. Using these emission factors for each plant together with production rate for previous years, historical emissions have been calculated. The calculations for Pb and Cd have been corrected for dust regulations, while emissions of mercury are not affected by these regulations.

Historical emissions of Cu, Cr and As are based on dust emissions for each plant. This has been recommended by the Norwegian Pollution Control Authority, since historical production rate data lack for some years and because changes in emissions will be easier to find when installation of dust control systems reduces the emissions of these metals.

Emission figures for Cu, Cr and Pb are annually reported for all the three plants. In 1999, the plants also reported Hg and Cd due to a heavy metal investigation under the leadership of the Norwegian Pollution Control Authority. After 1999, the plants have not been irequired to report these metals due to low emissions. However, instead of excluding the emissions of these metals from the plants from the inventory, reported figures for 1999 are used for coming years until better data exist.

POPs
Emission figures for PAH are reported from the plants to the Norwegian Pollution Control Authority. Two of the plants have reported emissions since 1991, while the third one has only reported the latest years. Historical emissions back to 1990 are then calculated based on production rate and an emission factor derived from the first year of reporting and production rate that year. No PAH profile is available for this source, so lacking of other information, the same profile as that of aluminium production is used (table 4.8). No emissions of dioxin are reported nor calculated.

Table 4.8- Distribution of PAH emission from silicon carbide production. Ratio X[1]/TSP

Component	Distribution of PAH emissions (ratio)
PAH (Norwegian standard)	1
PAH-6 (OSPAR)	0.3
PAH-4 (CLRTAP)	0.15

[1] X is either $PM_{2.5}$, PM_{10} or TSP.

Source: Finstad et al. (2001).

4.3.2.2.3. Activity data

The activity data used by the plants for the calculation of CO_2 and SO_2 emissions is the consumption of petrol coke in dry weight and the amount of silicon carbide produced. The activity data used by Statistics Norway for the calculation of CH_4 and CO emissions is the consumption of petrol coke as reported to Statistics Norway. Historical calculations of particle emissions are based on annually production rate and dust emission figures reported to the Norwegian Pollution Control Authority.

4.3.2.2.4. Emission factors

CO_2

Two plants use the emission factor 2.56 tonne CO_2 per tonne. The third plant's emission factor is in average for the period 1992-2004 2.88 tonne CO_2 per tonne produced silicon carbide.

CH_4

For calculation of methane emissions, the emission factor 10 kg/tonne petrol coke is used (IPCC 1997b).

CO

CO emissions are calculated from the consumption of petrol coke, using a factor of 0.4 tonnes CO/tonnes petrol coke, as recommended by Rosland (1987).

4.3.2.2.5. Uncertainties

Uncertainty estimates for greenhouse gases and long-range transboundary air pollutants are given in Appendix D.

CO_2 and CH_4

The estimate of the total yearly emissions of particularly CO_2 is considered to be of high quality. There is however, uncertainty connected to both activity data and the emission factors used in the calculations. The consumption of petrol coke that the plants report to Statistics Norway is not corrected for the water content.

Heavy metals

The historical calculations for heavy metals are based on a derived emission factor for each plant and either production- or dust data for previous years and can only be seen as estimates. The emission figures reported also vary from one year to another, and this is assumed to be, in addition to differences in raw materials, a result of few and uncertain measurements. For the two plants that have not reported emission figures for Hg and Cd since 1999, the same emission figures as those reported in 1999 are used for later years. This is also highly uncertain, but the emission figures are very small and have only marginal impact on the total emissions of these metals.

Particles

The particle size distribution used is not specific for production of silicon carbide, but used due to lack of specific size distribution data for this source. The particle size distribution can therefore only be seen as an estimate. For the years where reported emission figures do not exist, Statistics Norway has assumed that emissions are in the same order as the first year of reporting. This is uncertain and a result of lack of better data.

4.3.2.2.6. Completeness

Major missing emission components are not likely.

4.3.2.2.7. Source spesific QA/QC

The quality of the reported figures of CO_2 is controlled by Statistics Norway and the Norwegian Pollution Control Authority. Statistics Norway calculates the emissions from the consumption of petrol coke reported by the plant to Statistics Norway and the emission factor of 2.51 tonnes CO_2/tonne petrol coke (SINTEF 1998e). The comparison shows accordance between the reported data and Statistics Norway's estimates.

4.3.2.3. Production of calcium carbide

4.3.2.3.1. Description

One plant in Norway was producing calcium carbide until 2003. The production of calcium carbide generates CO_2 emissions when limestone is heated and when petrol coke is used as a reducing agent.

The reaction

(12) $CaCO_3 \rightarrow CaO + CO_2$

which takes place when limestone (calcium carbonate) is heated.

The reactions

(13) $CaO + C\ (petrol\ coke) \rightarrow CaC_2 + CO$

(14) $CO \xrightarrow{O_2} CO_2$

where petrol coke is used as a reducing agent to reduce the CaO to calcium carbide.

Some of the carbon from petrol coke will be sequestered in the product, but not permanently. Thus, this carbon is included in the emission estimate. NMVOC originate from the use of petrol coke in the production process, and NO_x is mainly produced during the high temperature oxidation of nitrogen in the air. Particles are also emitted during the production process. Emission of heavy metals is a result of the heavy metal content in the raw materials.

4.3.2.3.2. Method
CO_2
The figures in the National emission inventory are based on emission figures reported from the plant to the Norwegian Pollution Control Authority. The emission estimates are based on the amount of calcium carbide produced each year and an emission factor estimated by SINTEF (1998e).

NO_x
Emission figures for NO_x are annually reported to the Norwegian Pollution Control Authority. The reported values are based on calculations.

NMVOC
Reported figures are annually reported to the Norwegian Pollution Control Authority based on calculations.

Particles
Emission figures for particles are reported since 1992. Figures for 1990 and 1991 are assumed to be the same as for 1992. It does not exist any detailed information about the particle size distribution of the emissions from calcium carbide production. The Norwegian Pollution Control Authority assumes that the emissions are in the same order as emission of particles from production of ferro-alloys, where all particles are expected to be smaller than $PM_{2.5}$. This is however an uncertain estimate. A particle size distribution where PM_{10} and $PM_{2.5}$ is expected to be the same as TSP, is used in the Norwegian Inventory.

Heavy metals and POPs
Emission figures for heavy metals have been reported to the Norwegian Pollution Control Authority since 1999. Historical emissions are calculated based on production rate for Pb, Cd and Hg, and based on particle emissions for As, Cu and Cr (see section 4.3.2.3.3).

No emissions of PAH or dioxin are available.

4.3.2.3.3. Activity data
Particle emissions used in the calculations of As, Cu and Cr have been reported to the Norwegian Pollution Control Authority.

4.3.2.3.4. Emission factors
The emission factor used by the plants in the calculation of CO_2 has been estimated by SINTEF (1998e) to be 1.71 tonnes/ tonne. The default IPCC factor is 1.8 tonnes/tonne. SINTEF (1998e) concludes that the one reason for the difference between the factors is that the IPCC assumes that all calcium carbonate is calcinated.

4.3.2.3.5. Uncertainties
Uncertainty estimates for greenhouse gases and long-range transboundary air pollutants are given in Appendix D.

Heavy metals
Historical emissions are based on a derived emission factor for the first year of reporting in 1999 and calculated with production/particle emission figures for previous years. This is uncertain and only an estimate in lack of other data.

Particles
The particle size distribution used is not specific for production of silicon carbide, but used due to lack of specific size distribution data for this source. The particle size distribution can therefore only be seen as an estimate. For the years where reported emission figures do not exist, Statistics Norway has assumed that emissions are in the same order as the first year of reporting. This is uncertain and a result of lack of better data.

4.3.2.3.6. Completeness
Major missing emission components are not likely.

4.3.2.3.7. Source specific QA/QC
For CO_2, the data reported from the companies has been compared to calculations done by Statistics Norway. The amount of calcium carbide produced has been reported by the plant to Statistics Norway, and was multiplied with the emission factor 1.71 tonnes/ tonne (SINTEF 1998e). There is no other source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

4.3.3. Manufacture of other inorganic chemicals

IPCC 2B5
NFR 2B5
Last update: 01.09.05

4.3.3.1. Production of methanol
4.3.3.1.1. Description
One plant in Norway produces methanol. Natural gas and oxygen are used in the production of methanol. The conversion from the raw materials to methanol is done in various steps and on different locations at the plant. CH_4 and NMVOC are emitted during the production process. Indirect emission of CO_2 are calculated based on the emission of CH_4 and NMVOC, see Chapter 1.9.

4.3.3.1.2. Method
The plant reports emission figures for CH_4 and NMVOC to the Norwegian Pollution Control Authority. The reported emissions are based on measurements.

4.3.3.1.3. Uncertainties
No source specific uncertainty is known.

4.3.3.1.4. Completeness
Major missing emission components are not likely.

4.3.3.1.5. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

4.3.3.2. Production of titanium dioxide
4.3.3.2.1. Description
One plant in Norway produces titanium dioxide. The ore is chrushed and pulverized in mills. The chrushed raw material is separated in various steps. Ilmenite and the by-product magnetite are cleaned during acid treatment and flotation. The ilmenite concentrate is drained and the water content are reduced to approximately 3.5 per cent. Emissions of SO_2, heavy metals and particles from the plant are included in the inventory. The particle emissons are a result of the chrushing of the ore in the mills and from the annealing furnace, while the heavy metal emissions are due to the metal content in the raw material used.

4.3.3.2.2. Method
SO_2
The emission figures for SO_2 are based on calculations and are reported annually to the Norwegian Pollution Control Authority.

Particles
Since 1990 emissions of particles have been reported annually to the Norwegian Pollution Control Authority. The particles are assumed to be of size less than $PM_{2.5}$.

Heavy metals
Emissions figures for Pb, Cd and Hg have been reported from 1990 to 1999. After 1999, there has not been any reporting, as a result of very small emission figures. No emissions of persistent organic pollutants are reported nor calculated.

4.3.3.2.3. Uncertainties
No source specific uncertainty is known.

4.3.3.2.4. Completeness
Major missing emission components are not likely.

4.3.3.2.5. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

4.3.3.3. Production of sulphuric acid
4.3.3.3.1. Description
Three plants in Norway produce sulphuric acid. The production of sulphuric acid leads to emissions of SO_2. All the three plants report the emissions from the production to the Norwegian Pollution Control Authority, but only one plant have specified that the emissions come from the production of sulphuric acid. For the two other plants, the emissions have been included in the reported emissions from the plants' main production (production of nickel and zinc respectively).

4.3.3.3.2. Method
The plant reports annually emission figures for SO_2 to the Norwegian Pollution Control Authority. The reported figures are based on measurements.

4.3.3.3.3. Uncertainties
No source specific uncertainty is known.

4.3.3.3.4. Completeness
Major missing emission components are not likely.

4.3.3.3.5. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

4.3.3.4. Production of plastic
4.3.3.4.1. Description
Until 2000 two plants in this source category reported emissions to Norwegian Pollution Control Authority when one one of them was demerged to two separate companies. Today three plants report emissions under this source category. One of the plants produces ethylene, one propylene and polyethylen and the third plant has vinyl chloride production. Various components are emitted during the production of plastic.

CH_4 and NMVOC emissions are from leakages in the process. Direct CO_2 emission is from combustion and is reported in Chapter 3 Energy.

During the production process of ethylene and vinyl chloride there is an oxide chloride step for production of ethylene chloride, followed by cracking to vinyl chloride monomer and hydrochloric acid. Various chloride components are produced during these processes, including dioxin. However, most of the dioxin ends up in the EDC-tar, which is combusted in an own chloride recycling installation. Particles (PVC-dust) are also emitted during the production of vinyl chloride.

4.3.3.4.2. Method
CO_2
Indirect emission of CO_2 are calculated based on the emission of CH_4 and NMVOC, see Chapter 1.9.

CH_4 , NH_3 and NMVOC
Emission figures are annually reported to the Norwegian Pollution Control Authority. CH_4 and NMVOC emissions reported are based on measurements.

Particles
Emission figures have been reported to the Norwegian Pollution Control Authority since 1992. Emission figures for 1991 and 1990 are assumed to be the same as reported figures in 1992. The particle emissions have decreased since 1996 as a result of installation of cleaning devices. The emissions are purified in cyclones, but there is no available information regarding particle size. In lack of plant specific information, the distribution TSP=PM10=PM2,5, as in TNO (2002), is used in the calculation.

Dioxin
The plant producing vinyl chloride reports dioxin emission figures. Figures are reported since 1990 except for 1992 and 1994. Emission figures for 1992 and 1994 are based on the reported data for 1991 and 1993.

4.3.3.4.3. Uncertainties
It is difficult to measure leakages of CH_4 and NMVOC and therefore the uncertainty is regarded as being high.

The particle size distribution used is not specific for the plant, and the particles emitted might therefore have another distribution than the one suggested from TNO.

4.3.3.4.4. Completeness
Major missing emission components are not likely.

4.3.3.4.5. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

4.3.3.5. Production of explosives
4.3.3.5.1. Description
There has been one plant in Norway producing explosives, but the plant was closed down in 2001. Nitric acid was used as a raw material in the manufacture of explosives, and during the production of nitric acid, NO_x was emitted.

4.3.3.5.2. Method
NO_x
Emission figures were annually reported to the Norwegian Pollution Control Authority, and the figures were based on calculations.

4.3.3.5.3. Uncertainties
No source specific uncertainty is known.

4.3.3.5.4. Completeness
Particles
Reported emission figures to the Norwegian Pollution Control Authority exist only for 1997-1999. Annual emissions have been so low that they have not been included in the Norwegian inventory.

4.3.3.5.5. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

4.3.3.6. Chloralkali production
4.3.3.6.1. Description
One plant in Norway produces chloralkali. Before 1997, mercury was used in the chloralkali production and emitted during the process. In 1997, the plant changed their production process and stopped using mercury, but still there are some mercury emissions.

4.3.3.6.2. Method
Hg
Emission figures are reported to the Norwegian Pollution Control Authority.

4.3.3.6.3. Uncertainties
No source specific uncertainty is known.

4.3.3.6.4. Completeness
Major missing emission components are not likely.

4.3.3.6.5. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

4.3.3.7. Production of pigments
4.3.3.7.1. Description
Two plants are included in the inventory. One plant produces copper oxide for bottom paint and emits copper to air during the production process. Also minor amounts of arsenic and chromium are emitted. The other plant produces zinc chromate, and chromium is emitted.

4.3.3.7.2. Method
Emission figures are reported to the Norwegian Pollution Control Authority.

4.3.3.7.3. Uncertainties
Reported emission figures for 1990 and 1991 for the plant producing zinc chromate are not occurring. In the inventory, the same figure as reported for 1992 is used for 1990 and 1991.

4.3.3.7.4. Completeness
Major missing emission components are not likely.

4.3.3.7.5. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

4.3.3.8. Production of soap
4.3.3.8.1. Method
Two plants producing soap have reported emission figures for particles to the Norwegian Pollution Control Authority. One of the plants has only reported for 1990 and 1991. The plant has after 1991 had a temporary permission without reporting requirements and is therefore not included after 1991 due to lack of data. The other plant reported figures for 1992-1994. Emissions for 1990 and 1991 are assumed to be the same as reported figure in 1992, while emissions for 1995-1997 are assumed to be the same as reported figure in 1994. Annual emission figures are low.

The particles have been purified through filters and scrubbers and the Norwegian Pollution Control Authority assumes the sizes of the particles are smaller than $PM_{2.5}$.

4.3.3.8.2. Uncertainties
For the years where reported emission figures do not exist, Statistics Norway has assumed that emissions are in the same order as reported in one of the other years. This is uncertain and a result of lack of better data.

4.3.3.8.3. Completeness
Major missing emission components are not likely.

4.3.3.8.4. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

4.3.3.9. Paint and varnish production
4.3.3.9.1. Method
One plant producing paint has reported emission figures for particles to the Norwegian Pollution Control Authority since 1995, after first getting an emission permit in 1994. Annual emissions are small. It is assumed by the Norwegian Pollution Control Authority that the particles emitted are smaller than $PM_{2.5}$.

4.3.3.9.2. Uncertainties
No source specific uncertainty is known.

4.3.3.9.3. Completeness
Major missing emission components are not likely.

4.3.3.9.4. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure QA/QC procedure

4.4. Metal production
IPCC 2C
NFR 2C
Last update: 01.09.05

Metal production in Norway includes plants producing iron and steel, ferroalloys, aluminium, magnesium, nickel and zinc. Production of anodes is also included in this chapter. As shown in table 4.9, most of the figures in the national inventory are from the plant's annually report to the Norwegian Pollution Control Authority.

4.4.1. Production of iron and steel
IPCC 2C1
NFR 2C1
Last update: 01.09.05

4.4.1.1. Description
Three plants producing iron and steel are included in the Norwegian Inventory, but two of these only report emission figures for particles. In Norway, iron is produced from ilmenite, and coal is used as a reducing agent. Various components are emitted during the production process. Non-combustion emissions of CO_2 from an iron/steel production are primary from coal used as a reducing agent. SO_2 originates from the sulphur in the reducing agent used, while NO_x is produced primarily by the high temperature oxidation of nitrogen in the air. Heavy metal emissions are due to the metallurgical melting process and the content of heavy metals in the raw materials used. Particles are also emitted during the process.

Table 4.9. Metal production. Components emitted and included in the Norwegian inventory

	CO_2	CH_4	PFCs	SF_6	SO_2	NO_X	NH_3	NMVOC	CO	PM	HM	POP
Production of:												
Iron and steel	R	NA	NA	NA	R	R	NA	NA	NA	R	R	R
Ferroalloys	R	R	NA	NA	R	R	NA	E	NA	R	R	R
Primary aluminium	R	NA	R	R	R	E	NA	NA	NA	R	R	R/E
Secondary aluminium	NA	NA	NA	R	NA	NA	R	NA	NA	R	R	R
Magnesium	E	NA	NA	R	R	NA	NA	NA	R	R	R	R
Nickel	R	NA	NA	NA	R	R	R	NA	NA	R	R	NA
Zinc	NA	NA	NA	NA	R	NA	NA	NA	NA	R	R	NA
Anodes	R	NA	NA	NA	R	R	NA	NA	NA	R	R	R

E = Figures estimated by Statistics Norway.

R = Figures reported by the plant to the Norwegian Pollution Control Authority.

NA = Not Applicable.

4.4.1.2. Method

CO_2

In the Norwegian Inventory, emission figures for CO_2, annually reported to the Norwegian Pollution Control Authority, are used.

The emissions are calculated from the consumption of coal in dry weight and the content of carbon in the coal. The content of carbon in coal consumed is based on analyses of the carbon in each load of coal delivered to the plant. Four per cent of the carbon in the coal is assumed to be bound in the iron.

SO_2

SO_2 emissions are based on measurements and reported to the Norwegian Control Authority.

NO_x

NO_x emissions are estimated and reported to the Norwegian Control Authority.

Particles

Two of the plants have reported figures since 1990 while the third one has only reported since 1998. For this plant, historical emissions in the period 1990-1997 have been assumed to be the same as reported figure in 1998, since production rate data for previous years are not available.

The Norwegian Pollution Control Authority assumes that the particles emitted in the production of iron and steel are smaller than $PM_{2.5}$. We can however not disregard that some of the particles emitted are larger than $PM_{2.5}$.

Heavy metals and POPs

Two plants report emission figures to the Norwegian Control Authority. Reported figures for heavy metals (Pb, Cd, Cr, Cu, As and Hg) exist from 1990, 1992 or later, depending on type of heavy metal. For dioxins and PAH, reported figures have only been available from 1997 and 1999. In lack of production rate data for previous years, it has been assumed that yearly emissions are the same as in the first year of reporting.

4.4.1.3. Uncertainties

Uncertainty estimates for greenhouse gases and long-range transboundary air pollutants are given in Appendix D.

Heavy metals and POPs

Reported emission figures vary from one year to another, due to different raw materials, but mainly as a result of uncertain measurements. The reported figures are based on a limited number of measurements, and the emissions will vary from minute to minute, since the production of iron and steel is a non-continuous process. For the years where reported emission figures do not exist, Statistics Norway has assumed that emissions are in the same order as the first year of reporting. This is uncertain and a result of lack of better data.

Particles

The particle size distribution used is only an assumption, and we can not preclude that the distribution is different from the one used in the inventory. For the years where reported emission figures do not exist, Statistics Norway has assumed that emissions are in the same order as the first year of reporting. This is uncertain and only an estimate and a result of lack of better data.

4.4.1.4. Source specific QA/QC

CO_2 emission figures reported to the Norwegian Pollution Control Authority are compared with calculations at Statistics Norway using the amount of reducing agent and emission factors. This method is recommended by IPCC when data from measurements are not available.

Annually reported emission figures are first controlled by the Norwegian Pollution Control Authority and then by Statistics Norway.

Adjustments and recalculations have been done for years where reported emission figures seem to be unreasonably high or low compared with previous years. This is applicable when the variations in the reported emission figures do not have a natural explanation.

4.4.2. Production of ferroalloys

IPCC 2C2, Key category for CO_2
NFR 2C2
Last update: 01.09.05

4.4.2.1. Description

There were 14 plants producing ferroalloys in Norway in 2003. Ferrosilicon, silicon metal, ferromangan and siliconmangan are now produced in Norway. Ferrochromium was produced until summer in 2001. Ferrosilicon with 65 to 96 per cent Si and silicon metal with 98-99 per cent Si is produced. The raw material for silicon is quarts (SiO_2). SiO_2 is reduced to Si and CO using reducing agents like coal, coke and charcoal.

(15) $SiO_2 \rightarrow SiO \rightarrow Si + CO$

The waste gas CO and some SiO burns to form CO_2 and SiO_2 (silica dust).

In ferroalloy production, raw ore, carbon materials and slag forming materials are mixed and heated to high temperatures for reduction and smelting. The carbon materials used are coal, coke and some biocarbon (charcoal and wood). Electric submerged arc furnaces with graphite electrodes or consumable Søderberg

electrodes are used. The heat is produced by the electric arcs and by the resistance in the charge materials. The furnaces used in Norway are open, semi-covered or covered.

Several components are emitted from production of ferroalloys. Emission of CO_2 is a result of the oxidation of the reducing agent used in the production of ferroalloys. SO_2 originates from the sulphur in the reducing agent used, while NO_x is produced primarily by the high temperature oxidation of nitrogen in the air. NMVOC and CH_4 emissions originate from the use of coal and coke in the production processes. Heavy metals are emitted from the raw materials (ore) during the metallurgical process, and the particles emitted are mainly silica dust generated during the production process.

4.4.2.2. Method

CO_2

Emission data based on calculations is reported from each plant in an annual report to the Norwegian Pollution Control Authority. The method used in the calculation of CO_2 emissions from the production of ferroalloys is in accordance with method recommended by the IPCC (IPCC 1997b).

The plants use two different methods to calculate the CO_2 emissions. Most of the plants base their calculations on carbon mass balance in the process (methode I) while the other plants calculate the emissions from the consumption of the reducing agents and electrodes and national emission factors (method II), see table 4.11.

Indirect emission of CO_2 are calculated based on the emission of NMVOC, see Chapter 1.9.

CH_4

Most plants producing ferroalloys report emission figures to the Norwegian Pollution Control Authority. For the remaining plants, figures are not available or the emissions are so low that they are insignificant and is therefore not included in the inventory. Emission figures have been available since 1992. Emission figures for 1991 have been calculated by Statistics Norway, while the 1990 emission figures have been collected from SINTEF and Det Norske Veritas (2004).

SO_2

Each plant reports annually emission figures to the Norwegian Pollution Control Authority. Some of the sulphur is trapped in the product. For production of ferro manganese and silicon manganese, 98-99 per cent of the sulphur is trapped, while for other ferro-alloys it is assumed that about 5 per cent is trapped. The emissions are calculated from the consumption of reducing agents and electrodes and the content of sulphur in the materials.

NO_x

Emissions of NO_X originate from production of ferro silicon and silicon metal. Emission figures are annually reported to the Norwegian Pollution Control Authority. The reported emissions are calculated from the production of metal and metal specific emission factors, see table 4.12.

NMVOC

The emissions are estimated by Statistics Norway from the consumption of reducing agents and an emission factor.

Particles

All plants producing ferroalloys report emission figures to the Norwegian Pollution Control Authority. Some have reported since 1990, others since 1992. For plants reported since 1992, emission figures from 1990 and 1991 have been assumed to be the same as reported figures in 1992. According to the ferroalloy industry, particles emitted are smaller than $PM_{2.5}$ (Eikeland 2002). This is however an assumption, and we can not preclude that some of the particles might be larger than $PM_{2.5}$. In the inventory, we have decided to use this distribution for all particles emitted from the production of ferroalloys. This means that TSP=PM_{10}=$PM_{2.5}$.

Heavy metals

Emission figures for heavy metals are reported from all plants producing ferroalloys after the Norwegian Control Authority in 1999 imposed larger metallurgical plants to map their emissions of heavy metals. Most plants have therefore reported figures to the Norwegian Pollution Control Authority since 1999, but some reported for the first time in 2000 and 2001. An emission factor has been derived for each plant based on the emission figure and production rate for the first year of reporting. These emission factors have been used together with production rate for each year to calculate the emissions back to 1990 for each plant.

Dioxin

All plants producing ferrosilicon report emission figures for dioxins to the Norwegian Pollution Control Authority. It varies however when the plants started reporting, so calculations of historical figures back to 1990 have been necessary. An emission factor was derived for each plant based on reported emission data and production rate, and this factor was used to calculate historical emissions based on production rate for each year.

None of the four plants producing ferromanganese and ferrochromium[5] report emission figures for dioxin to the Norwegian Pollution Control Authority. The reason is probably that the emissions are so small that they

[5] The ferro chromium plant was closed down in 2003.

are not measured and therefore not reported (SFT 2001b). Instead, the emissions are calculated by Statistics Norway based on the general emission factor for combustion of coke and coal in the industry (table 4.13).

PAH
Emissions of PAH from the production of ferroalloys are reported to the Norwegian Pollution Control Authority for plants producing ferrosilicon and silicon metal. All these plants have reported emission figures since 2000. Historical emissions back to 1990 have been calculated based on production rate for each year and an emission factor derived for each plant based on reported figures for 2000, 2001 and 2002. Reported figures and historical calculations are only done for plants producing ferrosilicon and silicon metal. This is based on the assumption that these alloys are produced in open ovens and therefore cause larger emissions of PAH compared to other alloys that are produced in closed ovens and are assumed to cause no or minor emissions of PAH.

The PAH emission figures are reported according to Norwegian Standard, but no PAH profile is available. In lack of other data, the same profile as that for aluminium production is used.

Table 4.10. Distribution of PAH emission from production of ferroalloys

Component	Distribution of PAH emissions (ratio)
PAH (Norwegian standard)	1
PAH-6 (Ospar)	0.3
PAH-4 (CLRTAP)	0.15

Source: Finstad et al. (2001).

4.4.2.3. Activity data
The amounts of reducing agents that are used for the calculation of NMVOC emissions are annually reported to Statistics Norway from each plant.

4.4.2.4. Emission factors
CO_2
Emission factors used in the calculations (method II) by the plants are mainly the factors in table 4.11. The factors are from Norwegian sources, based on the actual composition of the raw materials.

Table 4.11. TabellEmission factors for production of ferroalloys. Tonnes CO_2/tonne reducing agent or electrode

	Coal	Coke	Electrodes
Ferro silicon	3.1	3.36	3.36
Silicon metal	3.1	3.36	3.54
Ferro chromium	-	3.22	3.51
Silicon manganese	-	3.24	3.51
Ferro manganese	-	3.24	3.51

Source: SINTEF (1998b, 1998c, 1998d and 1998e).

NO_X
The emission factors used in the calculations are based on measurements carried out at three plants.

Table 4.12. Emission factors for production of ferro silicon and silicon metal. Kg NO_x /tonne metal produced.

	kg per tonne metal produced	Source
Silicon metal	11	Measured in 1995 at the Fiskaa plant
Ferro silicon 90 per cent	12	Estimations
Ferro silicon 75 per cent	15	Measured in 1995 at Rana Metal and the Thamshavn plant
Ferro silicon 65 per cent	12	Estimations
Si96	11	Estimations

NMVOC
Statistics Norway uses an emission factor of 1.7 kg NMVOC/tonne coal or coke (EPA 1986) in the calculations.

Dioxin
Emission calculations of dioxin for those plants not reporting figures to the Norwegian Pollution Control Authority uses an emission factor of combustion of coke and coal in the industry (table 4.13).

Table 4.13. Emission factor used to calculate dioxin emission from production of ferro manganese/chromium

	Emission factor
Coal and coke	1.6 µg/tonne

Source: Bremmer et al. (1994) and Finstad et al. (2002a).

4.4.2.5. Uncertainties
Uncertainty estimates for greenhouse gases and long-range transboundary air pollutants are given in Appendix D.

Particles
The inventory uses a particle size distribution, which is an assumption from the ferroalloy industry and not based on measurements. We can therefore not preclude that some of the particles might be larger than $PM_{2.5}$.

Heavy metals and POPs
Historical emissions are based on a derived emission factor for the first year of reporting and calculated using production figures for previous years. This is uncertain since the calculation method does not consider quality changes of the raw materials or changes in the production profile at each plant that can have big impact on yearly emissions.

4.4.2.6. Source specific QA/QC

CO_2
The CO_2 emissions are calculated by Statistics Norway based on the IPCCs recommended Tier 1 method, using the reported amount of reducing agents (raw material) used. Emission factors used are the factors in table 4.11. The calculated emissions are used as a quality check of the reported data.

NO_X, NMVOC and CO
The reported emission figures for NO_X, NMVOC and CO are compared with calculations at Statistics Norway.

For the quality check on the reported NO_x emission figures, an emission factor estimated from two ferroalloy plants are used together with production data. The applied emission factor of 11.7 kg NO_x/ tonne ferroalloy is rather uncertain since it is estimated from measurements from only two of the Norwegian ferroalloy plants.

Emission figures for NMVOC are controlled by multiplying the amount of reducing agents with an emission factor recommended by EPA (1986).

PAH
In 2004, there was a quality improvement of the historical calculation of PAH. PAH was first included in the Norwegian Inventory in 2000, and at that time, only two plants producing ferro silicon and silicon metal reported emission figures to the Norwegian Pollution Control Authority for the year 1999. The ferroalloy industry and the Norwegian Pollution Control Authority therefore derived emission factors to estimate PAH emissions from the production of ferro silicon and silicon metal (Benestad 2000). It was then decided to use these factors in the Norwegian inventory to calculate PAH emissions. From 2000, all plants producing ferro silicon and silicon metal however started reporting emission figures to the Norwegian Pollution Control Authority, and these figures have been used instead of the calculated emissions based on emission factors and activity data. In 2004, the historical emissions were recalculated. Based on the plants' reported emission figures for 2000, 2001 and 2002 and production volumes, a specific emission factor for each plant was derived. These factors were then used to recalculate the plants' historical emissions of PAH. A specific emission factor for each plant was considered better to use for historical emissions, instead of using a default emission factor for all plants. The specific emission factors derived for each plant with the new method were lower than those suggested by Benestad (2000), and this caused approximately 2-12 per cent lower yearly PAH emissions from 1990 to 1999 from this source.

4.4.3. Production of primary aluminium

IPCC 2C3, Key category for PFC, (SF_6: 2C4, Key category for SF_6)
NFR 2C3
Last update: 01.09.05

4.4.3.1. Description
There are seven plants in Norway producing aluminium. Both prebaked anode and the Soederberg production methods are used. In the Soederberg technology, the anodes are baked in the electrolysis oven, while in the prebaked technology, the anodes are baked in a separate plant. In general the emissions are larger from the Soederberg technology than from the prebaked technology.

Production of aluminium leads to emission of various components as CO_2, SO_2, NO_x, perfluorocarbons (PFCs), heavy metals and persistent organic pollutants. The emission of CO_2 is due to the electrolysis process during the production of aluminium, while the SO_2 emissions are from the sulphur in the reducing agents used. NO_X is primarily produced by the high temperature oxidation of nitrogen in the air. All plants also report emissions of particles, heavy metals and PAH. Emissions of heavy metals are due to the metal content in the raw materials used and the reducing agents.

4.4.3.2. Method
CO_2
The inventory uses the emission figures reported to the Norwegian Pollution Control Authority, calculated by each plant on the basis of consumption of reducing agents. This includes carbon electrodes, electrode mass and petroleum coke. The emission factors are primarily calculated from the carbon content of the reducing agents.

Previously, Statistics Norway estimated the CO_2-emissions from consumption data provided by the plants, but now figures reported by the plants are used. Reported figures are available since 1992. For 1990 and 1991 there were no data, hence recalculation was made using production data and reported emission data for 1992.

The aluminium industry calculates the CO_2 emissions separate for each technology. The following methods are used:

<u>CO_2 from Prebake Cells</u>

$$(16) \qquad Q = A*C*3.67$$

Where
Q is the total yearly emissions of CO_2
A is the yearly net consumption of anodes
C is per cent carbon in the anodes

3.67 is the mol-factor CO_2/C

CO_2 from Soederberg Cells

$$(17) \quad Q = S*3.67*(K*C1+P*C2)$$

Where
Q is the total yearly emissions of CO_2
S is the yearly consumption of Soederberg paste
K is the share of coke in the Soederberg paste
P is the share of pitch in the Soederberg paste
K+P=1
C1 is the fraction of carbon in the coke. Fraction is per cent Carbon/100
C2 is the fraction of carbon in the pitch. Fraction is per cent Carbon/100

SO_2
The plants report emission figures of SO_2 to the Norwegian Pollution Control Authority. The figures are estimated by each plant based on the amounts of reducing agents used and their sulphur content. All plants have istalled flue gas treatment like for example sea water scrubber.

NO_x
NO_x emissions are estimated by Statistics Norway from the level of production and emission factor derived from measurements at two Norwegian plants. The figure is rather uncertain.

Perflourocarbons (PFCs)
The emissions of PFC are reported annually by the plants to Norwegian Pollution Control Authority.

Perfluorinated hydrocarbons (PFCs), e.g. tetrafluoromethane (CF_4) and hexafluoroethane (C_2F_6), are produced during anode effects (AE) in the Prebake and Soederberg cells, when the voltage of the cells increases from the normal 4-5V to 25-40V. During normal operating condition, PFCs are not produced. Starting of new electrolytic cells generates additional PFC emissions. The fluorine in the PFCs produced during anode effects originates from cryolite. Molten cryolite is necessary as a solvent for alumina in the production process.

Emissions of PFCs from a pot line (or from smelters) are dependent on the number of anode effects and their intensity and duration. Anode effect characteristics will be different from plant to plant and also depend on the technology used (Prebake or Soederberg).

In 1992, 1996-1997 and 2000-2001, the Norwegian aluminium industry measured emissions of PFCs from the smelters. For Soederberg potrooms, the monitoring also comprised PFCs in ventilation air from the potrooms. The measurements in production cells were carried out using a photoacoustic gas monitor.

The formula currently used in Norway for calculating CF_4 and C_2F_6 emissions from aluminium production is as follows:

$$(18) \quad Q = 1.01 \cdot [A \cdot B \cdot C \cdot D \cdot E + (F \cdot G)],$$

where Q is the total yearly emissions of CF_4 and C_2F_6

Variables to be reported each year:

- B number of anode effects per cell per day
- D average annual amperage in kA
- E number of cells in production multiplied by number of production days
- G number of "newly started" cells

Constants:

- A average measured emissions per anode effect minute per kA per cell
- C duration of anode effect in minutes
- F average emissions per new start of a cell
- 1.01 The measured amount of CF_4 + C_2F_6 is multiplied by 1.01 in order to compensate for incomplete monitoring of C_2F_6, see explanation below.

Measurements from 1992 showed that the content of C_2F_6 in anode gas was 1 to 10 per cent, and 3 per cent on average. The measured emissions of CF, that is CF_4 + C_2F_6, include all CF_4, but only about 70 per cent of the C_2F_6 emissions. This means that 1 per cent of the total emissions of CF_4 + C_2F_6 was not measured. The measured total figure for CF_4 + C_2F_6 is therefore multiplied by a factor of 1.01 to include non-measured C_2F_6. The total amount of C_2F_6 in the total estimated CF_4 +C_2F_6 emissions (Q) is then 4 per cent. These results were confirmed by the measurements made in 1996-97.

The variables of the calculation
Factor B related to the number of anode effects per cell per day, factor D related to the average annual amperage in kA, factor E related to the number of cells in production multiplied by number of production days, and factor G related to the number of newly started cells, are all based on measurements and registrations that are done more or less continuously as part of the regular monitoring of operating results and plant performance. The data are assumed to be of good quality, and uncertainties in the figures will probably have no significant effect on the calculated emissions.

The constants of the calculation
Factor A
The emissions of CF_4 and C_2F_6 are calculated in kg per year and kg per tonne aluminium produced. These

emissions are specified for each plant. For the plants that have both Soederberg and Prebake technology, the emissions are specific for each technology.

Monitoring of emissions followed by calculation of the average emissions of CF_4 per anode effect minute per kA per cell, was carried out in 1992, 1996-97 and 1999-2000. For Prebake-lines, the monitoring campaigns gave some differences in the results for each individual plant, while the average figure for all plants was fairly stable. The same situation applied for the Soederberg-lines.

Estimated uncertainty for both technologies is ± 20 per cent.

The results from the Prebake-lines are reasonably in line with results from ALCOA and with the IPCC recommendation. Also the average results for Soederberg-lines are in line with the IPCC recommendation, but with smaller margin.

Monitoring of emissions of CF_4 from Soederberg-lines is more difficult than from Prebake-lines, mainly due to the difficulty of getting representative results from fugitive emissions in ventilation air from the potrooms.

The monitoring results of C_2F_6 have significantly bigger uncertainty than for CF_4, and the uncertainty is probably bigger for Soederberg-lines than for Prebake-lines.

Monitoring results from Prebake-lines in 1999/2000 have an estimated uncertainty of 40 per cent. The values are lower than the IPCC recommendation and lower than some other reported results. The main reason for the deviations is possibly problems to achieve representative monitoring results.

Factor C
The Norwegian calculations of emissions are based on constant duration of anode effects. These constants are specific for each plant and each technology. This is a simplification, which contributes to an uncertainty of the calculated result.

At all the plants there are major efforts to reduce the length of the anode effects, and the reported results will therefore be less accurate when the efforts pay off.

In The Aluminium Sector Greenhouse Gas Protocol, International Aluminium Institute, May 2003, the recommended calculation of PFC emissions in accordance with Tier 3 is based on real duration of anode effects. The Norwegian method of calculation will probably be in line with this recommendation when the method has been evaluated in 2004. (See the next section Completeness).

The factor 1.01
The accuracy will depend on the quality of the monitoring results of CF_4 and C_2F_6 and their ratio.

Sulphur hexafluoride (SF_6)
SF_6 used as cover gas in the aluminium industry is assumed to be inert, and SF_6 emissions are therefore assumed to be equal to consumption. At one plant, SF_6 was used as cover gas in the production of a specific quality of aluminium from 1992 to 1996. The aluminium plant no longer produces this quality, which means that SF_6 emissions have stopped.

Particles
Emission figures have been reported to the Norwegian Pollution Control Authority since 1990. The Norwegian Pollution Control Authority assumes the particles emitted are smaller than PM_{10}. According to TNO (2002), PM_{10} is 97 per cent of TSP, and $PM_{2.5}$ is 43 per cent of TSP. The Norwegian Inventory uses the particle size distribution suggested by TNO (2002).

Heavy metals
The plants report emission figures to the Norwegian Pollution Control Authority. The first requirement for reporting came in 1999, so emission figures before that are insufficient. The concentrations of heavy metals in the air emissions are very low and therefore impossible to measure. Emissions are therefore calculated at each plant based on the mass flow.

Dioxin
Since the process use coal and coke as reducing agents, it is assumed that production of primary aluminium give dioxin emissions. Reported figures for dioxin are not available. The emissions are believed to be so small that reporting are not necessary. Emissions are therefore calculated based on the combustion factor of coal in the industry.

PAH
The reported emission data are assumed to be according to Norwegian standard (NS9815). It is further assumed, by the Norwegian Pollution Control Authority, that the emissions are due to emissions from the use of the Soederberg method. Historical emission figures have been calculated based on changes in production of aluminium after the Soederberg method.

The PAH- profile has been measured at three plants. These profiles show little variation. Based on these profiles it is belived that PAH-4 accounts for 15 per cent and PAH-OSPAR 30 per cent of total PAH emissions for production of aluminium after the Soederberg method (table 4.14).

Table 4.14. Distribution of PAH emissions from production of primary aluminium. Ratio

Component	Distribution of PAH emissions (ratio)
PAH (Norwegian standard)	1
PAH-6 (Ospar)	0.3
PAH-4 (CLRTAP)	0.15

4.4.3.3. Activity data

NO_X

The activity data for the NO_X-calculation are production figures, which are reported annually from the plants to the Norwegian Pollution Control Authority.

Dioxins

The calculation of emissions of dioxins is based on consumption of raw materials. The figures are reported annually from the plants to Statistics Norway.

4.4.3.4. Emission factors

NO_X

Statistics Norway uses the emission factor 0,00071 tonnes NO_X/ tonne produced aluminium in their calculations. This emission factor is assumed by the Norwegian Pollution Control Authority and is based on measurements.

Dioxins

Emissions of dioxin are calculated based on the consumption of coal and an emission factor from Bremmer et al. (1994).

Table 4.15. Emission factor used to calculate dioxin emissions from aluminium production

	Emission factor	Source
Coal and coke	1.6 µg/tonne	Bremmer et al. (1994)

4.4.3.5. Uncertainties

Uncertainty estimates for greenhouse gases and long-range transboundary air pollutants are given in Appendix D.

Perflourocarbons (PFCs)

The uncertainty in the emission estimates of PFCs from aluminium production is mostly determined by the uncertainty in the emission factors. PFCs from aluminium production are among the four source categories in the Norwegian GHG Inventory that is most important to the inventory's level and trend uncertainty (Rypdal and Zhang 2000). This is in spite of the efforts that have been done to improve the quality of the emission data.

With the purpose of monitoring the reduction of emissions from 1990 to 2005, the current method for calculation of climate gases is considered to be acceptable, even if it has some weaknesses.

In the future, the absolute emission values will be more important, and all climate gasses will therefore have to be monitored or calculated more precisely. The method for monitoring of emissions will therefore be evaluated and improved. Discussions on this issue started in 2004 in a cooperation between the aluminium industry and the environmental authorities.

The experience from other countries will be utilized.

Particles

The particle size distribution used is not specific for the plants, and might therefore be different from the one suggested by TNO (2002).

4.4.3.6. Completeness

Major missing emission components are not likely.

4.4.3.7. Source specific QA/QC

CO_2

The emission figures reported by the plants are controlled by the Norwegian Pollution Control Authority and Statistics Norway. Statistics Norway makes own estimates based on the consumption of reducing agents and production data collected in an annual survey and average emission factors. If errors are found, the plants are contacted and changes in the emissions are made when necessary.

Perflourocarbons (PFCs)

The emission figures from the aluminium plants are reported to the Norwegian Pollution Control Authority annually. As a quality control, it is checked that the reports are complete. Each figure is compared with similar reports from previous years and also related to technical changes and utilisation of production capacity during the year. If errors are found, the Norwegian Pollution Control Authority contacts the plant to discuss the reported data, and changes are made if necessary.

The Norwegian Pollution Control Authority has regular meetings with the aluminium industry where all plants are present. This forum is used for discussion of uncertainties and improvement possibilities.

The Norwegian Pollution Control Authority's auditing department are regularly auditing the aluminium plants. As part of the audits, their system for monitoring, calculation and reporting of emissions are controlled.

PAH

The Norwegian Pollution Control Authority had recently audits at all aluminium plants to check their system for monitoring of emissions of PAH. It will be considered whether similar audits should have climate gases as the main target.

Heavy metals
First requirement for reporting of heavy metals was given in 1999, and the reported figures were this year based on concentration measurements. The concentration of heavy metals in the air emissions are very low and therefore of high uncertainty. The reported emission figures showed big differences from plant to plant, also in the cases where the raw materials came from the same supplier. The Norwegian Pollution Control Authority has had a long discussion with the aluminium industry to find a better method to estimate heavy metals from aluminium production. In 2001 it was decided that reported figures should be based on calculations. New calculations have shown that earlier calculations gave too high emissions of heavy metals. It was therefore recommended by the Norwegian Pollution Control Authority to recalculate historical reported data based on the new calculation method. Recalculation of historical data are normally based on production rate data, but due to very low emissions and relative stable production rate, historical data are set to be the same as the first year of reporting.

4.4.4. Production of secondary aluminium

IPCC -, (SF_6: 2C4, Key category for SF_6)
NFR 2C3
Last update: 01.09.05

4.4.4.1. Description
One open mill in Norway is handling secondary aluminium production. Heavy metals and persistent organic pollutants (dioxin and PAH) are emitted in the production of secondary aluminium due to the remelting process. Particles are also emitted during the production process. For earlier years there have also been some emissions of NH_3 and SF_6.

4.4.4.2. Method
NH_3
For the years 1993-2001, emissions of NH_3 were reported from one plant. This plant closed down in 2001.

Sulphur hexafluoride (SF_6)
For the years 1998, 1999 and 2000, emissions of SF_6 have been reported to the Norwegian Pollution Control Authority.

Particles
The plant has reported emission figures from 1993 until its closure in 2001 to the Norwegian Pollution Control Authority. Emission figures for 1990 to 1992 are in the inventory assumed to be the same as reported figure in 1993. Following particle size distribution is assumed and used in the Norwegian inventory; PM_{10} is 0.8*TSP and $PM_{2.5}$ is 0.32*TSP (TNO 2002).

Heavy metals and POPs
Figures are reported annually to the Norwegian Pollution Control Authority. Emission figures exist since 1993, and emissions before 1993 have been supposed to be the same as reported figures in 1993.

The emission figures for heavy metals are based on metal analyses of dust samples. Figures of Pb, Cd and Cr have been reported since 1997. Annual figures can vary a lot from one year to another, and therefore we have used mean values for years when the changes can not be explained by the industry. We have assumed that the emission figures for 1990-1996 are the same as reported figures in 1997, since there are no reported figures of heavy metals and PAH before 1997.

4.4.4.3. Uncertainties
Heavy metals and POPs
The reported figures for heavy metals are estimated based on heavy metal content in the dust samples. The metal content were only analysed for a few dust samples yearly and the reported figures are therefore only a presumption of yearly emission figures. Calculation of emission figures before 1997 are assumed to be the same as reported figures in 1997, and this gives highly uncertain figures since raw materials and production variations may have changed in this period.

The reported emission figures for dioxins and particles vary from one year to another, and it is assumed this is due to uncertain measurements and process readjustments.

4.4.4.4. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

4.4.5. Production of magnesium

IPCC 2C5, (SF_6: 2C4, Key category for SF_6)
NFR 2C5
Last update: 01.09.05

4.4.5.1. Description
There is one plant in Norway producing magnesium. The plant closed down the production of primary magnesium in 2002, but the production of cast magnesium is continuing. From the mid-1970s, both the magnesium chloride brine process and the chlorination process were used for magnesium production. Since 1991, only the chlorination process was in use.

Production of magnesium leads to non-combustion CO_2 and CO emissions. During the calcinations of Dolomite ($MgCa(CO_3)_2$) to magnesium oxide, CO_2 is emitted. During the next step, magnesium oxide is chlorinated to magnesium chloride, and coke is added to bind the oxygen as CO and CO_2. SO_2 is emitted due to the sulphur in the reducing agent used.

In the foundry, producing cast magnesium, SF_6 is used as a cover gas to prevent oxidation of magnesium. The Norwegian producers of cast magnesium has assessed whether SF_6 used as cover gas reacts with other components in the furnace. The results indicate that it is relatively inert, and it is therefore assumed that all SF_6 used as cover gas is emitted to air.

4.4.5.2. Method

CO_2

The IPCC (1997b) recommends using the consumption of reducing agent as the activity data for estimating emissions. SINTEF (1998f), on the other hand, recommends using production volume in the calculations. The Norwegian emission inventory use production data as activity data. The CO_2 emissions are therefore calculated by Statistics Norway by using annual production volumes and the emission factor recommended by SINTEF (SINTEF 1998f).

CO

Emission figures of CO are reported annually to the Norwegian Pollution Control Authority.

SO_2

The SO_2 emissions are estimated from the amounts of reducing agent used (coke) and their sulphur content and reported from the plants to the Norwegian Pollution Control Authority.

SF_6

Studies performed by the Norwegian producer have assessed that SF_6 used as cover gas is inert. Therefore the consumption figures for the cover gas (SF_6) are used as the emission estimates in accordance with the IPCC Guidelines (IPCC 1997a, 1997b). The SF_6 emissions are reported annually to the Norwegian Pollution Control Authority.

Particles

The plant reported emission figures for particles for the first time for the year 1992. Emissions of particles for 1990 and 1991 are assumed to be larger than the reported figure in 1992, since a cleaning device was installed in 1992. Statistics Norway has no information that can be used to estimate emissions in 1990 and 1991, so the inventory uses the reported emission figure for 1992 also for 1990 and 1991. The Norwegian Pollution Control Authority assumes that reported figures also include emissions from combustion.

No information is found regarding the particle size distribution for particles emitted during magnesium production. In lack of other data, we use the same distribution as for aluminium production (PM_{10} is 97 per cent of TSP, and $PM_{2.5}$ is 43 per cent of TSP).

Heavy metals and POPs

Emission of heavy metals is due to the metal content in the reducing agent used. Emission data of Hg, As, Cr and dioxin are reported to the Norwegian Control Authority. Reported figures of heavy metals have only been available since 2000. Emission figures are calculated back to 1990 based on the production rate for each year.

During the chlorination process and the use of coke as a reducing agent, dioxin is emitted. Emission figures of dioxin have been reported to the Norwegian Pollution Control Authority since 1990.

4.4.5.3. Activity data

The Norwegian emission inventory uses production volumes as activity data in the calculation of CO_2. This method is recommended by SINTEF (1998f). The consumption figures used as emission figures for SF_6 are reported to the Norwegian Pollution Control Authority.

4.4.5.4. Emission factor

An emission factor of 4.07 tonnes CO_2/tonnes produced magnesium is used bu Statistics Norway to calculated the annually emissions of CO_2 (SINTEF 1998f).

4.4.5.5. Uncertainties

Uncertainty estimates for greenhouse gases and long-range transboundary air pollutants are given in Appendix D.

Particles

For years where reported emission figures do not exist, Statistics Norway has assumed that emissions are in the same order as that of the first year of reporting. This is uncertain and a result of lack of better data. The particle size distribution used is not specific for production of magnesium, but used due to lack of specific size distribution data for this source. The particle size distribution can therefore only be seen as an estimate.

Heavy metals

Historical emissions are based on a derived emission factor for the first year of reporting and calculated with production figures for previous years. This is uncertain and only an estimate since it does not consider annually changes in raw materials nor possible cleaning devices.

4.4.5.6. Completeness

Major missing emission components are not likely.

4.4.5.7. Source specific QA/QC

The last years reported emission data from the plant is compared with previous reported data and the emissions are compared with the production.

4.4.6. Other metals

IPCC 2C5
NFR 2C5
Last update: 01.09.05

In addition to the metals in the chapters above, nickel and zinc are also produced in Norway.

4.4.6.1. Production of nickel
4.4.6.1.1. Description
One plant in Norway produces nickel. During the production of nickel, CO_2, SO_2, NO_x, NH_3, particles and heavy metals are emitted. CO_2 is emitted in the production of nickel due to the soda from the production of nickel carbonate and use of coke as a reducing agent, while SO_2 is a result of the sulphur content in the coke used. NO_x is produced primarily by the high temperature oxidation of nitrogen in the air. Emission of heavy metals is due to the metal content in reducing agent used. Particles are also emitted during the production process. PAHs and dioxin are not reported or calculated.

4.4.6.1.2. Methods
CO_2
Emission figures are annually reported from the plant to the Norwegian Pollution Control Authority based on calculation of material balance.

SO_2
Emission figures of SO_2 are reported from the plant to the Norwegian Pollution Control Authority based on continuous measurements. Flue gas treatment is installed at the plant.

NO_x
Emission figures of NO_x are annually reported from the plant to the Norwegian Pollution Control Authority. The emission figures are based on calculations.

NH_3
Emission figures based on calculations are annually reported from the plant to the Norwegian Pollution Control Authority.

Particles
Emission figures of particles have been reported to the Norwegian Pollution Control Authority since 1992. Emissions in 1990 and 1991 are assumed to be the same as reported figure in 1992. The emission permit sets requirements to emissions from the melting furnace, transport, crushing and packing of the raw materials and products. The Norwegian Pollution Control Authority assumes that the particles emitted are smaller than $PM_{2.5}$. This means that TSP=PM10=PM2,5 in used in the inventory.

Heavy metals and POPs
Emission figures for Cu have been reported to the Norwegian Pollution Control Authority since 1990. Reported figures for Cd, Hg and Pb were available from 1990-1994, but because of low emissions the plant stopped reporting these metals.

4.4.6.1.3. Uncertainties
Uncertainty estimates for greenhouse gases and long-range transboundary air pollutants are given in Appendix D.

Particles
The particle size distribution used is only an assumption and we can not preclude that the distribution might be different than the one suggested. The particle size distribution can therefore only be seen as an estimate.

4.4.6.1.4. Completeness
Major missing emission components are not likely.

4.4.6.1.5. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

4.4.6.2. Production of zinc
4.4.6.2.1. Description
One plant in Norway produces zinc. SO_2, particles and heavy metals are emitted during the process. Emission of SO_2 originates from the sulphur in the reducing agent used.

4.4.6.2.2. Method
SO_2
The plant reports emission figures to the Norwegian Pollution Control Authority. The SO_2 emissions are estimated from infrequent measurements combined with calculations.

Particles
Emission figures for particles have been reported since 1991. Emissions for 1990 are assumed to be the same as reported figure for 1991. It is assumed that of the particles emitted, 90 per cent is PM_{10} and 80 per cent is $PM_{2.5}$ (TNO 2002) and this particle size distribution is used in the Norwegian inventory.

Heavy metals and POPs
The plant reports emission figures for Cd, Pb and Hg. Reported figures exist since 1991, and emissions in 1990 are assumed to be the same as reported figures in 1991.

Figures are not reported for PAHs and dioxin.

4.4.6.2.3. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

4.4.7. Manufacture of anodes
IPCC 2C5
NFR 2C5
Last update: 01.09.05

4.4.7.1. Description
Two plants in Norway produce anodes. One plant produces prebaked anodes and the other one produces anodes for ferroalloy production. Prebaked anodes and coal electrodes are an alternative to the use of coal and coke as reducing agents in the production process for aluminium and ferroalloys. The anodes and coal electrodes are produced from coal and coke. The production of anodes and coal electrodes leads to emissions of CO_2, NO_x, SO_2, PAH and heavy metals.

4.4.7.2. Method
CO_2, SO_2 and NO_x
Emission figures of SO_2 are based on measurements while CO_2 and NO_X emissions are calculated and reported to the Norwegian Pollution Control Authority.

Particles
Production of anodes leads to emission of particles. One of the plants has reported since 1990, while the other one has reported since 1992. Emission figures for 1990 and 1991 are assumed to be the same as reported figure in 1992 for this plant. The Norwegian Pollution Control Authority assumes the particles emitted are smaller than PM_{10}, but also expects some to be smaller than $PM_{2.5}$. No information has been found regarding the particle size distribution, so in lack of other data we use the same distribution profile as used for production of aluminium where PM10 is 97 per cent of TSP and PM2,5 is 43 per cent of TSP .

PAH
Emission figures for PAH are based on measurements and reported from both plants to the Norwegian Pollution Control Authority. One plant has developed a new and better method for measuring PAH. This metod is used for the peiode 1992 to 2003. The reported figures of PAH are assumed to be according to the Norwegian standard (NS9815). Measurements from production of Soederberg paste (at three Norwegians plants) and a PAH-profile of baked anodes from U.S. EPA are used to derive a PAH-profile to find the emission of PAH-OSPAR and PAH-4. Based on these profiles it is assumed that PAH-OSPAR and PAH-4 account for respectively 25 per cent and 5 per cent of the total PAH emissions (table 4.16).

Table 4.16. Distribution of PAH emissions from production of anodes. Ratio

Component	Distribution of PAH emissions (ratio)
PAH (Norwegian standard)	1
PAH-6 (Ospar)	0.25
PAH-4 (CLRTAP)	0.05

Source: SFT (1999f).

Heavy metals
Production of anodes leads to emission of heavy metals due to the metal content in the reducing agents (coke and coal). Emission figures are based on measurements and are reported for arsenic and mercury from one plant since 2001. Emission figures have not been measured nor reported before 2001 and are therefore not available for previous years. Historical emission figures back to 1990 are assumed to be the same as reported figures in 2001.

4.4.7.3. Uncertainties
Historical calculations of heavy metals from 2001 to 1990 are very uncertain since they are assumed to be the same as reported figures for the first year of reporting (2001). Annually changes in production volumes, coke quality and the amount of heavy metals in the reducing agents are not taken into account, and the historical emissions can only be seen as an estimate in lack of better data.

4.4.7.4. Completeness
Major missing emission components are not likely.

4.4.7.5. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

4.5. Other production
IPCC 2D
NFR 2D

4.5.1. Pulp and paper
IPCC -
NFR 2D1
Last update: 01.09.05

4.5.1.1. Description
Pulp and paper production has three major processing steps; pulping, bleaching and paper production. Kraft (sulphate) pulping is the most widely used pulping process and is generally used to produce strong paper products: The Kraft pulping process includes bleaching, chemical recovery and by-products recovery. The sulphite pulping is another chemical pulping process. It produces a weaker paper than some other types of pulping, but the pulp is less coloured, making it more suitable for printing, often with little bleaching. In Norway, SO_2 and particles are reported emitted from production of pulp and paper. In the Kraft pulping

process, sodium sulphide and sodium hydroxide are used to chemically dissolve the lignin that binds the cellulose fibres, and in the acid sulphite pulping process, sulphurous acid solution is used. SO_2 is emitted in these processes.

4.5.1.2. Method
SO_2
Emission figures are reported from producers of chemical pulp to the Norwegian Pollution Control Authority. SO_2 is measured continuously and emission estimates are made from these measurements.

Particles
Four plants producing pulp and paper report non-combustion emissions of particles to the Norwegian Pollution Control Authority. Two of these plants have not reported emission figures from combustion and it is assumed that the reported non-combustion emission figures include emissions from combustion. It varies when the plants started reporting emission figures for particles, and due to lack of data, emission for those years is assumed to be the same as in the first year of reporting.

Two of the plants state that they clean the emissions by electric filter and wet scrubbers, and it is assumed by the Norwegian Pollution Control Authority that the particles emitted are smaller than $PM_{2.5}$. The other two clean their emissions using only wet scrubbers, and it is assumed the particles are smaller than PM_{10}. According to TNO (2002), $PM_{2.5}$ is 20 per cent of PM_{10} and PM_{10} is the same as TSP.

4.5.1.3. Uncertainties
The particle size distribution used is not plant specific and might therefore be different from the one suggested by TNO.

4.5.1.4. Completeness
Major missing emission components are not likely.

4.5.1.5. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

4.5.2. Food and Drink
IPCC 2D2
NFR 2D2
Last update: 01.09.05

4.5.2.1. Production of bread and beer
4.5.2.1.1. Method
NMVOC
Production of bread and beer (and other similar yeast products) involves fermentation processes that lead to emission of NMVOC (ethanol). Emissions are calculated based on production volumes and emission factors.

4.5.2.1.2. Activity data
Production volumes of bread and beverages are annually reported to Statistics Norway.

4.5.2.1.3. Emission factors
The emission factors are taken from EEA (1996).

Table 4.17. NMVOC emission factors from production of bread and beverage

	Emission factor	Unit
Production of bread	0.003	tonnes/tonnes produced
Production of beverage	0.2	kg/1000 litres

Source: EEA (1996).

4.5.2.1.4. Uncertainties
The emission factors used are recommended by EEA (1996) and are not specific for Norwegian conditions.

4.5.2.1.5. Completeness
Major missing emission components are not likely.

4.5.2.1.6. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

4.5.2.2. Carbonic acid to breweries
As mentioned under section 4.3.1.1, some CO_2 from ammonia production is used as carbonic acid in carbonated beverages. During the ammonia production, CO_2 is generated and then captured and sold to other companies in Norway or exported. Most of it is sold for lemonade production. All of the emissions are reported under this source, although the largest part of the emissions takes place after the bottles are opened, and not in the breweries.

The figures are based on the sales statistics from the ammonia producing plant.

4.5.2.3. Production of bio protein
CO_2 emissions from production of bio protein from natural gas are included from the year 2001 when this production started. The bio protein is being used as animal fodder. Emission data reported from the plant to the Norwegian Pollution Control Authority are used.

4.6. Consumption of halocarbons and SF_6
IPCC 2F, Key category for HFC
NFR -
Last update: 01.09.05

4.6.1. HFCs and PFCs from products and processes

4.6.1.1. Description

HFCs and PFCs are used as substitutes for ozone depleting substances (CFCs and HCFCs) that are being phased out according to the Montreal Protocol. They are used in varied applications, including refrigeration and air conditioning equipment, as well as in foam blowing, fire extinguishers, aerosol propellants and analysing purposes. There are no production of HFCs and PFCs in Norway. The HFCs and PFCs registered for use in Norway are HFC-23, HFC-32, HFC-134a, HFC-143a, HFC-152a, HFC-227ea and PFC-218.

In January 2003 a tax on import and production of HFC and PFC was introduced. In July 2004 this tax was supplemented with a refund for the destruction of used gas. In 2004 the tax and refund were both 183 NOK (appr. 22 Euro) pr. tonnes of CO_2-equivalents. This has lead to a considerable decrease in emissions in 2003 due to, among others, better maintenance. With regards to emission calculations 2003 must, however, be considered a transitional year, since we expect some time delay before the market adjusted to these new realities and that some increased purchases of gas took place just before the tax was introduced. Emissions for 2003 are estimated using a simplified methodology based on, among others, import statistics and information from users. Work has been established to completely review the methodology based on these new realities. Unless otherwise stated, the information in this chapter is based on the methodology used for the years prior to the introduction of the tax.

4.6.1.2. Method

Actual emissions of HFCs and PFCs are calculated using the Tier 2 methodology. The emissions are calculated on a detailed level, based on yearly consumption figures from bulk importers and emission characteristics related to specific processes and equipment (SFT 1999). Maintenance routines and processes for recovery of chemicals are also taken into account. By accounting for the time lag in emissions from the compounds are introduced into the equipment and until they leak out, it gives the actual emissions. Figures for import of products containing HFCs and PFCs in 1995-1997 were collected through a survey in 1999 (SFT 1999a), and the activity data for the following years were estimated by extrapolating these figures. Figures on imported bulk are collected each year.

We have also calculated the potential emissions employing the Tier 1b methodology, which only considers the import and export of chemicals in bulk and in products without time lag. It was found that the ratio between potential (Tier 1b) and actual emissions (Tier 2) was about 4:1 in 2002.

4.6.1.3. Activity data

Routines for the collection of information on imports of chemicals in bulk were established in 1990. The reporting system covers CFCs, HCFCs, HFCs and PFCs. Importers of bulk chemicals are contacted yearly by the Norwegian Pollution Control Authorithy, and are required to provide information on the types, amounts and application categories of the chemicals they import. A reporting system for imports and exports of equipment containing HFCs and PFCs has also been established. Since the introduction of the tax in 2003 information on import/export in bulk and products is also available from custom statistics. In future calculation this information will probably replace today's reporting system.

4.6.1.4. Emission factors

Emission characteristics for the different categories of equipment and products are defined by expert judgement (SFT 1999d) (table 4.18).

Table 4.18. Emission factors for HFCs from products and lifetime of products

Application category	Emissions during lifetime (per cent of initial charge)	Lifetime of products (years)
Refrigeration and air conditioning		
Household refrigerators and freezers	1.5	15
Commercial and industrial applications	3.5	15
Refrigerated transport	15	15
Air conditioning aggregates and heat pumps	4	15
Water/liquid refrigerating aggregates, water-based heat pumps	5	15
Mobile air conditioners	10	12
Foam		
Polyurethane with diffusion barrier	1	40
Polyurethane without diffusion barrier	5	20
Extruded polystyrene	3	30
Fire extinguishers	5	15
Solvents	50	2
Aerosol propellants	50	2

Source: SFT (1999d).

4.6.1.5. Uncertainties

The uncertainties of the different components of the national greenhouse gas inventory were evaluated in detail in 1999 by Statistics Norway (SFT 1999). The uncertainty both in relation to the Tier 1b (which only includes bulk chemicals) and the Tier 2 methods were assessed. Concerning the Tier 2 method, both the leakage rate (emission factor) and the stored amount of chemicals (activity data) were considered quite uncertain. The uncertainty of the leakage rate was calculated at ±50 per cent for HFC, while the uncertainty of the stored amount was found to be about ± 25 per cent. Furthermore, it was found that the uncertainty related to the Tier 2 method appeared

to be higher than the uncertainty of Tier 1a. However, these figures are not directly comparable, and it is clear that the Tier 2 method predicts actual annual emissions much better.

4.6.1.6. Completeness

Major missing emission sources are not likely. The emissions are probably underestimated, as some imported bulk are not included in current import statistics. New statistics based on taxation data are being prepared.

4.6.1.7. Source specific QA/QC

There is no specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

4.6.2. Emissions of SF_6 from products and processes

4.6.2.1. Description

In Mars 2002, a voluntary agreement was signed between the Ministry of Environment and the most important users and producers of GIS (gas-insulated switchgear). According to this agreement emission from this sector should be reduced by 13 per cent in 2005 and 30 per cent in 2010 with 2000 as base year. For the following up of this agreement, the users (electricity plants and -distributors) and producers (one factory) report yearly to the government.

4.6.2.2. Method

The methodology for estimating SF_6 emissions was revised in 1999 (SFT 1999c). Today's method is largely in accordance with the Tier 2 methodology in the IPPC guidelines for emission inventories (IPCC 1997a,b). The emissions reported in the inventory take into account imports, exports, recycling, banking, technical lifetimes of products, and different rates of leakage from processes, products and production processes.

Emissions from production of GIS (one factory) were included for the first time in 2003. The company has, as part of the voluntary agreement with the Ministry of the Environment, made detailed emission estimates for the years 2003 and 2000. For intermediate years, emissions are estimated based on production data. These emissions constitute a significant part of the national emissions of SF_6. In recent years emissions rates have been considerably reduced due to new investments and better routines. The company now performs detailed emission calculations based on accounting of the SF_6 use throughout the whole production chain.

4.6.2.3. Activity data

Data is collected from direct consultations with importers and exporters of bulk chemicals and products containing SF_6, and from companies that use SF_6 in various processes.

4.6.2.4. Emission factors

Leakage rates and product lifetimes used in the calculations are shown in tables 4.19 and 4.20.

Table 4.19. Yearly rate of leakage of SF_6 from different processes

Non-combustion emission source	Leakage rate (per cent of input of SF_6)
Secondary magnesium foundries	100
Tracer gas in the offshore sector	0
Tracer gas in scientific experiments	100
Production of semiconductors	50
Medical use	100
Production of sound-insulating windows	2
Other minor sources	100

Source: SFT (1999c).

Table 4.20. Product lifetimes and leakage rates from products containing SF_6

Product emission source	Yearly rate of leakage (per cent of remaining content)	Product lifetime (years)
Gas-insulated switchgear (GIS)	1	30
Electrical transformers for measurements	1	30
Sound-insulating windows	1	30
Footwear (trainers)	25	9
Other minor sources	..	..

Source: SFT (1999c).

4.6.2.5. Completeness

Major missing emission components are not likely.

4.6.2.6. Source specific QA/QC

During the work with the new methodology for 2003 emissions, historical data were recalculated, emission factors from different sources were established and the bank of SF_6 in existing installations were estimated. New sources that have been included in this inventory were emissions from production of GIS, the use of SF_6 as a tracer gas, in medical surgery, in the production of semiconductors and in sound-insulating windows, and emissions of SF_6 from electrical transformers and footwear. Some other minor sources were also included. For GIS, information from the industry, attained through the voluntary agreement with the Ministry of Environment, was important input in this recalculation.

5. Solvent and other product use

IPCC 3
NFR 3

5.1. Overview

This chapter describes emissions from solvents and other products. Use of solvents and products containing solvents lead to emissions of non-methane volatile organic compounds (NMVOC), which is regarded as an indirect greenhouse gas. The NMVOC emissions will over a period of time in the atmosphere oxidise to CO_2.

In addition to solvents emitting NMVOC, there are other products that emit other volatile components. PAH emissions from creosote treated materials and tarry jointing paste cause emissions of PAH. PAH and dioxin are also emitted during production of asphalt. Emissions of N_2O from anaesthesia procedures and spray cans as well as mercury from mercury-containing products are also included in the Norwegian inventory.

5.2. Solvent losses (NMVOC)

IPCC 3A, 3B and 3C
NFR 3A, 3B and 3C
Last update: 01.09.05

5.2.1. Method

The methodology used to estimate emissions from use of solvents and products containing solvents has been based on a solvent balance approach (Rypdal 1995a). This method was used for 1990-1998 but has since then not been updated annually. The methodology described here is therefore the one used from 1990-1998. 1998 figures are used for the following years.

Solvents are both imported to and produced in Norway. Most of the solvents used will sooner or later evaporate to air. Solvents not emitted within the country are either exported, used as raw materials, incinerated or broken down in water. The solvent balance follows the flow of solvents from production, imports and exports, via transformation, to incineration or consumption. This methodology gives independent emission estimates for each year of inventory and in principle covers all fugitive sources.

The equation applied for the solvent balance is:

(19) *Emissions = [(Production + Imports - Exports - Destruction - Raw material use) *Solvent content *Fraction emitted] + Emissions from certain industrial processes*

The solvent balance is based on the commodities in the foreign trade and production statistics that are either pure solvents or contain solvents. The equation is applied to each commodity, and total emissions are given by the sum of emissions from all commodities.

In the following, data of major importance for the solvent balance are described.

- *Imports and exports* of the various commodities are determined by Statistics Norway in collaboration with the customs authorities.
- *Production* of the commodities in Norway is based on the manufacturing statistics from Statistics Norway, which cover all main manufacturers annually.
- *Destruction* of solvent waste and paint is given by official statistics on waste delivered and incinerated (Norsas). In addition, the Norwegian Pollution Control Authority (SFT) has information about incineration in licensed plants.
- *Raw materials* used in industrial processes: data are gathered by Statistics Norway (Manufacturing Statistics). However, these data are not collected annually, but at roughly five-year intervals. Due to the infrequent collection these data make a large contribution to the uncertainty in the related emission figures.
- The *solvent content* is determined using several sources, the most important of which is the Norwegian Product Register. The average solvent content is determined from the average chemical composition of the product category. The solvent contents of the remaining commodities are, with few exceptions, taken from investigations in other countries.
- *Fraction emitted* to air: An amount is estimated for each commodity. Generally, the fraction is higher

for products that are not water soluble than for those that are.
- In certain *industrial processes* where solvents are used as raw materials, fractions of the solvents may evaporate to air. Emissions from these plants have been added to the solvent balance where data are available. The emission estimates or emission factors are provided by the Norwegian Pollution Control Authority. However, figures have not been delivered every year and are not available for the most recent years for several plants.

NMVOC and CO_2
The use of solvents leads to emissions of non-methane volatile organic compounds (NMVOC), which is regarded as an indirect greenhouse gas. The NMVOC emissions will over a period of time in the atmosphere oxidise to CO_2, which is included in the total greenhouse gas emissions reported to UNFCCC (see chapter 1.9).

5.2.2. Activity data
Activity data used in the solvent balance is collected by Statistics Norway in cooperation with authorities like the Norwegian Pollution Control Authority and the Norwegian Product Register.

5.2.3. Uncertainties
An uncertainty analysis was performed for long-range transboundary air pollutants by Statistics Norway (Rypdal and Zhang 2001). The analyses conclude that the source category Solvents are one of the highest ranked NMVOC sources with regard to uncertainty.

Of the data used in the solvent balance, listed above, the amount of *raw materials* used in industrial processes and the *fraction emitted* to air will probably be the most uncertain figures and contribute most to the uncertainty in the figures for total emissions of solvents.

As mentioned earlier in this chapter, the calculations have not been updated since 1998, so the figures reported for instance for 2002, are actually the 1998 figures. The methodology needs to be reviewed and improved before calculating new data.

5.2.4. Completeness
No major missing emission sources are likely.

5.2.5. Source specific QA/QC
Internal checks of the time-series of calculated emissions data and input activity data have been conducted by Statistics Norway and corrections are made when errors are found.

5.3. Use of solvents
IPCC -
NFR 3C
Last update: 01.09.05

5.3.1. Creosote-treated materials
5.3.1.1. Description
Creosote is mainly used in quay materials and conduction poles, but also in fence poles and roof boards. In Norway there is a requirement that all creosote in use should contain less than 50 mg/kg benzo(a)pyren (NTI 2000). PAH-components will evaporate from the creosote-treated materials in hot weather. In addition, PAH-components will evaporate during impregnation. The smallest PAH-components, like naphthalene, are most volatile, but several components used in wood treatment will not evaporate. It is assumed that 5-10 per cent will evaporate during the first 3-4 years (Evans 2000), depending on the creosote oil used.

5.3.1.2. Method
Emission of PAH is calculated based on the import of creosote oil and emission factors. For simplicity, it is assumed that all PAH is emitted the same year as the materials are produced.

5.3.1.3. Activity data
Imported data of creosote oil (product 27.07.9100) is given by statistics of foreign trade at Statistics Norway.

5.3.1.4. Emission factors
The emission factors used, are those recommended used in the Norwegian Pollution Control Authority's guidelines for reporting to the North Sea agreement and based on foreign studies (table 5.1).

Table 5.1. Emission factors for evaporating from creosote-treated materials. 10^{-6} kg/m^2/year

Name	Wood treated in "old days"	Recently treated wood
	10^{-6} kg/m^2/year	10^{-6} kg/m^2/year
Benzo(a)pyrene	0.74	0.74
Benzo(b)fluoranthene	..	..
Benzo(k)fluoranthene	0.15	0.15
Indeno(1,2,3-cd)pyrene	0.016	0.016
Fluoranthene	370	520
Benzo(ghi)perylene	..	..
Fenanthrene	1400	4800
Anthracene	52	260
Pyrene	..	..
Benzo(a)fluorene	..	..
Benzo(b)fluorene	..	..
Benzo(a)anthracene	11	70
Crysene/triphenylene	13	13
Benzo(e)pyrene	..	..
Dibenzo(ah)anthracene	..	..
Dibenzo(ae)pyrene	..	..
Dibenzo(ah)pyrene	..	..
Dibenzo(ai)pyrene	..	..
Acenaphthene	..	..
Fluorene	..	..
Norwegian standard 9815	1 847 (100.0)	5 664 (100.0)
Borneff (PAH-6)	371 (20.1)	521 (9.2)
LRTAP (PAH-4)	1 (0.1)	1 (0.0)

Source: SFT (2001a).

5.3.1.5. Uncertainties
In the inventory it is assumed that all PAH is emitted the same year as the materials are used. This is however not the case since PAH will be emitted as long as the creosote-treated materials are in use. However, most of it is likely to be emitted during the first years.

See also chapter 5.2.3.

5.3.1.6. Completeness
No major missing emission components or sources are likely.

5.3.1.7. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

5.3.2. Tarry jointing paste

5.3.2.1. Method
Tarry jointing paste contains PAH-components and can evaporate to air. NILU/NIVA (1995) have estimated an annual emission of 125 kg/year. This estimation is based on imported tarry paste and a tar content of 16 per cent. This kind of jointing paste is mainly used at airports. There is no available PAH-profile for this emission, and due to the lack of data, the same PAH-profile as that of asphalt production is used (table 5.2). The emission is assumed to be rather constant each year.

Table 5.2. Emission of PAH from use of tarry jointing paste[1]. kg PAH/year

Norwegian standard 9815	125
Borneff (PAH-6)	3
LRTAP (PAH-4)	0.0

[1] Emission factors are from production of asphalt.

5.3.2.2. Uncertainties
There is uncertainty regarding the PAH-profile since in lack of a specific profile, the same PAH-profile as for asphalt production is used.

5.3.2.3. Completeness
There are a couple of very minor sources of PAH that are not included in the Norwegian inventory. PAH-containing products are used in tar paper and fishing net. According to NILU/NIVA (1995), the annual emissions are low. In Rypdal and Mykkelbost (1997), emission factors of 0.3 g/tonnes and 28 g/tonnes are given for tar paper and fishing net respectively, but emissions from these sources are not included in the inventory.

Also anticorrosive paint used for treatment of ships and platforms is a potential source for PAH emissions. In Rypdal and Mykkelbost (1997), emission factors of 7.5 mg/ship/year at shipyard, 1.9 mg/ship/year at harbour and 96 mg/ship/year in service are given. This presupposes treatment each third year. The emissions are low compared to other sources and not included in the inventory.

5.3.2.4. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

5.4. Production of asphalt

IPCC -
NFR 3C
Last update: 01.09.05

5.4.1. Method

PAH
Most of the asphalt produced in Norway uses the batch-method (Haakonsen et al. 1998). Emissions are calculated by multiplying the amount of asphalt produced with an emission factor.

Dioxin
Asphalt preparations and asphalt recycling are supposed to be a possible dioxin source, especially in countries using extensive recycling, and that use salt on the roads during winter. A lot of salt is used on Norwegian roads during winter, and when this asphalt is heated during recycling, it is assumed to give emissions of dioxins (Hansen 2000).

5.4.2. Activity data

The activity data used is production of asphalt in Norway. In NILU/NIVA (1995), there is a figure of production of asphalt from 1991. The same figure is used for all years due to the lack of better data.

5.4.3. Emission factors

PAH
NILU/NIVA (1995) estimated the emission of PAH to be 15 mg/tonne asphalt. This includes however naphthalene and other components not to be included in PAH after Norwegian standard (NS3815). However, if this emission factor is combined with speciation data from Jebsens miljøteknikk (1991), an emission factor of 2.8 mg/ton is found. This agrees well with the emission factor 2.0 mg/ton suggested by US. EPA.

Dioxin
Two emission factors are found in the literature. OSPAR (SFT 2001a) suggest an emission factor of 0.047 μg/ton asphalt. This emission factor is however assumed to be very high since it is based on data from a plant only re-circulating old asphalt. Fyns Amt (2000) operates with a much lower emission factor, which probably reflects dioxin emissions from preparation of new asphalt. Since Norway both makes new asphalt and recycles old asphalt it is assumed that an emission factor in between those suggested from OSPAR and Fyns Amt would be most correct for Norwegian conditions (table 5.3).

Table 5.3 Dioxin emission factor for asphalt production. µg I-TEQ/tonne produced asphalt

Source	Emission factor
OSPAR (SFT 2001a)	0.047
Fyns Amt (2000)	0.0022
Emission factor chosen	0.025

5.4.4. Uncertainties
The activity data used are from 1991, and due to the lack of better information, the same figure has been used for all years. The emission factors used, both for estimating PAH and dioxin, are also uncertain. The annual emissions are low however, and will not have any impact on the total level of these types of emissions.

5.4.5. Completeness
No major missing emission components are likely.

5.4.6. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

5.5. Other product use
IPCC 3D
NFR 3D
Last update: 01.09.05

5.5.1. Use of N_2O in anaesthesia
5.5.1.1. Method
N_2O is used in anaesthesia procedures and will lead to emissions of N_2O. The figures are based on N_2O data from the two major producers and importers in 2000. In the inventory, sale is set to be equal to consumption in each year.

5.5.1.2. Activity data
For this source, actual sale of N_2O is used for the year 2000.

5.5.1.3. Emission factors
As mentioned, no emission factors are used since the figures are based on sales of N_2O.

5.5.1.4. Uncertainties
The figures are uncertain. There may be small importers not included in Statistics Norway's telephone survey with 2000 data, but the emissions are small, so it is believed that the uncertainty is at an acceptable level.

5.5.1.5. Completeness
A minor consumption from small importers may be missing, but these will probably account for an insignificant fraction of the total N_2O emissions.

5.5.1.6. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

5.5.2. Use of N_2O as propellant
N_2O is used as a propellant in spray boxes, and this use will lead to emissions of N_2O. It is also used in research work, for instance in the food industry and at universities. Small amounts are used at engineering workshops, among others for dragracing. There is no production of N_2O for these purposes in Norway.

5.5.2.1. Method
Information on sale volumes is given from the plants to Statistics Norway. Statistics Norway assumes that all propellant is released to air.

5.5.2.2. Uncertainties
The figures for 2000 are used for all years. It is believed that all figures from all major importers are included in the inventory.

5.5.2.3. Completeness
No major missing emission components are likely.

5.5.3. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

5.5.4. Mercury-containing products
5.5.4.1. Method
Breakage of mercury-containing thermometers, fluorescent tubes and various measuring- and analytical instruments lead to emissions of mercury. The emission estimates are based on an annual report from the Norwegian Pollution Control Authority ("Miljøgifter i produkter"). The sale of mercury-containing thermometers and fluorescent tubes has decreased strongly since the mid-1990s, and the mercury content in these products has been reduced. A prohibition against the production, import and export of mercury-containing products began in 1998, except for some thermometers for professional use, which were then prohibited in 2001. Since these products have long operating life times, there will be emissions from these products for many years. In the calculations, however, it is assumed that the emissions occur the same year as the product is sold.

For thermometers, it is assumed that all mercury is emitted in hospitals, despite some breakage of mercury-containing thermometers that occur in households. For fluorescent tubes, all emissions are placed in households, although emissions exist in all sectors. For measuring and analytical instruments, all emissions are placed under research and development work.

5.5.4.2. Uncertainties
The emissions are assumed to be emitted the same year as the products are sold. This is not accurate, since most of these products have long operating life times. It is however impossible to predict the annual breakage and the mercury content in each of them.

5.5.4.3. Completeness
No major missing emission components are likely.

5.5.4.4. *Source specific QA/QC*
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

6. Agriculture

IPCC 4
NFR 4
Last update: 01.09.05

6.1. Overview

Agriculture contributes particularly to CH_4, N_2O and NH_3 emissions. Domestic animals are the major source of CH_4 emissions from agriculture. Both enteric fermentation and manure management contribute to non-combustion emissions of CH_4. Manure management also generates emissions of N_2O.

Microbiological processes in soil lead to emissions of N_2O. Three sources of N_2O are distinguished in the IPCC methodology and are included in the Norwegian inventory:

1. direct emissions from agricultural soils (from use of synthetic fertilisers, animal excreta nitrogen used as fertiliser, biological nitrogen fixation, crop residues, industrial and urban wastes and cultivation of soils with a high organic content)
2. direct soil emissions from animal production (emissions from droppings on pastures)
3. N_2O emissions indirectly induced by agricultural activities (N losses by volatilisation, leaching and runoff).

Animal manure and the use of fertiliser also generate emissions of NH_3. Another source of NH_3 is treatment of straw using NH_3 as a chemical. Non-combustion emissions of particles in the agricultural sector are also calculated.

There are also some emissions arising from the burning of agricultural residues described in chapter 6.5.

6.2. Emissions from enteric fermentation in domestic livestock

IPCC 4A, Key category for CH_4
NFR -
Last update: 01.09.05

6.2.1. Description

CH_4 is the only important pollutant emitted from this source category. NH_3 can be emitted in small amounts, but no separate estimates have been made for NH_3 from manure. The production of CH_4 by enteric fermentation in animals varies with digestive system and feed intake. Ruminants such as cattle and sheep produce most methane. However, enteric fermentation in pseudo-ruminants (e.g. horses) and monogastric animals (e.g. pigs) is also of significance. Norway has also tame reindeer emitting some CH_4 that is included in the inventory.

6.2.2. Method

The methodology for calculating CH_4 from enteric fermentation is in accordance with IPCC's Good Practice Guidance Tier 1 method (IPCC 1997a, 1997b). The numbers of animals of each kind and average emission factors of tonnes CH_4/ animal/ year for each kind of animal are used to calculate the emissions.

6.2.3. Activity data

Emissions are estimated from the animal population (IPCC Tier 1). The main source of the livestock statistics is the register of production subsidies. The register covers 90-100 per cent of the animal populations, except for horses and reindeer. The register is used in order to get consistent time series of data. Animals are counted twice a year and the register is updated with these counts. The average number of the two counts is used. In addition to the animals included in the register of production subsidies, an estimate of the number of horses that are not used in farming is obtained from the Norwegian Agricultural Economics Research Institute (NILF). The number of reindeer is obtained from the Norwegian Reindeer Husbandry Administration.

For some categories of animals not living a whole year, for instance lambs, lifetime is taken into account to get a yearly average for the number of animals. An expert judgment suggests an average lifetime of 143 days for lambs (UMB 2001). The formula for calculating the average figure for lambs will then be:

(20) $$\text{Lambs} * \frac{143}{365}$$

There exist some differences between these numbers and the FAO statistics. The explanation is that the figures to the FAO are supplied by the NILF. NILF elaborates an overall calculation for the agricultural sector, which is the basis for the annual negotiations for the economic compensation to the sector. The overall calculation includes a grouping of all agricultural activities, comprising area, number of animals and production data. This method is a little different from the one used by Statistics Norway. Differences include

- Different emphasis on the dates for counting, 31.07 and 31.12
- NILF does not register pigs under 8 weeks, whilst Statistics Norway does.

6.2.4. Emission factors

The emissions depend on several factors and therefore vary between different individuals of one kind of animal. However, because of a lack of data to perform Tier 2 calculations, the Tier 1 default emission factors for each kind of animal (IPPC 1997a, 1997b) are used. The emissions from domestic reindeer, deer, ostrich and fur-bearing animals are included in the Norwegian calculations. Emission factors for these animals are developed by scaling emission factors for other animals that are assumed most similar with regard to digestive system and feeding. The scaling is done by comparing average weights for the actual animal groups. The emission factor used for reindeer is 11 kg/animal/yr, and has been estimated by scaling the emission factors for goats and sheep according to carcass weight. The emission factor for deer of 52.64 kg/animal/yr has been estimated by scaling the emission factor for dairy cattle, and the emission factor 4.97 kg/animal/yr for ostrich by scaling the emission factor for horses. The emission factor for fur-bearing animals is set to 0.10 kg/animal/yr, and has been estimated by scaling the emission factor for swine.

Table 6.1. Emission factors for CH_4 from enteric fermentation and different animal types

Animal	Emission factor (Tonnes/animal/year)
Dairy cattle	0.1
Non-dairy cattle	0.048
Horses	0.018
Sheep, incl. lambs	0.008
Goats	0.005
Pigs	0.0015
Hens	0.00002
Turkeys	0.00002
Reindeer	0.011
Deer	0.053
Ostrich	0.0050
Fur-bearing animals	0.0001

Source: IPCC (1997a, 1997b) and Agricultural Statistics from Statistics Norway.

6.2.5. Uncertainties

Activity data

The data are considered to be known within ±5-10 per cent. There is also an uncertainty connected to the fact that some animals are only alive part of the year.

Emission factors

Although the emissions depend on several factors and therefore vary between different individuals of one kind of animal, average emission factors for each kind are used. The standard deviation of the emission factors is considered to be ±25 per cent. The use of IPCC Tier 1 emission factors leads to enhanced uncertainty compared with Tier 2.

6.2.6. Completeness

Major missing emission sources are not likely. There has been a tendency the last years for an increase in the body mass for dairy cattle. This constitutes an uncertainty factor that is not reflected in the simple Tier 1 methodology.

6.2.7. Source specific QA/QC

In 2001, a project was initiated to determine the exact number of animal populations. This was completed in 2002. The revised data on animal populations form the basis for the emission calculations for all years.

6.3. Emissions from manure management

IPCC 4B
NFR 4B
Last update: 01.09.05

6.3.1. Description

The relevant pollutants emitted from this source category are CH_4 (IPCC 4B(a)), N_2O (IPCC 4B(b)) and NH_3 (NFR 4B).

Organic material in manure is transformed to CH_4 in an anaerobic environment by microbiological processes. Emissions from cattle are most important in Norway for all three components. The emissions from manure depend on several factors; type of animal, feeding, manure management system and weather conditions (temperature and humidity).

During storage and handling of manure (i.e. before the manure is added to soils), some nitrogen is converted to N_2O. The amount released depends on the system and duration of manure management. Solid storage and dry lot of manure is the most important source.

In the IPCC default method a NH_3 volatilisation fraction of 20 per cent is used for the total N excretion by animals in the country. But in the Norwegian emission inventory, yearly updated NH_3 volatilisation values from Statistics Norway's NH_3 model are used, which are expected to give more correct values for Norway. Emissions of NH_3 from manure depend on

several factors, e.g. type of animal, nitrogen content in fodder, manure management, climate, time of spreading of manure, cultivation practices and characteristics of the soil.

6.3.2. Method

CH_4

Emissions of methane from manure are estimated using the following equation, in accordance with the IPCC Tier 2 method (IPCC 1997a, 1997b):

$$(21)\quad E_i = \frac{N_i \cdot M_i \cdot VS_i \cdot B_{0_i} \cdot MCF_i}{1000}$$

E: Emissions of methane
N: Population of animals
M: Production of manure (kg/animal/year)
VS: Volatile solids (per cent)[6]
B_0: Maximum methane-producing capacity (m^3/kg-VS)
MCF: Methane conversion factor
$_i$: Species

Table 6.2. Norwegian factors used to estimate CH_4 from manure management in the IPCC Tier 2 method

	Manure production (kg/ animal/day)	VS (per cent)	B_0 (m^3/kg-VS)	MCF (per - cent)
Dairy cattle	45	9.2	0.18	8
Bulls > 1 year	35	9.2	0.21	8
Heifers > 1 year	30	9.2	0.21	8
Non-dairy cattle < 1 year	15	9.2	0.21	8
Horses	25.5	16.4	0.21	8
Sheep > 1 year	2	19.5	0.19	5
Sheep < 1 year	1	19.5	0.19	5
Diary goats	1.8	23	0.19	5
Other goats	1	23	0.19	5
Pigs for breeding	9	9.5	0.21	8
Pigs for slaughter	4.5	9.5	0.21	8
Hens	0.16	15.6	0.25	8
Chicks bred for laying hens	0.085	19.4	0.25	8
Chicks for slaughter	0.085	19.4	0.25	8
Ducks for breeding	0.17	16	0.25	8
Ducks for slaughter	0.057	16	0.25	8
Turkey and goose for breeding	0.7	16	0.25	8
Turkey and goose for slaughter	0.29	16	0.25	8
Mink, males	0.35	16	0.25	8
Mink, females	0.7	16	0.25	8
Fox, males	0.56	16	0.25	8
Fox, females	1.12	16	0.25	8
Reindeer	2	19.5	0.19	2
Deer	23.7	9.2	0.18	8
Ostrich	7.05	16.4	0.21	8

Source: Agricultural Statistics from Statistics Norway and Norwegian University of Life Sciences.

The factors M, VS, B_0 and MCF are average factors meant to represent the whole country. The factor B_0 represents the maximum potential production of methane under optimum conditions. MCF is a correction of B_0 according to how the manure is handled reflecting Norwegian manure handling practices for each type of animal waste. The factors are estimated jointly by Statistics Norway and the Norwegian University of Life Sciences (Institute of Chemistry and Biotechnology, Section for Microbiology).

N_2O

In Norway, all animal excreta that are not deposited during grazing are managed as manure. N_2O from manure is estimated in accordance with the IPCC default method (IPCC 1997b), but with Norwegian values for N in excreta from different animals according to table 6.3. Norwegian values are also used for the fraction of total excretion per species for each management system (MS) and for pasture. The same fractions are used every year and are given in table 6.3.

Table 6.3. N in excreta from different animals

	kg/animal/year[1]
Dairy cattle	82
Heifer < 1 year	29
Bull < 1 year	24
Heifer > 1 year	35
Bull > 1 year	35
Horses	50
Sheep < 1 year	7.7
Sheep > 1 year	11.6
Goats	15.5
Pigs for breeding	18.3
Pigs for slaughtering[2]	4.4
Hens	0.7
Chicks bred for laying hens[2]	0.147
Chicks for slaughtering[2]	0.053
Ducks, turkeys/ goose for breeding[2]	2
Ducks, turkeys/ goose for slaughtering[2]	0.34
Mink	4.27
Foxes	9
Reindeer	6
Deer	12
Ostrich	12

[1] Includes pasture.

[2] Per stalled animal. Stall we define as the room for one animal. An animal that lives one year needs one stall the whole year. But for example in a stall (or pen) for slaughter swine you breed more than one slaughter swine per year. This means that the N in excreta for dairy cattle is from one cattle per year, but for slaughter swine is "per stalled animal" equal to 2.5 slaughter swine per stall (or pen) per year.

Source: Sundstøl and Mroz (1988) and estimations by Statistics Norway.

[6] Volatile solids (VS) are the degradable organic material in livestock manure (IPCC 1997a,b).

Table 6.5. Fraction of total excretion per specie for each management system and for pasture

	Anaero-bic Lagoon	Liquid system	Solid storage and drylot	Pasture range and paddock	Other manure management systems
Dairy cattle	0	0.68	0.05	0.27	0
Non-dairy cattle	0	0.64	0.05	0.31	0
Poultry	0	0.27	0.73	0	0
Sheep	0	0.17	0.38	0.44	0
Swine	0	0.88	0.12	0	0
Other animals	0	0.14	0.41	0.45	0

Source: Gundersen and Rognstad (2001) and data for pasture times from Tine BA (2003) (Dairy cattle, goat), Statistics Norway's Sample Survey 2001 (Statistics Norway 2002) (non-dairy cattle, sheep) and expert judgements.

The emissions of nitrous oxide from manure are estimated using the following equation, in accordance with the IPCC Tier 2 method (IPCC 1997a, 1997b):

$$(22)\quad E = \sum_s \left\{ \left[\sum_i \left(N_i \cdot Nex_i \cdot MS_{i,s} \right) \right] \cdot EF_s \right\}$$

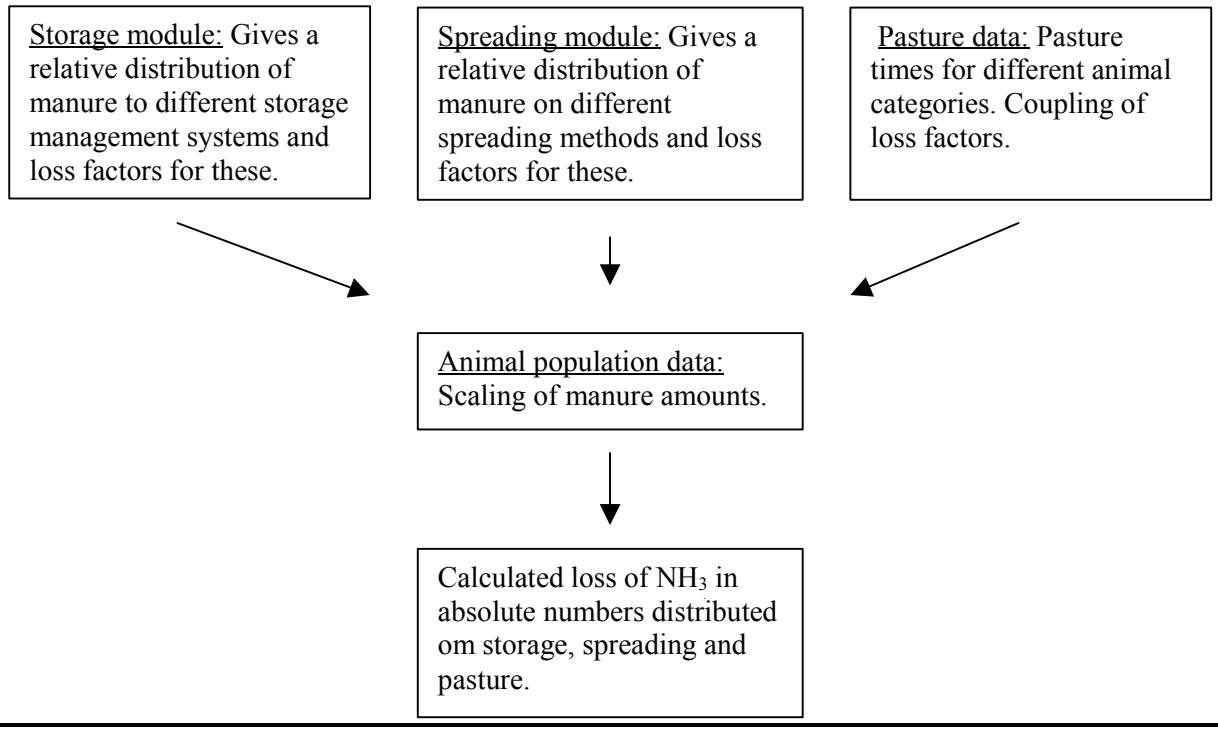
E: Emissions of N_2O-N (kg N_2O-N/year, N_2O-N is the nitrate amount in the nitrous oxide compound)
N: Population of animals
Nex: Annual average N excretion (kg N/animal/year)
MS: Fraction of total excretion per specie for each management system
EF: N_2O emission factor (kg N_2O-N/kg N)
$_s$: Manure management system
$_i$: Species

For liquid system and solid storage and dry lot a correction is made for the NH_3 volatilisation by manure storage.

NH_3
Statistics Norway's NH_3 model is used for calculating the emissions of NH_3 from manure management. The principle of the model is illustrated in figure 6.1.

The storage module in the NH_3 model gives the relative distribution of manure to the different storage management systems. Total emissions from storage are estimated by multiplying the different emission factors for the storage systems by the amount of manure for each storage system, and summarizing the results. The amount of manure is estimated by the number of animals and manure production factors for each type of animal (see table 6.3).

Figure 6.1. The principle of the NH_3 model



6.3.3. Activity data

CH_4 and N_2O

Emissions are estimated from the animal population. How the animal population is estimated is described in section 6.2.3.

NH_3

Activity data on storage systems are rare, and the only source practically available is the Statistics Norway survey of different storage systems in 2000 (Gundersen and Rognstad 2001). Data for storage systems are unavailable for other years than 2000. Analyses and estimations of the effects on emissions of the assumed changes in storage systems since 1990, show that the assumed change is of little significance to the emissions. In addition, data on animal populations are used to estimate the amounts of manure. How the animal population is estimated is described in section 6.2.3.

The manure is distributed to the following storage systems categories:

- Manure cellar for slurry
- Manure pit for slurry
- Indoor built up/deep litter
- Outdoor built up/enclosure
- Storage for solid dung and urine

Each of these categories are given for all combinations of the following productions and regions:

Regions:

- South-Eastern Norway
- Hedmark and Oppland
- Rogaland
- Western Norway
- Trøndelag
- Northern Norway

Production:

- Cattle
- Pork
- Sheep and goat
- Poultry
- Horse, farm raised fur-bearing animals and rabbit

6.3.4. Emission factors

CH_4

The calculated average emission factors for different animal types are shown in table 6.6. They are country specific factors, which may deviate from the IPCC default values.

Table 6.6 Average CH_4 emission factors for manure management in the Norwegian method. Tier 2

	Emission factor (kg/animal/day)
Dairy cattle	14.41
Bulls > 1 year	13.07
Heifers > 1 year	11.20
Non-dairy cattle < 1 year	5.60
Horses	16.98
Sheep > 1 year	0.90
Sheep < 1 year	0.45
Diary goats	0.95
Other goats	0.53
Pigs for breeding	3.47
Pigs for slaughter	1.74
Hens	0.12
Chicks bred for laying hens	0.08
Chicks for slaughter	0.08
Ducks for breeding	0.13
Ducks for slaughter	0.04
Turkey and goose for breeding	0.54
Turkey and goose for slaughter	0.23
Mink, males	0.27
Mink, females	0.54
Fox, males	0.43
Fox, females	0.87
Reindeer	0.36
Deer	7.58
Ostrich	4.69

Source: Agricultural Statistics from Statistics Norway.

N_2O

The IPCC default values for N_2O emission factors from manure management are used in the calculations. These are consistent with the good practice guidance (IPCC 2001).

Table 6.7. N_2O emission factors for manure management per manure management system

Manure management system	Emission factor, kg N_2O-N/kg N
Anaerobic lagoon	0.001
Liquid system	0.001
Daily spread	0
Solid storage and dry lot	0.02
Pasture range and paddock	0.02
Other system	0.005

Source: IPCC (1997b).

NH_3

Emission factors vary with production and storage system; in the model there is no variation between regions. The factors used are shown in table 6.8:

Table 6.8. Emissions factors for various storage systems and productions. Per cent losses of N of total N

	Storage system						
	Manure cellar for slurry	Open manure pit for slurry	Manure pit for slurry with lid	Open flag-stones	Indoor built up/deep litter	Outdoor built up/enclosure	Storage for solid dung and urine
	Gutter	Gutter	Drainage to gutter				
Cattle, milking cow:							
Loss from animal room	5	5	5	5	8	8	5
Loss from storage room	2	9	2	2	15	15	15
Total loss	7	14	7	7	23	23	20
Pigs:							
Loss from animal room	15	15	15	15	15	15	20
Loss from storage room	4	6	2	2	25	25	30
Total loss	19	21	17	17	40	40	50
Sheep and goats:							
Loss from animal room	15	15	15	15	15	15	15
Loss from storage room	2	6	2	2	10	10	10
Total loss	17	21	17	17	25	25	25
Poultry:							
Loss from animal room	12	10	12	12	25	25	25
Loss from storage room	15	15	15	15	25	25	25
Total loss	27	25	27	27	50	50	50
Other animals:							
Loss from animal room	5	0	0	0	15	15	15
Loss from storage room	10	0	0	0	15	15	15
Total loss	15	0	0	0	30	30	30

Source: Morken (2003a).

The factors in table 6.8 above are based on data from Denmark, Germany and Netherlands, since measurements of NH_3-losses in storage rooms have so far not been carried out in Norway.

The factors are combined with the activity data in the survey (Gundersen and Rognstad 2001), and emission factors for NH_3 emissions from storage of manure and stalled animals are calculated for production and region (table 6.9). To estimate losses, these emission factors are in turn multiplied with the amount of manure (based on number of animals and N-factors per animal). The number of animals is the only activity data that differs from year to year. New additional data on storage facilities will be available from the sample survey of agriculture and forestry 2003.

Table 6.9 Average emission factors for the manure storage systems used, distributed on type of animal production and region. Per cent of total N

	South-Eastern Norway	Hedmark/ Oppland	Roga-land	Western Norway	Trønde-lag	Northern Norway
Cattle	9.6	8.2	8.8	8.1	7.7	7.7
Pigs	25.4	22.3	20.1	21.5	21.0	21.9
Sheep and goats	23.5	22.8	19.1	22.1	22.8	23.4
Poultry	47.0	46.4	38.7	37.3	41.7	44.5
Other animals	27.9	25.5	20.2	24.5	26.3	25.6

Source: Statistics Norway, NH_3-model estimations.

6.3.5. Uncertainties

6.3.5.1. Activity data

CH_4

The data for the number of animals are considered to be known within ±5-10 per cent (Rypdal and Zhang 2000). There is also an uncertainty connected to the fact that some animals are only alive part of the year. Other activity data is the treatment of manure (which will determine the emission factor), which has been assessed by expert judgements. This will contribute to the uncertainty.

N_2O

Emissions are estimated from the animal population. The data are considered to be known within ±5-10 per cent (Rypdal and Zhang 2000). There is also an uncertainty connected to the fact that some animals are only alive part of the year.

For the emissions of N_2O from manure management, Norwegian data for N in excreta are used. The nitrogen excretion factors are uncertain, but the range is considered to be within ±15 per cent (SFT 1999a). The uncertainty is connected to differences in excretion between farms in different parts of the country, that the survey farms may not have been representative, general measurement uncertainty and the fact that fodder and fodder practices have changed since the factors were determined.

There is also an uncertainty connected to the division between different storage systems for manure.

NH_3
Animal population data are considered to be known within ±5-10 per cent (Rypdal and Zhang 2001). There is also an uncertainty connected to the fact that some animals are only alive part of the year. The uncertainty for manure use is considered to be ±20 per cent (Rypdal and Zhang 2001). Uncertainty connected to the distribution between storage systems has not been estimated, but this uncertainty is assumed to be much larger than the uncertainty in the animal population data.

6.3.5.2. Emission factors
CH_4
Norway is using the IPCC default factors (Tier 2 methodology) for the emission of CH_4, but with some national data. The emission factors are considered to have the uncertainty range ±25 per cent (Rypdal and Zhang 2000).

N_2O
For the emission of N_2O from different storage systems, IPCC default emission factors are used. They have an uncertainty range of -50 to +100 per cent (IPCC 2001) except for the storage category "daily spread" where it is not applicable.

NH_3
Ammonia emissions from agriculture are estimated based on national conditions. There is not made any uncertainty analysis for the revised NH_3 model, which is in use since 2003. The revision of the model has reduced the uncertainty, but there are still uncertainties in several parameters (fraction of manure left on pastures, amount of manure, conditions of storage, conditions of spreading and climate conditions).

6.3.6. Completeness
Major missing emission sources are not likely.

6.3.7. Source specific QA/QC
In a Nordic project in 2002, the results for emissions of both CH_4 and N_2O from manure management in the national emission inventories have been compared with the results using the IPCC default methodology and the IPCC default factors (Petersen and Olesen 2002). This study contributed to discover differences and gaps in each of the Nordic national methodologies.

Statistics Norway has, in cooperation with the Norwegian University of Life Sciences (UMB), made improvements in the calculation model for NH_3 emissions from the agricultural sector. Data sources used for the recalculations in the revised NH_3 model are coefficients from the Norwegian University of Life Sciences, and two surveys from Statistics Norway; a manure survey (Gundersen and Rognstad 2001) and the sample survey of agriculture and forestry (2001). Statistics Norway's detailed manure survey gives more extended activity data which are better related to emission source categories, for manure management and spreading. New loss factors for different manure management categories are also used in the revised NH_3-model. These factors are closer connected to specific activities.

6.4. Direct and indirect emissions from agricultural soils
IPCC 4D, Key category for N_2O
NFR 4D
Last update: 01.09.05

6.4.1. Description
Three sources of N_2O from agricultural soils are distinguished in the IPCC methodology, namely:

- Direct emissions from agricultural soils (from use of synthetic fertilisers, animal excreta nitrogen used as fertiliser, biological nitrogen fixation, crop residues, industrial and urban wastes and cultivation of soils with a high organic content);
- Direct soil emissions from animal production (emissions from droppings on pastures);
- N_2O emissions indirectly induced by agricultural activities (N losses by volatilisation, leaching and runoff).

The use of synthetic fertilisers, animal excreta nitrogen used as fertiliser, and droppings on pastures also results in emissions of NH_3. For these sources, the calculated amount of nitrogen that is emitted directly as N_2O has been corrected for the nitrogen emitted as NH_3.

6.4.2. Method
6.4.2.1. Synthetic fertiliser
N_2O
The direct emissions of N_2O from use of synthetic fertiliser are calculated from data on total annual amount of fertiliser sold in Norway and its nitrogen content, multiplied with the IPCC default emission factor. The emissions are corrected for NH_3 that volatilises during spreading.

NH_3
Statistics Norway's NH_3 model (described in section 6.3.2) is used for calculating the emissions of NH_3 from the use of synthetic fertiliser. The calculations of NH_3 emissions from the use of synthetic fertiliser are based on the amounts of nitrogen supplied and emission factors for the percentage of nitrogen emitted as NH_3 during spreading.

6.4.2.2. Manure applied to soils

N_2O

In Norway, all animal excreta that are not deposited during grazing are used as manure and applied to soils. Further, it is assumed that animals do not emit N_2O themselves, but emissions of N_2O and NH_3 from manure management before manure application on fields will be taken into account (see section 6.3.2).

The emission of N_2O from manure used as fertiliser is calculated by multiplying the total amount of N in manure used as fertiliser with the IPCC default emission factor. The N_2O emissions are corrected for NH_3 that volatilises during spreading.

NH_3

Statistics Norway's NH_3 model is used for calculating emissions of NH_3 from spreading of manure on cultivated fields and meadow. The principle for the model is given in figure 6.1in chapter 6.3.2. A spreading module in the NH_3 model gives the relative distribution of manure spread as fertiliser, distributed on different spreading methods. Total emissions from spreading are estimated by emission factors for the different spreading methods multiplied by the amount of manure. The amount of manure is estimated by the number of animals and manure production factors for each type of animal.

6.4.2.3. N_2O from biological nitrogen fixation

Another source of N_2O emissions is biological nitrogen fixation. The most important N-fixing crop in Norway is clover. The amount of nitrogen fixed by a crop is very uncertain, and it is difficult to assign a conversion factor for N_2O emissions derived from nitrogen fixation (IPCC 1997a, 1997b). The amount of nitrogen fixed is multiplied with the IPCC default emission factor.

6.4.2.4. N_2O from crop residues

Concerning re-utilisation of nitrogen from crop residues, there is only limited information. N_2O emissions associated with crop residue decomposition are calculated by estimating the amount of nitrogen entering soils as crop residue, as recommended by the IPCC (1997a, 1997b). The amount of nitrogen in crop residues returned to soils is assumed to be equal to that in the harvest (Aakra and Bleken 1997). The amount of different harvested crops are multiplied with country specific N-factors, see table 6.10. The amount harvested N has then been corrected for the amount burned on fields and for the water content that is set as 15 per cent (IPCC default for wheat and barley). The remaining amount has been multiplied with the IPCC default emission factor.

Table 6.10. N-factors used for the calculation of the nitrogen content in crop residues

	per cent N
Grass	1.8
Cereals	1.7
Straw	0.6
Potatoes	0.35
Roots for feed	0.25
Green fodder	0.25
Fruits	0.06
Berries	0.11
Vegetables	0.25

Source: Aspmo (1986) and Statistics Norway.

6.4.2.5. N_2O from industrial and urban wastes

No data are available for the amount of N in industrial waste applied as fertiliser, but this source is assumed to be very limited in Norway. Data for the N_2O emission arising from sewage sludge applied on fields has been calculated by multiplying the amount of nitrate in the sewage sludge applied with the IPCC default emission factor. Statistics Norway (waste water statistics) annually gives values for the amount of sewage sludge, and the fraction of the sewage sludge that are applied on fields. The N-content in the sludge is given in Statistics Norway (2001), and the same value of 2.82 per cent are used for all years.

6.4.2.6. N_2O from cultivation of soils with a high organic content

Large N_2O emissions occur as a result of cultivation of organic soils (histosols) due to enhanced mineralization of old, N-rich organic matter (IPCC 1997a, 1997b). The emissions are calculated using the IPCC default emission factor of 8 kg N_2O-N/ha per year, and an approximation of the area of cultivated organic soil in Norway. The same activity data are used for all years, due to lack of annual data. Jordforsk (the Norwegian Centre for Soil and Environmental Research) has estimated that there is about 64 438.1 ha organic agriculture soils based on more than 500 000 soil samples. However, they expect organic soils to be underrepresented in their sampling. Jordforsk expect the real area to be between 70 000 and 100 000 ha (Jordforsk 2004). It is assumed to be 85 000 ha in the calculations. The area estimate of organic soils is based on measurements of C in soil (Jordforsk 2004). The estimate takes into account that the C in soil is gradually decreased and after some decades the soil is no longer classified as organic.

6.4.2.7. Direct soil emissions from animal production (emissions from droppings on pastures)

N_2O

The fraction of the total amount of animal manure produced that is droppings on pastures is given by national data for the distribution of manure to different storage systems (Gundersen and Rognstad 2001) and data for pasture times (table 6.5). The amount of N deposited during grazing is multiplied with the IPCC default emission factor. The resulting

emissions are corrected for the amount of NH_3 volatilised.

NH_3
Statistics Norway's NH_3 model is used for calculating the emissions of NH_3 from pastures. Animal population data, data for pasture times, and factors for the nitrate amount in excreta for different animal categories give the nitrate amounts for the animal categories on pastures. Specific emission factors by animal category are used.

6.4.2.8. N losses by volatilisation
Atmospheric deposition of nitrogen compounds fertilises soils and surface waters, and enhances biogenic N_2O formation. Climate and fertiliser type influence the NH_3 volatilisation. Deposition of NH_3 is assumed to correspond to the amount of NH_3 that volatilises during the spreading of synthetic fertiliser, storage and spreading of manure, and volatilisation from pastures. This amount is obtained from Statistics Norway's NH_3 model. The N_2O emissions are calculated by multiplying the amount of N from deposition with the IPCC default emission factor.

6.4.2.9. N_2O from leaching and runoff
A considerable amount of fertiliser nitrogen is lost from agricultural soils through leaching and runoff. Fertiliser nitrogen in ground water and surface waters enhances biogenic production of N_2O as the nitrogen undergoes nitrification and denitrification. The fraction of the fertiliser and manure nitrogen lost to leaching and surface runoff may range from 10 to 80 per cent. The IPCC (1997a, 1997b) proposes a default value of 30 per cent, but in the Norwegian inventory a national factor of 18 per cent (Jordforsk 1998) is used. This country specific factor has been estimated from a runoff model by Jordforsk (Norwegian Centre for Soil and Environmental Research), and is believed to give better results under Norwegian conditions. The amount of nitrogen lost to leaching is multiplied with the IPCC default emission factor to calculate the emission of N_2O.

6.4.3. Activity data
N_2O
The activity data significant for the estimation of direct and indirect emissions of N_2O from agricultural soils and N_2O emissions from pastures, and the sources for the activity data are listed in table 6.11.

Table 6.11. Activity data for non-combustion emissions of N_2O in the agriculture

	Sources
Consumption of synthetic fertilizer	Norwegian Food Safety Authority
Number of animals	Statistics Norway (applications for productions subsidies)
Distribution between manure storage systems	Gundersen and Rognstad (2001)
Pasture times for different animal categories	Tine BA (2003) (Dairy cattle, goat), Statistics Norway's Sample Survey 2001 (Statistics Norway 2002) (non-dairy cattle, sheep), expert judgements.
Biological N-fixation	Aakra and Bleken (1997)
Crop yield	Statistics Norway
Amount of sewage sludge	Statistics Norway, waste water statistics
Fraction sewage sludge applied on fields	Statistics Norway, waste water statistics
Area of cultivated organic soils	Jordforsk (2004)

NH_3
Synthetic fertiliser
The Norwegian Food Safety Authority calculates a total value for annual consumption of synthetic fertilisers in Norway based on sale figures. For the calculation of the emission of NH_3 we need a specification of the use of different types of synthetic fertiliser. Due to the lack of newer data, we have to assume that the percentual distribution between the usage of different fertiliser types is the same as in 1994, see table 6.13.

Animal manure applied to soil and pasture
There are several sources of activity data on spreading of manure in the NH_3-model. The main sources are the manure survey in 2000 by Statistics Norway (Gundersen and Rognstad 2001), various sample surveys of agriculture and forestry 1990-2001 and the annual animal population. Animal population is updated annually. The animal population estimation methodology is described in section 6.2.3. Data from the manure survey exists only for 2000, while the data from the sample surveys have been updated for several, but not all, years.

Data for time on pasture and share of animals on pasture are collected from the Sample Survey in Statistics Norway 2000 and from TINE BA (TINE BA is the sales and marketing organisation for Norway's dairy cooperative and covers most of the milk production). The data from TINE BA comprises pasture data for goats and milking cows and is updated annually. All other pasture data are from the Statistics Norway Sample survey 2000. The parameters used in the calculations and their sources are shown in table 6.12.

Table 6.12. Parameters included in the estimation of NH_3 emissions from manure

Parameters (input)	Sources
Number of animals	Statistics Norway (applications for productions subsidies)
Nitrogen factors for manure	Various sources, compiled by Statistics Norway
Area where manure is spread, split on cultivated field and meadow.	Statistics Norway (Sample Surveys of Agriculture), Gundersen and Rognstad (2001)
Area where manure is spread, split on spring and autumn.	Statistics Norway (Sample Surveys of Agriculture), Gundersen and Rognstad (2001)
Cultivation practices concerning the addition of water to manure, spreading techniques, and usage and time of harrowing and ploughing.	Gundersen and Rognstad (2001), expert judgements
Pasture times for different animal categories	Tine BA (Dairy cattle, goats), Statistics Norway's Sample Survey 2001 (non-dairy cattle, sheep), expert judgements.

6.4.4. Emission factors

N_2O

The IPCC default emission factor of 0.0125 kg N_2O-N/kg N has been used for all sources of direct N_2O emissions from agricultural soils, with the following two exceptions: Emissions of N_2O from animals on pastures are calculated using the IPCC factor of 0.02 kg N_2O-N/kg N, and the emissions that occur as a result of cultivation of organic soils are calculated by using the IPCC default emission factor of 8 kg N_2O-N/ha per year (IPCC 2001).

The IPCC default emission factor of 0.01 kg N_2O-N/kg NH_3-N is used to calculate emissions of N_2O from NH_3 volatilised. The IPCC default emission factor of 0.025 kg N_2O-N/kg N lost to leaching/runoff is used.

NH_3

Synthetic fertiliser

Different types of synthetic fertilisers are being used, resulting in different emissions of NH_3. Their share, based on data from 1994, and their NH_3 emission factors are shown in table 6.13.

Table 6.13. Emission factors for NH_3-N for different fertilisers and their share of the total use of fertiliser

Fertiliser	Emission factor (per cent of applied N)	Used (per cent)
Urea	15	0.3
Ammonium sulphate and Ammonium nitrate	5	0.02
Calcium nitrate	0	9.7
Calcium ammonium nitrate	1	10.7
NPK (Nitrogen, phosphate, potassium)	1	77.6
Other	1	1.6

Source: ECETOC (1994) and Norsk Hydro (1995).

Animal manure applied to soil and pasture

Emission factors for spreading of stored manure vary with spreading method, water contents, type and time of treatment of soil, time of year of spreading, cultivation, and region. The basic factors used are shown in table 6.14.

Table 6.14. Emissions factors for NH_3-N for various methods of spreading of manure. Per cent of total N

			Western and northern Norway			Southern and eastern Norway		
			Spring	Summer	Autumn	Spring	Summer	Autumn
Meadow								
Surface spreading			0.5	0.6	0.4	0.5	0.6	0.4
Injection			0.1	0.1	0.05	0.1	0.1	0.05
Water mixing			0.3	0.3	0.2	0.3	0.3	0.2
Dry manure			0.04	0.1	0.1	0.04	0.1	0.1
Open fields								
Method	Time before down-moulding	Type of down-moulding						
Surface spreading	0-4 hrs	plow	0.2		0.2	0.15		0.3
Surface spreading	+ 4 hrs	plow	0.5		0.35	0.4		0.4
Surface spreading	0-4 hrs	harrow	0.4		0.35	0.35		0.35
Surface spreading	+ 4 hrs	harrow	0.5		0.45	0.45		0.45
Water mixing	0-4 hrs	plow	0.1		0.1	0.1		0.15
Water mixing	+ 4 hrs	plow	0.25		0.2	0.2		0.25
Water mixing	0-4 hrs	harrow	0.2		0.2	0.2		0.2
Water mixing	+ 4 hrs	harrow	0.3		0.25	0.25		0.25
Dry manure			0.04		0.1	0.04		0.1

Source: Morken and Nesheim (2004).

Table 6.15. Average NH_3 emission factors for cultivated fields and meadows after time of spreading and region. Per cent. 2000

	South-Eastern Norway		Hedmark/ Oppland		Rogaland		Western Norway		Trøndelag		Northern Norway	
	Field	Meadow	Field	Meadow	Field	Meadow	Field	Meadow	Field	Meadow	Field	Meadow
Spring	32.9	43.1	35.3	43.0	23.2	49.1	4.0	40.4	28.7	46.8	5.1	49.5
Autumn	28.5	31.1	28.9	31.0	21.2	36.0	10.0	29.4	31.1	34.3	11.0	36.4

Source: Statistics Norway, NH_3-model estimations.

The factors in table 6.14 are combined with the activity data in the survey (Gundersen and Rognstad 2001) and a time series on mixture of water in manure, and emission factors for NH_3 emissions from spreading of manure distributed to meadow and cultivated fields, time of season and region are calculated (see table 6.15). These factors are in turn connected to activity data that are updated in the years since 1990, i.e. number of animals (amount of manure), time of spreading and type of cultivation of the areas where the manure is spread.

The emission factors used for the calculation of the NH_3 emissions from grazing animals are shown in table 6.16. These are the same as the emission factors used in Germany (Dämmgen et al. 2002) and Denmark (Hutchings et al. 2001).

Table 6.16. NH_3 emission factors from droppings from grazing animals on pasture. Per cent

	N-loss/N applied
Cattle	7.5
Sheep and goats	4.1
Reindeer	4.1
Other animals	7.5

Source: Dämmgen et al. (2002), Hutchings et al. (2001).

6.4.5. Uncertainties

6.4.5.1. Activity data

There are several types of activity data entering the calculation scheme:

Sales of nitrogen fertiliser: The data are based on sales figures during one year (The Norwegian Food Safety Authority). The uncertainty in the sales figures is within ±5 per cent (Rypdal and Zhang 2000). Another possible error is that sale does not equal consumption in a particular year due to storage. The distribution between the use of the various types of nitrogen fertiliser is fixed to an investigation in 1994, and the error connected to this approach will probably increase over the years.

NH_3 losses from fertilizer containing ammonium (NH_4) are related to soil pH. This could probably also lead to uncertainness, but Norwegian soils are very dominated by soils with low pH, which leads to small losses of this type.

Amount of nitrogen in manure: The figures are generated for each animal type, by multiplying the number of animals with a nitrogen excretion factor. The nitrogen excretion factors are uncertain. However, due to research on nitrogen leakage problems in parts of Norway, the certainty has been improved over time (the range is considered to be within ±15 per cent (SFT 1999a)). The uncertainty is connected to differences in excreted N between farms in different parts of the country, that the farms included in the same survey may not have been representative, general measurement uncertainty and the fact that fodder and feeding practices have changed since the factors were determined.

The uncertainty connected to the estimate of the amount of manure is higher than for the amount of synthetic fertiliser used.

Fate of manure: There is significant uncertainty connected to the allocation of manure between what is used as fertiliser and droppings on pastures.

Nitrogen in crop residues left after harvest: Norwegian factors have been used. These are 40 per cent lower than the IPCC default factors (SFT 1999a). The amount of nitrogen in the harvest is determined within ±10 per cent (SFT 1999a), but the expansion factor to account for nitrogen left after harvest is very uncertain. The assessed uncertainty range is about ±50 per cent (SFT 1999a).

Deposition of other agricultural emissions: The data are based on national NH_3 emission figures. These are within ±30 per cent (SFT 1999a).

Leakage of nitrogen: The upper limit for the leakage is the applied nitrogen. The uncertainty is roughly about ±70 per cent (SFT 1999a).

Cultivation of organic soils: Data are based on a one-year survey, and are uncertain by more than a factor of three (SFT 1999a).

6.4.5.2. Emission factors

N_2O

The uncertainties in the N_2O emission factors are high. In Rypdal and Zhang (2000), a factor of two was assumed, according to IPCC (1997b). In IPCC (2001), these uncertainty intervals have been narrowed somewhat. Aardenne et al. (1998) has estimated a 95

per cent confidence interval uncertainty (in emissions) of -40 to +70 per cent for this source, but this may not contain all systematic errors.

NH_3
The uncertainty in the estimate of emissions of NH_3 from use of fertiliser is assessed to be about ±20 per cent (Rypdal and Zhang 2001). This uncertainty could be lower if better data on fertiliser composition were obtained. The uncertainty is higher for animal manure (±30 per cent (Rypdal and Zhang 2001)). This is due to uncertainties in several parameters (fraction of manure left on pastures, amount of manure, conditions of storage, conditions of spreading and climate conditions) (Rypdal and Zhang 2001). Other factors that could lead to uncertainness are variation in storage periods, variation in house types and climate, variation in manure properties.

6.4.6. Completeness
All sources described in the IPCC reporting guidelines are included in the estimates. However, the emission factors might not be reflecting national conditions.

6.4.7. Source specific QA/QC
In a Nordic project in 2002, the estimates for emissions of direct and indirect N_2O from agricultural soils in the national emission inventories have been compared with the results using the IPCC default methodology and the IPCC default factors. The results for the Nordic countries are presented in a report (Petersen and Olesen 2002). The report concludes that there are significant differences between the Nordic countries in the application of the IPCC methodology. It states that there is a clear need to improve this IPCC methodology and to make it more locally adapted, but based on common guidelines. The emission factors for nitrous oxide from both direct and indirect sources should be differentiated more than what is currently the case. There is a need to re-evaluate the principles of the current IPCC methodology for some of the emissions from manure management.

In 2002, the calculation methodologies for the agricultural soil emission sources have been surveyed and one source has been added (industrial and urban waste). Some work is being done to find more updated activity data.

Statistics Norway has, in cooperation with the Norwegian University of Life Sciences (UMB), made improvements in the calculation model for NH_3 emissions from the agricultural sector. Data sources used for the recalculations in the revised NH_3 model are coefficients from the Norwegian University of Life Sciences, and two surveys from Statistics Norway; a manure survey (Gundersen and Rognstad 2001) and the sample survey of agriculture and forestry (2001). Statistics Norway's detailed manure survey gives more extended activity data which are better related to emission source categories, for manure management and spreading. New loss factors for different manure management categories are also used in the revised NH_3-model. These factors are closer connected to specific activities.

6.5. Emissions from agricultural residue burning (agricultural wastes)
IPCC 4F
NFR 4F
Last update: 01.09.05

6.5.1. Description
Burning of agricultural residues gives emissions of a large range of standard combustion products. Included in the inventory are emissions of CH_4, N_2O and NO_X, the heavy metals Pb, Cd, Hg, As, Cu and Cr, and PAH and dioxin.

6.5.2. Method
CH_4, N_2O and NO_X
The emissions from the burning of crop residues are being calculated according to the guidelines in the IPCC reference manual (IPCC 1997b).

$$(23)\quad CR = CRB * Fdm * Fo * Fc$$

CR:	Amount of carbon released (tonnes C/yr)
CRB:	Amount of crop residue burned (tonnes/yr)
Fdm:	Dry matter fraction
Fo:	Fraction oxidised
Fc:	Carbon fraction

The amount of carbon released is calculated according to equation (23). In the IPCC manual a default value of 0.9 for the fraction oxidised is given, and water content of 15 per cent for wheat and barley, which are the main cereals that gives straw in Norway. To find the C-fraction in Norwegian straw, the default values given for wheat and barley in the IPCC manual are being used, and scaled according to the per cent distribution between the two cereals in Norway in 1999 due to Food and Agriculture Organization of the United Nations (FAO 2002).

$$(24)\quad E_i = CR * ER * MW_i * (N/C)$$

E:	Emissions (tonnes/yr)
CR:	Carbon released (tonnes C/yr)
ER:	Emission ratio
MW:	Molecular weight conversion factor
N/C:	Nitrogen/Carbon-ratio
¡:	Emission component

Table 6.17. Factors used for agricultural residue burning in Norway

Factor	Value			Source
Fdm	0.85			IPCC (1997b)
Fo	0.9			IPCC (1997b)
Fc	0.4643			IPCC (1997b), FAO (2002)
	CH_4	N_2O	NO_x	
ER	0.005	0.007	0.121	IPCC (1997b)
MW	16/12	44/28	46/14	IPCC (1997b)
N/C	-	0.012	0.012	IPCC (1997b)

To calculate the emissions of CH_4, the amount of carbon released is multiplied with an emission ratio. The emission ratio gives the mass of the actual chemical substance emitted (in C-units) related to the mass of the total carbon emissions by residual burning. To get total amount of emissions of the actual emission component, a molecular weight conversion factor must also be multiplied.

For N_2O and NO_X, the emission ratio gives the ratio of emissions of N_2O relative to the N-content of the crop residuals. This factor also has to be multiplied with the ratio between nitrogen and carbon.

For the emission ratios, the IPCC default values are used. As N/C ratio a value of 0.012 is used, which is the IPCC default value for wheat.

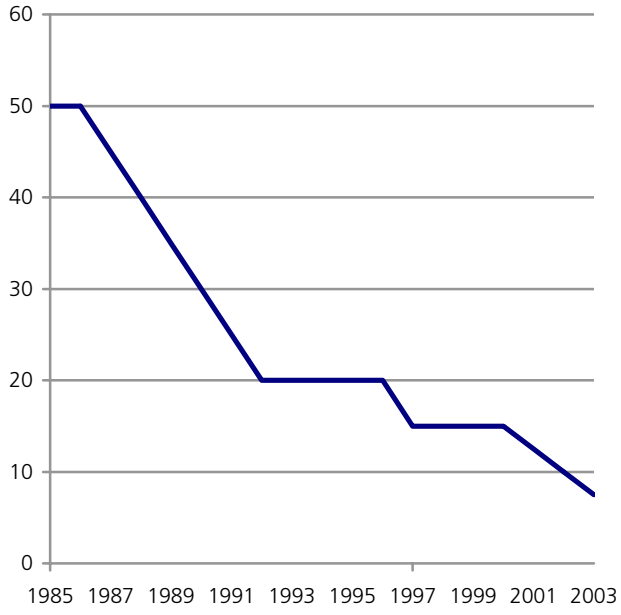
Heavy metals and POPs
Emission factors for heavy metals from agricultural residue burning are not found in the literature. Due to this lack of emission factors, emissions of heavy metals are calculated by using the same emission factors as burning of wood in small stoves in private households. The emission factors in PARCOM-ATMOS (TNO 1992) are used for Pb, Cd and Hg while the emission factors recommended in EPA (2002) are used for As, Cu and Cr.

The emissions of dioxin and PAH are calculated based on emission factors respectively from OSPAR (SFT 2001a) and NILU/NIVA (1995). The emission profile used for PAH is the one presented for open burning of garden waste (EPA 1998).

6.5.3. Activity data

The annual amount of crop residue burned on the fields (CRB) is calculated based on crop production data from Statistics Norway, and estimates of the fraction burned made by the Norwegian Crop Research Institute and Statistics Norway.

Figure 6.2. Fraction of crop residue burned. Per cent



Source: The Norwegian Crop Research Institute and Statistics Norway.

6.5.4. Emission factors

Table 6.18. Emission factors for agricultural residue burning. g emitted/tonnes crop residue burned

Components	Emission factors
Greenhouse gases	
CH_4	2 400
N_2O	46.9
Precursors	
NO_x	1 700
Heavy metals	
Pb	0.05
Hg	0.1
Cd	0.1
As	0.159
Cr	0.152
Cu	0.354
POPs	
PAH-total	30.0
PAH-6	13.9
PAH-4	3.0
Dioxin[1]	17

[1] The unit of the dioxin emission factor is µg I-TEQ/tonnes crop residue burned.

6.5.5. Uncertainties

6.5.5.1. Activity data
The uncertainty concerning the amount of crop residues and other agricultural waste is high. An exact estimate of the uncertainty has not been made, but the amount can be underestimated due to lack of adequate statistics in this area.

6.5.5.2. Emission factors
IPCC default factors are used for the fractions of dry matter, carbon and the fraction oxidised. For the N/C-ratio and the emission ratio, IPCC default factors are also used. The ranges for the emission ratios are ±40 per cent for CH_4, ±28.6 per cent for N_2O and ±22.3 per cent for NO_X (IPCC 1997b). The uncertainty in the data applied can be larger than this for all pollutants.

The emission factors used for heavy metals are not specific for agricultural residue burning, but for wood burning in small stoves in private households. It is expected that use of these emission factors will underestimate the emission of heavy metals from agricultural residue burning considering the two different burning conditions.

6.5.6. Completeness
As mentioned, the estimations may not be entirely complete, since the statistics are not of particularly high quality or completeness.

6.5.7. Source specific QA/QC
In 2002, the emissions of CH_4, N_2O, NO_X and dioxin from agricultural residual burning were included in the Norwegian inventory, and in 2003, the emissions of As, Cr and Cu were added. The time series was included but it should be noted that the figures for the earlier years have a higher uncertainty than the more recent years.

6.6. Other agricultural emission sources
IPCC -
NFR 4G
Last update: 01.09.05

6.6.1. Description
Straw treated with NH_3 to be utilised as fodder is a source for NH_3 emissions in Norway. Agricultural activities are also a source for non-combustion emissions of particles.

6.6.2. NH_3 emissions from treatment of straw
6.6.2.1. Method
Emissions of NH_3 from treatment of straw depend only on the amount of NH_3 used. The total amount of NH_3 used for treatment of straw in Norway is multiplied with the share of the NH_3 that is not integrated in the straw.

6.6.2.2. Activity data
The amount of NH_3 used per year is obtained from Norsk Hydro and the Norwegian Agricultural Supply Cooperative. The area of cultivated fields is given from a sample survey of agriculture and forestry made by Statistics Norway (2003).

6.6.2.3. Emission factor
It is estimated that 65 per cent of the NH_3 applied is not integrated with the straw, and is therefore emitted after the treatment (Morken 2003b). The same estimation is being used in Denmark.

6.6.2.4. Uncertainties
Uncertainty in the estimate of emissions from NH_3 treatment of straw is rather low (±5 per cent) (Rypdal and Zhang 2001).

6.6.2.5. Completeness
Major missing emission components are not likely.

6.6.2.6. Source specific QA/QC
There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

6.6.3. Particle emissions from the agricultural sector
Agriculture is responsible for various types of non-combustion emissions of particles. This is for example dust from crop that is harvested, soil dust from work with agricultural machines, wood particles from felling of trees etc.

6.6.3.1. Method
Due to the relatively few analyses of particle emissions from agriculture the calculations from this source are limited. Emission figures for three types of non-combustion emissions of particles from the agriculture are calculated; emissions from reapers, and from loading and transport on the fields. The total grain cultivation area in Norway is multiplied with emission factors, which gives emissions per area unit. For other actual activities in the agricultural fields, no emission factors have been found.

6.6.3.2. Activity data
The total grain cultivation area in Norway is used as activity data. Data source used are statistics over the area on holdings used for grain seeds from Statistics Norway.

6.6.3.3. Emission factor
The emission factors used are shown in table 6.19. These factors refer to wheat cultivation, but they are used for all grain cultivation in Norway. The factors are based on measurements of particles with a diameter less than 7 μm. No measurements have been made for estimating the ratio between $PM_{2.5}$, PM_{10} and TSP. Therefore the estimation has been made that the calculated emission figures (in reality PM_7) is PM_{10} = $PM_{2.5}$ = TSP.

Table 6.19. Emission factors for non-combustion emissions of particles from the agricultural sector

Emission source	g/km^2
Reaper	170
Loading	12
Transport	110

Source: EPA (1998).

6.6.3.4. Uncertainties

No uncertainty analysis has been made for this source. The few studies made in this field give a relatively high uncertainty for this source.

6.6.3.5. Completeness

The information about this emission source is poor, and it is likely that there are more particle sources from the agricultural sector than included here.

6.6.3.6. Source specific QA/QC

There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

7. Waste

IPCC 1A and 6
NFR 1A1a
Last update: 01.09.05

7.1. Overview

This sector includes emissions from landfills (6A), waste water handling (6B) and small scale waste incineration (6C). Waste incineration with energy utilisation is accounted for under 1A (Energy combustion). Waste incineration included here are emissions from natural gas flared outside the energy sector, methane flared at landfills and combustion of hospital waste and cremations.

7.2. Solid waste disposal on land

IPCC 6A, Key category for CH_4
NFR 6A
Last update: 01.09.05

7.2.1. Managed Waste Disposal on Land

IPCC 6A1
NFR 6A1
Last update: 01.09.05

7.2.1.1. Description

CH_4 and non-fossile CO_2 are emitted during biological decomposition of waste. This transformation of organic matter takes place in several steps. During the first weeks or months, decomposition is aerobic, and the main decomposition product is CO_2. When there is no more oxygen left, the decomposition becomes anaerobic, and methane emissions start to increase. After a year or so, CH_4 emissions reach a peak, after that the emissions will decrease over some decades (SFT 1999e and Barlaz 2004).

The emissions of methane have decreased slightly since 1996 due to a reduction of the amount of waste disposed at disposal sites. This reduction is the result of several measures, which were introduced in the waste sector, particularly in the 1990s. With a few exceptions, it is prohibited to dispose easy degradable organic waste at landfills in Norway. In 1999 a tax was introduced on waste delivered to final disposal sites. This tax was equal to 320 NOK per tonne waste disposed at landfill sites in 2002, and increased to 327 NOK from 2003. In addition, landfills receiving biodegradable waste (waste containing degradable organic carbon (DOC)) are required to collect and treat landfill gas. In 2002 a total of 60 landfills had installed a landfill gas extraction system, and approximately 22 ktonnes of methane was recovered in 2002. In addition, the amounts of waste recycled have increased significantly since 1990.

7.2.1.2. *Method*

CH_4

In 1999, the Norwegian Pollution Control Authority (SFT) developed a model for calculating methane emissions from landfills (SFT 1999e). The model was based on the IPCC theoretical first order kinetics methodologies (IPCC 1997b) and the method was consistent with the IPCC Good Practice Guidance. The effect of weather conditions had also been taken into account.

However, both the former Norwegian and the IPCC 1997 model contain a mathematical error. As the rate of reaction decreases over the year, the average rate of reaction over the year has to be found. This is done through integration and neither the former Norwegian model, nor the IPCC 1997 model, contained such integration. The result was that with a half-life time of 10 years the emissions were underestimated by 3.5 per cent. The models were also complicated and difficult to understand, and gave a poor view into the calculations. Therefore a new model taking account of these issues was developed in 2004. Methane emissions are in the new model calculated from the amount deposited every year, and the amounts added at the end (SFT 2005a).

This new model starts with the calculation of the amount of dissimilating $DDOC_m$ (mass of dissimilatable organic carbon = the part of DOC (degradable organic carbon) that will dissimilate (degrade) under anaeronic conditions) contained in the amount of material being landfilled. This is done in exactly the same way as in the former Norwegian model.

As this is a first order reaction, the amount of product formed will always be proportional to the amount of reactant. This means that it is of no concern to the process when the $DDOC_m$ came into the landfill. As far as we know the amount of $DDOC_m$ in the landfill at the start of the year, all years can be considered to be the first calculating year. This simplifies calculations. With reaction start set to be on January 1 the year after landfilling, the "motor" of the new calculating model has been made out of these two very simple equations:

(26) $DDOC_{mdiss} = (DDOC_{ma(ly)} + DDOC_{md}) * (1- e\hat{}-k)$
(27) $DDOC_{ma} = (DDOC_{ma(ly)} + DDOC_{md}) * e\hat{}-k.$

Equation (26) calculates DDOCmass dissimilating ($DDOC_{mdiss}$), from the not dissimilated DDOC mass accumulated from last year ($DDOC_{ma(ly)}$), plus DDOC mass landfilled last year ($DDOC_{md}$). Equation (27) calculates the DDOCmass accumulated as not dissimilated ($DDOC_{ma}$), for next year's calculations from the same basis as equation (26).

After that the amount of dissimilated $DDOC_m$ has been found, CH_4 produced and CH_4 emitted is found by using the same set of procedures and factors as in the former model.

The full set of equations is found below. If the reaction is set to start in the year of landfilling, separate calculations have to be made for that year and two extra calculating equations will have to be added. They are included in the equations below.

To calculate $DDOC_{md}$ from the amount of material

(28) $DDOC_{md} = W * MCF * DOC * DOC_f$

To calculate $DDOC_m$ accumulated in the SWDS

(29) $DDOC_{ml} = DDOC_{md} * e\hat{}-k*((13-M)/12)$
(30) $DDOC_{ma} = DDOC_{ma(ly)} * e\hat{}-k + DDOC_{ml}$

To calculate $DDOC_m$ dissimilated

(31) $DDOC_{mdi} = DDOC_{md} * (1-e\hat{}-k*((13-M)/12))$

(32) $DDOC_{mdiss} = DDOC_{ma(ly)} * (1-e\hat{}-k) + DDOC_{mdi}$

To calculate methane produced from DDOC dissimilated

(33) $CH_{4\ prod} = DDOC_{mdiss} * F * 16/12$

To calculate methane emitted

(34) CH_4 *emitted in year T =* $(\bullet\ CH_{4\ prod}(T)) - R(T)) * (1-OX)$

Where:

W	:	amount landfilled
MCF	:	Methane Correction Factor
M	:	Month number for reaction start. (January 1, year after landfilling, M=13)
DOC	:	Degradable Organic Carbon
DOC_f	:	Fraction of DOC dissimilating, anaerobic conditions
DDOC	:	Dissimilatable Organic Carbon, anaerobic conditions
$DDOC_{md}$	:	DDOC mass landfilled
$DDOC_{ml}$	:	DDOC mass left not dissimilated from DDOCm landfilled, year of landfilling
$DDOC_{ma}$	:	DDOC mass left not dissimilated at end of year
$DDOC_{ma(ly)}$	:	DDOC mass accumulated from last year
$DDOC_{mdi}$	:	DDOC mass dissimilated from DDOCm landfilled, year of landfilling
$DDOC_{mdiss}$	:	DDOC mass dissimilated in calculation year
$CH_{4\ prod}$	:	CH_4 produced
F	:	Fraction of CH_4 by volume in generated landfill gas
16/12	:	Conversion factor from C to CH_4
R(T)	:	Recovered CH_4 in year of calculation
OX	:	Oxidation factor (fraction).

7.2.1.3. Activity data

The amount of different waste materials is compiled in annual surveys carried out by Statistics Norway. These data are used as input into the model used to calculate methane emissions. For the new model, historic data have been recalculated from the former waste category basis, to a material waste basis. The model is based on types of materials food waste, paper, wood and textiles.

Data from each landfill site with methane recovery units are compiled by the county governors and reported to the Norwegian Pollution Control Authority. These data are imported into the national model for calculating methane from landfills.

7.2.1.4. Emission factor

The emission factors used in the Norwegian model are a mixture of country-specific factors, estimated by a range of officials and Norwegian waste experts. IPCC defaults values are applied where country-specific information is not available. Table 7.1 shows some of the variables used in the calculations of methane emissions from solid waste disposals.

Table 7.1 Variables used in the calculations of methane from landfills

	Type of waste		
Variables	Food waste	Paper	Wood and textiles
$t_{1/2}$ (half life time)	2.8 years	8.4 years	10.5 years
DOC	0.170 Mg/Mg	0.370 Mg/Mg	0.400 Mg/Mg
DOC_i (Part of DOC dissimilating)	0.5	0.5	0.5
Ox. Methane oxidized in top layer	0.1	0.1	0.1
F. Part of methane in generated landfill gas	0.5	0.5	0.5

Source: SFT (2005a).

7.2.1.5. Uncertainties
The importance of the uncertainties in calculations of methane from landfills will decrease with decreased source contribution and improved IPCC default parameter values, but most likely it will still remain among the main uncertainties in the Norwegian GHG inventory.

The methodology Statistics Norway/the Norwegian Pollution Control Authority use to calculate methane emissions from landfills is identical for the whole time series. The quality of the activity data used in the model has been improved in the last years. This is also the case regarding the data for recovered methane.

7.2.1.6. Completeness
Major missiong emission sources are not likely.

7.2.1.7. Source specific QA/QC
Internal checks of time series for all emission sources are made every year when an emission calculation for a new year is done.

Internal checks of time series of waste data, methane recovered at landfill sites and calculated methane emissions from the model are carried out and corrections are made if any kinds of errors are found. If there is a change in the trend of methane recovered from a landfill site, the site is contacted to identify a plausible explanation. Corrections are made if there is no plausible explanation of the change.

7.2.2. Unmanaged Waste Disposal Sites
IPCC 6A2
NFR 6A2
Last update: 01.09.05

In Norway landfilling of solid waste has been regulated and controlled for some decades, and unmanaged landfills are from before 1970. Futhermore, the methane emissions for all years have been calculated from the total amounts of landfilled materials. Therefore Norway does not separately report emissions from unauthorized/unmanaged SWDSs.

7.3. Waste water handling
IPCC 6B
NFR 6B
Last update: 01.09.05

7.3.1. Method
CH_4
Emissions of methane from domestic and commercial waste water have been calculated. Emissions from breweries, dairies and slaughterhouses are included. Emissions of methane from industries with their own waste water treatment plants are small, because the plants are mainly aerobic or the methane gas is being recovered. CH_4 from domestic sludge is calculated together with the waste water emissions.

Emissions of methane from domestic waste water are calculated according to the IPCC default methodology:

$$(35)\quad E_i = N_i * D * B_0 * MCF$$

E: Emissions of methane
N: Population in Norway
D: Organic load in biochemical oxygen demand (kg BOD/1000 persons/year)
B_0: Maximum methane-producing capacity (kg CH_4/kg DC)
MCF: Methane conversion factor
$_i$: Year

N_2O
In this section only emissions of nitrous oxide from domestic and commercial wastewater have been calculated. The N_2O from sewage sludge applied on fields is included under Agriculture in chapter 6.4.2.5. For N_2O, emissions are calculated from nitrification/ denitrification that occurs in the pipelines and the N_2O emissions that occur as a by-product in biological nitrogen removal plants. This is assumed to be a more precise method than the recommended IPCC method that is based on the annual per capita protein intake.

7.3.2. Activity data
CH_4
Data for the number of residents in Norway are given from Statistics Norway's population statistics. The IPCC default value of 18 250 kg BOD/1000 persons/year is used for D, the degradable organic component in the waste, for all years.

N_2O
A yearly estimate for the amount of nitrate supplied to the pipelines is obtained from the waste water statistics at Statistics Norway.

Data for the amount of nitrogen that is removed in the biological step in the actual waste water plants are given by The Norwegian Pollution Control Authority (SFT).

7.3.3. Emission factor

CH_4

The IPCC emission factor for B_0 of 0.6 kg CH_4/kg DC is used. The methane conversion factor (MCF) is, according to good practice, given by the fraction of BOD that will ultimately degrade anaerobically. A country-specific factor of 0.02 is used for the fraction that is anaerobic treated. The factor is from Statistics Norway (waste water statistics), and corresponds to the fraction of the waste water plants that are categorized as "Sealed tank" and partly the category "Separate toilet system".

N_2O

For calculation of the emissions from the pipelines, we use the IPCC default emission factor of 0.01 kg N_2O-N/kg sewage-N produced.

It is assumed that 2 per cent of the nitrogen removed from plants will form N_2O. This country-specific emission factor is given in SFT (1992), and the assumption is based on measurements in plants and comparisons with factors used in Sweden.

7.3.3.1. Uncertainties

Uncertainty estimates for this source are given in Appendix D.

7.3.3.2. Completeness

Major missing emission components are not likely.

7.3.3.3. Source specific QA/QC

There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

7.4. Waste incineration

IPCC 1A1a, 1A2d and 6C
NFR 1A1a, 1A2d and 6C
Last update: 01.09.05

7.4.1. Description

Emissions from waste incineration in district heating plants are reported under energy (IPCC 1A1a), as the energy is utilised, and therefore described in chapter 3.2.2. In 2003, there were 10 waste incineration plants where household waste is incinerated. In addition, some incineration plants burn waste other than household waste, mainly wooden waste, paper, pasteboard and cardboard. These emissions are reported and described under energy (IPCC 1A2d). Waste, other than household waste, is also used as energy source in some manufacturing industries. In this chapter, the focus will be on waste reported in IPCC sector 6C. This includes emissions from flaring, except flaring from energy sectors, and emissions from cremation and hospital waste.

7.4.2. Method

Emissions from flaring of landfill gas by landfills are estimated. The emissions are estimated by multiplying the amount of gas flared with the emission factors shown in table 7.2. Emissions from flaring of natural gas by production of methanol are also estimated. The amount of gas used in flaring is multiplied by appropriate emission factors, found in table 7.2. There is one exception, emissions of NO_x, which are reported from the plant directly to the Norwegian Pollution Control Authority.

Emissions from cremation and hospital waste are estimated by emission factors multiplied with activity data. For hospital waste, the emissions of heavy metals used in the model are reported to the Norwegian Pollution Control Authority.

7.4.3. Activity data

Landfill gas

The total amount of landfill gas extracted each year is reported by landfills to the Norwegian Pollution Control Authority. Statistics Norway subtracts the amount utilized for district heating and thermal power, which is given by the energy statistics in Statistics Norway. To find the amount flared of the remaining landfill gas, a fraction given from a survey of waste statistics from Statistics Norway is used. This survey is made every third year, but is planned to be annual in the coming years.

Natural gas

The amount of natural gas flared by the production of methanol is reported directly to Statistics Norway.

Hospital waste

The amount of hospital waste was reported to Statistics Norway for the years 1998 and 1999. For the period 1990-1997 the average for 1998 and 1999 has been used. After 1999 there has been no collection of hospital waste data. Due to the lack of better information, the waste amount for 1999 has been used to calculate the emissions for subsequent years.

Cremation

The number of cremated bodies is taken from the death statistics at Statistics Norway (Statistical Yearbook). It is assumed that the average weight of a body is 60 kilogram. Further is it assumed that 40 per cent is dry substance. The weight of a coffin is set to 25 kilogram.

7.4.4. Emission factors

Table 7.2. Emission factors for flare, cremation and hospital waste incineration

Component	Flare Landfill gas kg/tonnes	Flare Natural gas Tonnes/Sm^3	Cremation Tonnes/ tonnes	Hospital waste Tonnes/ tonnes
SO_2	0.02	0	0.00037	0.0014
CO_2	275	2340	0	0.3
CO	0.04	1.5	0.015	0.0028
NO_x	0.17	Reported to SFT	0.0009	0.0014
Particles	0.14	0.0018	0.0024	0.0005
NMVOC	0	0.06	0.0013	0.0007
CH_4	0.37	0.24	0.00024	0.00023
N_2O	0.0015	0.02	0.0003	
		mg/tonne	mg/tonne	mg/tonne
Pb	NA	0.3	0.37959	Plant-specific emission factors
Cd	NA	1.7	0.63408	Plant-specific emission factors
Hg	NA	1	102 040.8	Reported
Cu	NA	16	0.1573	2594.6
Cr	NA	21	0.1722	4705.6
As	NA	3.8	0.22387	1272.4
Dioxin	NA	0.00005	0.20408	0.29685
PAH	NA	1.44	700 000	2.5
PAH-4	NA	0	10 000	0.04
PAH-Ospar	NA	0.8	230 000	0.9

NA=Not Applicable.

7.4.5. Uncertainties

7.4.5.1. Activity data

Amount of hospital waste

No new data has been reported since 1999. The amount of waste today may vary from the data reported in 1998 and 1999.

7.4.5.2. Emission factors

If the composition of the hospital waste is different to the waste the emission factors are based on, the calculated emissions will be incorrect. Combustion engineering and processes also influence the emissions. These uncertainties have not been calculated.

7.4.5.3. Source specific QA/QC

There is no source specific QA/QC procedure for this sector. See section 1.5.1 for the description of the general QA/QC procedure.

7.5. Other emission sources from the waste sector

IPCC -

NFR 6D

Last update: 01.09.05

7.5.1. Description

Other emission sources that included in the waste sector are emissions from car fires, house fires, combustion of tobacco, emissions from recovering processes in the waste trade, and emission from the combustion of hazardous waste.

7.5.2. Method

7.5.2.1. Car- and house fires

Particles, heavy metals and POPs

Emissions of particles and dioxins are calculated from car fires and house fires. In addition, heavy metals are calculated for house fires. Emissions are calculated by multiplying the annually number of car- and house fires with emission factors. Four types of buildings are separated with different emission factors: detached house, undetached house, apartment building and industrial building.

7.5.2.2. Tobacco

NO_X, NMVOC, CO, particles, heavy metals and POPs

The emission components included from the combustion of tobacco are NO_X, NMVOC, CO, particles, heavy metals and POPs (Persistent organic pollutants). Emission figures have been calculated by multiplying the annual consumption of tobacco with emission factors for each pollutant.

7.5.2.3. Waste trade

NH_3, particles, heavy metals and POPs

Emissions from recovering processes in the waste trade includes emissions of NH_3, particles, heavy metals and PAH. The emission figures are reported annually by the actual plants to the Norwegian Pollution Control Authority. Emissions originating from the combustion of hazardous waste include heavy metals and dioxins and emission figures are reported to the Norwegian Pollution Control Authority.

7.5.3. Activity data

7.5.3.1. Car- and house fires

Data for the number of car- and house fires are provided annually by the Directorate for Civil Protection and Emergency Planning. These figures only include fires reported to the fire service.

7.5.3.2. Tobacco

The total consumption of tobacco in Norway is given by the net import of tobacco from Statistics Norway's external trade statistics.

7.5.4. Emission factor

7.5.4.1. Car fires

The emission factor for particles is given by EPA (2002). EPA recommends the factor of 0.9 kg/car for combustion of wrecked cars without car tyres, and a factor for combustion of car tyres of 1.4 kg/car. This results in an overall emission factor of 2.3 kg/car. The emission factor for emission of dioxins from car fires is found in Hansen (2000).

7.5.4.2. House fires

It is difficult to estimate the amount of material burned in a house fire. In Finstad et. al. (2002a) a calculation was made that has been used to scale the chosen emission factors, to reflect how much of the building got lost in the fire. This scaling calculation is based on the amount of damage estimated in monetary value, and value on how much of the building and the furniture was burned. The emission factors used for particles in the inventory are given by scaling the emission factors used for combustion of fuelwood in the households (Haakonsen and Kvingedal 2001). The emission factors for heavy metals are given by scaling the emission factors for combustion of wooden waste in the industry (EPA 2002). For dioxins, OSPAR (SFT 2001a) gives the emission factor of 170 μg I-TEQ per tonne burned material. The scaled emission factors used for the different building types are given in table 7.3.

Table 7.3. Emission factors used for car fires and house fires, emission unit/fire

	Car	Detached house	Undetached house	Apartement building	Iindustrial building
TSP (kg)	0.0023	0.14382	0.06162	0.04378	0.02723
PM_{10} (kg)	0.0023	0.14382	0.06162	0.04378	0.02723
$PM_{2.5}$ (kg)	0.0023	0.14382	0.06162	0.04378	0.02723
Pb (g)		0.00042	0.00018	0.00013	8E-05
Cd (g)		0.00085	0.00036	0.00026	0.00016
Hg (g)		0.00085	0.00036	0.00026	0.00016
As (g)		0.00135	0.00058	0.00041	0.00025
Cr (g)		0.00129	0.00055	0.00039	0.00024
Cu (g)		0.00299	0.00128	0.00091	0.00057
Dioxin (µg)	0.047	1.43817	0.61621	0.43779	0.27234

7.5.4.3. Tobacco

Table 7.4 gives emission factors used for tobacco combustion. For NO_X, NMVOC and CO the emission factors are calculated by Statistics Norway, based on values given in Directorate for Health (1990).

Table 7.4. Emission factors used for tobacco combustion

	Tobacco (unit/tonne tobacco)	Source
NO_X (kg)	0.0034652	Statistics Norway, Directorate for Health (1990)
NMVOC (kg)	0.0048374	Statistics Norway, Directorate for Health (1990)
CO (kg)	0.1215475	Statistics Norway, Directorate for Health (1990)
TSP (kg)	0.04	TNO (2002)
PM_{10} (kg)	0.04	TNO (2002)
$PM_{2.5}$ (kg)	0.04	TNO (2002)
Pb (g)	0.00005	Finstad et al. (2001)
Cd (g)	0.0001	Finstad et al. (2001)
Hg (g)	0.0001	Finstad et al. (2001)
As (g)	0.000159	Finstad and Rypdal (2003)
Cr (g)	0.000354	Finstad and Rypdal (2003)
Cu (g)	0.000152	Finstad and Rypdal (2003)
PAH (g)	0.00825	Finstad et al. (2001)
PAH OSPAR (g)	0.00125	Finstad et al. (2001)
Dioxin (µg)	0.0013	Finstad et al. (2002a)

8. Recalculations

The Norwegian emission inventory is every year recalculated for the entire time series for all components, to account for new knowledge on activity data and emission factors and to correct for some errors in the calculations. This chapter describes recalculations performed in the Norwegian emissions inventory 2004/2005. Most of the recalculations have been performed for 2002 because the energy accounts for 2002 that was the basis for last year's calculations were "preliminary". Now the "final" figures for the energy accounts are available. This is due to the fact that final energy consumption figures from the manufacturing statistics and some other final energy figures now are included in the energy accounts. These types of revisions caused by the energy balance will not be commented specifically under each sector.

8.1. Overall description of the recalculations for the greenhouse gases

The most important recalculations are

1. Recalculation of land-based industry and offshore oil industry, caused by inclusion of emission figures reported to the Norwegian Pollution Control Authority and Norwegian Petroleum Directorate. Emissions were earlier estimated by emission factor and activity data.
2. A new calculation method in the methane emission model contributes to lower emissions from landfills than previous calculations suggest.

8.2. Specific description of the recalculations for the greenhouse gases

8.2.1. Energy

As mentioned above, most of the recalculations for 2002 are caused by revisions in the energy accounts from “preliminary” in last year's calculations to “final” in this year's calculations.

8.2.1.1. Fuel Combustion Activities

1A1a Public Electricity and Heat Production

An amount of wood waste is removed from one district heating plant for 2001 in order to avoid double counting.

Another recalculation performed concerns emissions of N_2O from district heating plants. As emissions of NO_X are reported from each plant to the Norwegian Pollution Control Authority, an estimated amount of 2.5 per cent of this NO_X is subtracted and reported to the UNFCCC as N_2O. This methodology has until recently been applied to all district heating plants except from three of them and for the years 2001 onwards. In these cases, N_2O emissions were calculated through consumption data and appropriate emission factors. Emissions of N_2O for these three district heating plants have now been estimated for the years after 2000 according to the methodology applied to all other plants.

1A1c Manufacture of Solid Fuels and Other Energy Industries

CO_2 emissions from extraction of oil and gas have been recalculated. For the year 2003 emission figures for each field reported by all field operators are used in the emission model. For the years 1990-2002 emission estimates are based on field-specific emission factors, which vary from year to year. This is an important improvement in the national inventory, given that earlier one universal emission factor was used for all fields and for all years.

1A2a Iron and Steel

The emission figures for two plants consuming CO-gas have been recalculated. In this submission reported figures have been used for these two plants; for 1990 to 2003 for one of the plants and for 1997 to 2003 for the other plant. The CO_2 is now reported under non combustion emissions.

1A2c Chemicals

For one plant, CO_2 figures for all years (1990-2003) reported to the Norwegian Pollution Control Authority replace figures based on emission factors and activity data.

There have been minor revisions in the energy accounts for some sectors.

1A3b Road Transportation
New figures on average mileage and driven kilometres for passenger cars for the years 2000 to 2003 are now available from the Institute of Transport Economics (TØI), and are used in the calculation. These changes influence on all emissions.

The decrease in emission of CO_2 from light and heavy duty vehicles in 2002 is due to changes in consumption of diesel according to the revisions in the energy accounts (final figures)

1A3d Navigation
Emissions of CO_2 for 2002 are reduced in the final energy accounts. The sale was lower than what was assumed in the preliminary energy accounts.

Emission factor for CH_4 from LPG- ferry has changed. Emissions for the years 2000-2002 have decreased due to this change.

Furthermore, revisions in the energy accounts give small revisions in other emission figures.

1A4bi Residential plants
Estimates for the amount of wood and oil products used in households in 2002 are updated. Emissions of all components increased in 2002 based on the final energy accounts.

8.2.1.2. Fugitive Emissions From Fuels
1B1a Coal Mining and Handling
Final production figures for coal mining in 2002 were higher than the preliminary figures. Emissions of methane have therefore increased compared to previous submission.

1B2ai Exploration Production, Transport
Non-combustion emission of CH_4 from oil loading on shore for one terminal has been revised for the whole time series. The emission figures for this terminal were based on calculations by Statistics Norway and the Norwegian Pollution Control Authority (emission factor * activity data) in the previous submission. Now reported figures are used. The percentage distribution between CH_4 and NMVOC for 2003 has been used as distribution formula for all years. This has led to an increase in emissions of CH_4. At the same time reported CH_4 non-combustion emissions from a refinery are included in the inventory. These figures replace formerly estimated figures for the years 1990 to 2003. Reported emissions from 1992 are used for 1990 and 1991 to missing figures.

1B2c Venting and flaring
For one gasterminal, CO_2, and NO_x figures for flaring for all years (1990-2003) reported to the Norwegian Pollution Control Authority replace estimates based on emission factors and activity data.

Emission of CH_4 from flaring of crude oil is deleted for the year 1980 to 1991. This is done after consultation with the Norwegian Pollution Control Authority.

In addition minor revisions (flaring at refineries) in the energy accounts have also given some minor recalculations in the emission figures.

8.2.2. Industrial processes

2B1 Ammonia Production
For one plant, CO_2 figures for all years (1990-2003) reported to the Norwegian Pollution Control Authority replace figures based on emission factors and activity data.

2B4 Carbide Production
Emissions of CO_2 have decreased due to revision of the whole time series for all factories producing carbide. Now emissions reported to the Norwegian Pollution Control Authority are included in the inventory, previous calculation made by Statistics Norway was based on emission factor and activity data.

2C Metal Production
Reported emissions of CO_2 from two ferroalloy plants are now used instead of using the values calculated by Statistics Norway that were used before. So now the total CO_2 emission from ferro alloy production is based on emissions reported by the plants to the Norwegian Pollution Control Authority. This change has increased the emissions of CO_2 for the whole time series. Emission figures of CO_2 from one plant are revised for 2002. Previously an incorrect figure was reported.

2D Food and Drink
CO_2 emissions from production of bio protein from natural gas are included for the years 2001 to 2003. This is a new source from 2001, and the bio protein is being used as animal fodder.

2F Consumption of Halocarbons and Sulphur Hexafluoride
Emissions of SF_6 from production of medium voltage switches are included for the first time and a timeseries is established.

3D Other
N_2O from propellant gas, drag racing and research is for the first time included in the inventory.

8.2.3. Agriculture
Statistics Norway has made improvements in the calculation model for N_2O emissions from the agricultural sector. This gives changes in the figures for all reported years for several emission sources for N_2O. National N-factors used for calculating NH_3 are now also used for estimation of N_2O.

4B Manure Management
Emissions of N_2O from storage of manure are revised. The percentage distribution between different storage systems for manure and grazing is adjusted to Norwegian condition. The estimated emissions of N_2O from storage have been corrected for losses of N due to transformation of N_2O to volatile NH_3. The correction has been distributed on storage systems after how much the different storage systems are being used.

4D Agricultural Soils
Emissions of N_2O from spreading of manure, grazing animals and leakage have been revised for all years due to new knowledge. Emissions have decreased for all years. The new calculations are adjusted to Norwegian condition. A new figure for the area of cultivated histosols are now available from Jordforsk, and are used for all years. Emissions of N_2O from crop residue are recalculated for all years. These emissions have earlier been reported constant since 1998.

4F Field burning of agricultural residue
The share of straw burnt has been changed, based on new estimates for the years 2001-2004, from 15 per cent and gradually down to 7.5 per cent. Emissions of CH_4 and N_2O have decreased.

8.2.4. Waste

6A Solid Waste Disposal on Land
Corrections in the methane emission model gives lower calculated emissions from landfills than previous calculations. In this new model is it assumed that plastic is not degradable. In the old methane emission model was it assumed that plastic was degradable, and contributed to about 13 per cent of total methane emissions from landfills. Some factors have also been changed in the new model.

Emission of CO_2 from solid waste disposal is removed. In the old methane emission model it was assumed that plastic and textiles were degradable, and generated emission of CH_4 during degradation. Indirect emissions of CO_2 were also estimated for the fossil part. Now plastics and textile is considered not degradable. Hence there are no fossil CO_2 emissions from this emission source. For further explanations see Chapter 7 Waste.

8.3. Implications of the recalculations for the greenhouse gases

8.3.1. Implications for emissions levels

Tables 8.1 and 8.2 show the effects of recalculations on the emission figures for the greenhouse gases 1990-2002.

Table 8.1. Recalculations in 2005 submission to the UNFCCC compared to the 2004 submission. CO_2, CH_4 and N_2O. Tonnes CO_2-equivalents

	CO_2			CH_4			N_2O		
	Previous submission	Latest submission	Difference (%)	Previous submission	Latest submission	Difference (%)	Previous submission	Latest submission	Difference (%)
1990	34690.2	34414.1	-0.8	6448.6	5159.2	-20.0	5517.1	5064.2	-8.2
1991	33559.1	33541.1	-0.1	6540.9	5194.3	-20.6	5362.3	4919.2	-8.3
1992	33930.6	33762.7	-0.5	6627.0	5258.3	-20.7	4684.0	4256.2	-9.1
1993	35565.0	35408.3	-0.4	6757.4	5303.4	-21.5	5046.9	4603.9	-8.8
1994	37296.1	37265.8	-0.1	6844.2	5381.4	-21.4	5144.3	4722.4	-8.2
1995	37389.9	37225.2	-0.4	6902.5	5389.8	-21.9	5225.8	4800.1	-8.1
1996	40606.8	40392.8	-0.5	6980.9	5421.6	-22.3	5225.0	4887.0	-6.5
1997	40569.5	40565.5	0.0	7033.0	5478.0	-22.1	5163.8	4821.8	-6.6
1998	40838.3	40774.4	-0.2	6951.9	5320.7	-23.5	5448.3	5102.9	-6.3
1999	41316.8	41625.6	0.7	6905.8	5226.8	-24.3	5666.6	5299.1	-6.5
2000	40856.8	41143.6	0.7	7007.3	5317.7	-24.1	5549.8	5222.9	-5.9
2001	42065.5	42664.3	1.4	7002.1	5293.4	-24.4	5554.2	5211.0	-6.2
2002	40945.2	41238.9	0.7	6875.1	5119.2	-25.5	5814.9	5419.2	-6.8

Table 8.2. Recalculations in 2005 submission to the UNFCCC compared to the 2004 submission. HFCs, PFCs and SF_6. Tonnes CO_2-equivalents

	HFCs			PFCs			SF_6		
	Previous submission	HFCs Latest submission	Difference (%)	Previous submission	PFCs Latest submission	Difference (%)	Previous submission	SF6 Latest submission	Difference (%)
1990	0.02	0.02	0.00	3294.40	3294.40	0.00	2185.96	2202.02	0.73
1991	0.11	0.11	0.00	2523.63	2523.63	0.00	2065.89	2084.73	0.91
1992	0.34	0.34	0.00	2016.46	2016.46	0.00	687.63	707.82	2.94
1993	2.43	2.43	0.00	1980.37	1980.37	0.00	718.87	744.65	3.59
1994	9.23	9.23	0.00	1710.38	1710.38	0.00	854.45	886.67	3.77
1995	25.88	25.88	0.00	1561.93	1561.93	0.00	577.97	617.41	6.82
1996	52.87	52.87	0.00	1439.84	1439.84	0.00	543.14	584.49	7.61
1997	88.43	88.43	0.00	1376.67	1376.67	0.00	548.01	591.15	7.87
1998	132.64	132.64	0.00	1267.18	1267.18	0.00	694.54	738.88	6.38
1999	179.45	179.45	0.00	1123.01	1123.01	0.00	840.75	886.71	5.47
2000	232.10	232.10	0.00	899.24	899.24	0.00	890.81	947.93	6.41
2001	291.68	291.68	0.00	1043.41	1043.41	0.00	764.99	805.50	5.30
2002	365.12	365.12	0.00	1119.95	1119.95	0.00	222.35	253.30	13.92

Table 8.3. Trends in emissions 1990-2002. This submission vs. previous submission. GHG. Per cent change 1990-2002

	GHG	CO_2	CH_4	N_2O	PFCs	SF_6	HFCs
This submission	6.75	19.83	-0.78	7.01	-66.00	-88.50	1992097
Previous submission	6.15	18.03	6.61	5.40	-66.00	-89.83	1992097

8.3.2. Implications for emission trends

As a result of the different recalculations for 1990-2002 there have been some changes in the trends. The differences are shown in table 8.3.

8.4. Overall description of the recalculations for the long-range transbundary air pollutants

The single most important recalculations are

1. The emission factor for mercury from combustion of wood and wood waste is reduced due to better knowledge. The same factor is used for black liquor. The Norwegian factor is now harmonized with the Swedish and Finnish factors. This is a result of the program for review, improvement and harmonization of the Nordic Air Emission Inventories, which is financed by the Nordic Council of Ministers.
2. Emission of lead from tyre and break wear is included in the inventory for the first time.

8.5. Specific description of the recalculations for the long-range transbundary air pollutants

8.5.1. Energy

1A1a Public Electricity and Heat Production

Emissions of SO_2 were reported incorrectly for one waste incineration plant in 2002. The new figure has increased the SO_2-emissions. CO emissions have increased due to changes for wood waste in the energy accounts. There has been a decrease in the emissions of mercury due to lower emission factor for combustion of wood waste.

One new plant burning waste has been included. This has increased the emissions of dioxins. The amount of wood waste from one plant burning waste is removed due to an earlier double count (2001).

1A1b Petroleum refining

Increased emissions of SO_2 are due to new figures from one plant for the years 1990 to 2000. Revised figures for the use of heavy distillates have lead to higher emissions of arsenic and chromium for 2002.

1A1c Manufacture of Solid Fuels and Other Energy Industries

The recalculation is caused by inclusion of revised emission figures for NO_X from one plant, reported to the Norwegian Pollution Control Authority. Emissions were earlier estimated by emission factor and activity data.

1A2a Iron and Steel

Emission figures for SO_2 from two plants are revised due to new data. Previous calculations were based on emission factor and activity data for those years where data from INKOSYS were missing. Reported data from the years 1992 to 2003 for one plant, and reported data from 1997 to 2003 for the other plant is now included in the inventory. The second plant did also report new figures for NO_X for the period 1997 to 2003.

Hg emissions have been reduced due to the new emission factor for wood waste.

1A2c Chemicals

An increase of SO_2 and NO_X emissions are due to changes in the energy accounts.

1A2d Pulp, Paper and Print

New revised emission figures for SO_2 have been reported for three pulp and paper plants. A decrease in CO emissions in 2002 is due to changes in the energy accounts. Hg emissions for all years are reduced due to the new emission factor for wood waste and black liquor. There have been changes in the emissions of HM in 2000-2002, because of revised consumption figures in the energy accounts.

1A2f Other

Emissions of Hg are reduced due to the new emission factor for wood waste. Revised figures for the use of wood waste in one sector (232010) have decreased the emissions of HM for the years 1998 to 2002.

1A3b Road transportation

New figures on average mileage and driven kilometres for passenger cars for the years 2000 to 2003 are now available from the Institute of Transport Economics (TØI). Emissions of CO and NMVOC from passenger cars using gasoline increase when the estimate for average distance (km) driven per vehicle increases. This is because a greater part is emitted from cold starts. There are minor revisions for the other components. Emissions from heavy duty vehicles (gasoline) are reduced because these emissions are estimated by subtracting emissions from passenger cars from total emissions from road traffic. Emissions of Hg, Cu and PAH-OSPAR are reduced for 2002 due to changes in use of diesel in the energy accounts.

1A3bvi R.T., Automobile tyre and brake wear

Revised activity data for 1991 and 1994 give higher emissions of TSP, PM_{10} and $PM_{2.5}$. Emissions of heavy metals (Pb, Cd, As, Cr and Cu) are now calculated

based on annual mileage and emission factors. Emissions of Pb from automobile brake wear, and emissions of As from tyre wear are included for the first time. Emissions of Cu have increased due to correction of the emission factor for Cu for heavy duty vehicles.

1A3dii National Navigation
Emissions of SO_2 for the year 2002 are reduced due to lower sale of marine oil. The sale was lower than what was assumed in the preliminary energy accounts. Transfer of some marine fuel from oil drilling to oil extraction causes higher emissions of NO_x for all years, as the latter sector has a higher emission factor than the former.

Emissions of dioxins and HM for the year 2002 are reduced due to lower sale of marine oil.

1A4bi Residential plants
Emissions from fuel wood consumption are revised for the years 1990-2003. The revision is caused by the effect of better knowledge of the distribution of the consumption between different types of stoves/fire-places, and the effects this has on the emission factors. Statistics Norway has carried out a survey of use of wood for heating and heating habits in two large cities, Trondheim and Bergen. The project has led to better emission factors and a better estimate on wood consumption by county.

Emissions of particles have decreased for the years 1990 to 2002 due to a lower emission factor for combustion in old stoves in Trondheim and Bergen (the emission factor for Oslo has been reduced earlier). The decrease is higher for the years after 1998 due to the introduction of new, less polluting stoves. The new emission factor for old stoves in large cities is documented in Finstad et al. (2004). The revision is due to new figures on average load on stoves in Norway. The emission factor for PM is reduced in proportion to the increase in the load.

Emissions of CO decrease after 1998 due to due to introduction of new, less polluting stoves. New stoves have lower emission factor than conventional stoves. Hg emissions are reduced due to the new emission factor for wood.

Updated estimates for the amount of wood used in households in 2002 are higher than the "preliminary" energy accounts showed. Emissions of all components, including heavy metals, PAH and dioxins, increased in 2002 due to this revision.

1A4ci Stationary
An increase of emissions of Pb, Cr and Cu for 2002 is due to the inclusion in the energy accounts of combustion of hazardous waste in agriculture.

1B2ai Exploration Production, Transport
Non-combustion emission from one plant has been revised for the whole time series. Previous calculation was based on emission factor and activity data. The percentage distribution between CH_4 and NMVOC for 2003 has been used as distribution formula for all years. This has led to an increase in the emissions of CH_4 and to lower emissions of NMVOC. At the same time, reported figures from another plant replace formerly estimated figures. This causes higher emissions of NMVOC from this plant, and overall higher NMVOC emissions from this sector in 1990-1996 and 1998-2000.

1B2aiv Refining / Storage
Emissions of SO_2 from one plant have been reduced for 1990 to 2000. This is because some of the emissions now have been defined as stationary. Total emissions from the plant are unchanged.

1B2c Venting and flaring
For one plant, NO_x figures for all years (1987-2003) reported to the Norwegian Pollution Control Authority replace figures based on emission factors and activity data. Minor revisions have been made in the energy accounts.

8.5.2. Industrial processes

2A1 Cement Production
Particle size distribution for emitted particles from cement production was earlier wrong for PM_{10}. PM_{10} is assumed to be 85 per cent of TSP, not 90, and $PM_{2.5}$ is 30 per cent of TSP. The emission factor for PM_{10} has been changed from 0.9 to 0.85.

2A7 Other including Non Fuel Mining & Construction
Emissions of $PM_{2.5}$ and PM_{10} have decreased for the whole time series as a result of revised emission factors. The emission factors for PM_{10} is changed from 0.9 to 0.85, and for $PM_{2.5}$ from 0.4 to 0.3. New figures for 2000 and 2002 for buildings completed from the Building statistics are now available. These are used for calculation of emissions of TSP, PM_{10} and $PM_{2.5}$ from the building and construction industry.

Mercury emissions from production of mineral white are included in the inventory for the years 1990-1999. This leads to increased emissions of mercury for this period. The plants have reported emission figures to the Norwegian Pollution Control Authority since 2000. For one of the plants, historical emissions are based on reported figure in 2000 and production volumes. For the other plant, emission figures for 1990-1999 are assumed to be the same as the reported figure in 2000, due to lack of production data for previous years.

In the 2004 report, figures from 2001 were used for 2002 for emission of cadmium, arsenic and chromium from Rock wool production. Now, the 2002 emission

figures are estimates based on emission and production figures from one factory. The emission factors estimated are multiplied with the amount produced at the other factories. One factory closed at the end of 2002. Since production figures for 2003 not are available, emission figures for 2002 is temporary used for 2003.

2B4 Carbide Production
Emission figures of chromium and copper were reported incorrectly for one plant in 2002. New figures from the plant have decreased the emissions.

2C Metal production
Emissions of PM_{10} have decreased for the whole time series as a result of revised emission factor. PM_{10} is changed from PM_{10} =TSP to PM_{10} = 0.97 * TSP. Emissions of TSP, PM_{10} and $PM_{2.5}$ have increased for the years 1999 to 2003 because one new plant is included.

Emissions of NO_X from aluminium production have been revised for the whole time series. Production figures from the Norwegian Pollution Control Authority have replaced production figures from Statistics Norway. The calculations are still based on emission factors and activity data. Revised activity data have caused somewhat higher NMVOC emissions 1991-2002.

One anode producing plant has developed a new and better method for measuring PAH. This method is used for the period 1992 to 2002. This has led to revised emission figures for this plant. This also influences emissions of PAH-OSPAR and PAH-4. Therefore the emissions are higher than previously reported.

The figures for use of reducing agents in ferroalloys production have been corrected for two plants for the years 1990 to 2000. Emissions of dioxins from production of ferroalloys have therefore increased. Emissions of dioxins are calculated by Statistics Norway based on the general emission factor for combustion of coke and coal. The amount of reducing agents has increased because it now includes the total amount of reducing agents used. Earlier an amount representing CO gas sold was subtracted.

For one ferroalloys production plant, reported emissions of SO_2 have been used instead of calculated, for the years 1990-2003. For another, reported emissions of SO_2 and NO_x have been used instead of calculated for the years 1997-2003.

3D Other
N_2O from propellant gas, drag racing and research is for the first time included in the inventory.

8.5.3. Agriculture

4B Manure Management and 4D Agricultural Soils
New final figures for the population of different animals have been used for 2002 in the calculations of NH_3 emissions.

4B13 Other
Final figures for domestic animals for 2002 have increased the emissions of NH_3.

4D1 Direct Soil Emission
Final figures for domestic animals for 2002 have increased the emissions of NH_3 from manure.

4F Field burning of agricultural waste
The share of straw burnt has been changed, based on new estimates for the years 2001-2004, from 15 per cent and gradually down to 7.5 per cent.

8.5.4. Waste

6C Waste incineration (e)
New revised figures for production at one plant for the years 2000-2002 has led to small changes in the emissions. The number of cremated bodies has increased for the years 2000-2002, because non-residents in the municipalities are now included. This has led to higher emissions of mercury, PAH and dioxins.

6D Other waste (f)
Lead, cadmium, mercury, PM_{10} and TSP emissions from one plant have been included in the inventory for the first time. This leads to increased emissions for the years 1997 to 2002.

8.6. Implications of the recalculations for the long-range transbundary air pollutants

8.6.1. Implications for emissions levels

Table 8.4 shows the effects of recalculations on the emission figures for the main pollutants 1990-2002, table 8.5 the effect on the PM emissions and table 8.6 the effects on the POP and heavy metal emission figures.

Table 8.4. Recalculations in 2004 submission compared to the 2003 submission. Main pollutants

	SO_2 tonnes	NO_x tonnes	NMVOC tonnes	CO tonnes	NH_3 tonnes
1990	-391	153	134	90	0
1991	-43	190	582	80	0
1992	-112	133	1059	56	0
1993	-97	225	2405	23	0
1994	25	281	1309	54	3.6380E-12
1995	26	437	310	78	0
1996	77	284	-1663	24	0
1997	133	343	-1344	-39	0
1998	74	614	375	-2735	0
1999	20	497	1887	-5122	0
2000	-17	222	754	-6388	-1
2001	-15	138	-94	-6698	-2
2002	56	-2040	384	11607	443

Tables 8.5 and 8.6 show the total effect of the recalculations performed in the 2003 submission for TSP, PM_{10}, $PM_{2.5}$, HM and POPs.

Table 8.5. Recalculations in 2005 submission compared to the 2004 submission. Particulate Matter

	TSP tonnes	PM_{10} tonnes	$PM_{2.5}$ tonnes
1990	-123	-202	-135
1991	-12	-89	-24
1992	-119	-182	-123
1993	-95	-158	-102
1994	-53	-116	-62
1995	-52	-107	-60
1996	-34	-85	-38
1997	-15	-76	-21
1998	-799	-853	-805
1999	-1 620	-1 681	-1 627
2000	-3 160	-2 720	-2 595
2001	-2 692	-2 777	-2 706
2002	2 474	2 345	2 423

Table 8.6. Recalculations in 2004 submission compared to the 2003 submission. POPs and heavy metals

	Lead Kg	Cad-mium Kg	Mer-cury Kg	Arse-nic Kg	Chro-mium Kg	Copper Kg	PAH-4 (CLRTAP) Kg	Dioxins mg
1990	1034	-7	-212	0	-332	265	0	0.0000
1991	1021	-7	-191	0	-327	3603	0	0.0000
1992	1023	-7	-195	0	-321	304	1125	0.0000
1993	1036	-7	-207	0	-337	296	-492	0.0001
1994	1072	-7	-224	0	-337	1514	888	0.0001
1995	1082	-7	-226	0	-339	359	1063	0.0001
1996	1120	-7	-228	0	-341	393	1313	0.0001
1997	1157	-7	-240	0	-341	455	1488	0.0001
1998	1189	-9	-242	-3	-344	418	1312	0.0001
1999	1198	-8	-253	-2	-344	411	924	0.0001
2000	1205	-17	-247	-2	-361	333	1609	0.0002
2001	1236	-26	-260	7	-340	428	1133	-0.0004
2002	1255	-35	-255	-27	-372	248	1818	-0.0003

8.6.2. Implications for emission trends

As a result of the different recalculations for 1990-2002 there have been some small changes in the trends. The differences are shown in the tables below.

Table 8.7. Trends in emissions 1990-2002. This submission vs. previous submission. Main Pollutants. Per cent change 1990-2002

	SO_2	NO_x	NMVOC	CO	NH_3
This submission	-57.4	-5.8	17.2	-37.6	11.3
Previous submission	-57.8	-4.8	17.2	-38.9	9.2

Table 8.8. Trends in emissions 1990-2002. This submission vs. previous submission. Particulate Matter. Per cent change 1990-2002

	TSP	PM_{10}	$PM_{2.5}$
This submission	-9.9	-8.4	-6.4
Previous submission	-12.8	-12.0	-10.5

Table 8.9. Trends in emissions 1990-2002. This submission vs previous submission. POPs and heavy metals. Per cent change 1990-2002

	Lead	Cad-mium	Mer-cury	Ars-enic	Chro-mium	Copper	PAH-4 (CLRTAP)	Dioxins
This submission	-95.9	-59.9	-56.5	-43.6	-56.2	-11.6	4.5	-76.0
Previous submission	-96.6	-58.0	-46.9	-42.7	-54.4	-11.6	0.1	-75.8

9. Areas for further improvement

9.1. Overview

There are several areas where improvement actions are needed to improve the Norwegian emission inventory system. In this chapter the main issues are listed. For greenhouse gases the yearly international reviews identifies areas where the Norwegian inventory needs improvements to be consistent with the IPCC Guidelines.

9.2. General

- The latest uncertainty analyses are from the year 2000 for greenhouse gases, and from 2001 for long-range air pollutants, and they need to be updated to reflect the changes made in the inventory since then. The uncertainty analysis could also be improved by including a discussion of the factors influencing the high uncertainty of a number of parameters.
- Many of the emission factors used in the inventory are relatively old, some over 10 years, and they need to be analysed. Some of them also lack good documentation and source references.
- There is also a need to better the quality of the data reported from the plants that are used in the inventory. A better documentation of the reported data is needed (calculation methodology, measuring methodology etc.).

9.3. Energy

- Emissions from road traffic (both greenhouse gases and LRTAP-gases) are calculated by a model that was developed in the early nineties and revised in 1998/1999. The model has not been updated since and do not reflect new knowledge that have occured since then. Especially the N_2O emission factors for road transportation in the national emission inventory are far too high compared to those of other European countries. In order to deal with this inadequacy in the national inventory, a project has been scheduled in 2005 aiming at updating these emission factors. The model must be updated for all emission compounds (N_2O, NO_x, CO, VOC and particles).
- The emission estimations for navigation needs to be updated, especially the figures for NO_x. The methodology calculating NO_x emissions from navigation used today do not reflect the effects of efforts made to reduce the emissions. There is a large uncertainty connected to the calculations for emissions from navigation, both in the activity data and in the emission factors.
- Fuel wood is the second most important energy source in private households in Norway. For emissions of particulates this is the single most important emission source and fuel wood are also an important source for heavy metals, PAHs and dioxins. Nevertheless the consumption figures and therefor also the emission figures are uncertain and they are published 2-3 years after the reporting year. In 2005 a project that aims to produce better statistics on fuel wood use and emissions from it was initiated. Statistics Norway hopes this can be the start of a new annual official statistics for fuel wood consumption and emissions. If this is the case depends on both quality of the first results from the project and external funding.
- Wear of asphalt from studded tyres is one of the most important sources to particulates in Norway (along with fuel wood burning and road traffic exhaust). The model used for calculating these emissions was developed in 1998 and needs evaluation and probably revision too.
- The sulphur content in fuel wood and carbon used for stationary combustion need to be revised. The calculations used today are connected to a large uncertainty.
- The energy inventory that is used as input to the Norwegian emission inventory has for some sectors a need for an update. A project is initiated in 2005, with the aim to review the methods and data sources used in the energy inventory, and to propose alternative sources and methods where that are needed. For use of petroleum products in the inventory Statistics Norway's sale statistics for petroleum products are used. The division between sectors in the sale statistics is not so fine as the one needed in the energy inventory. A number of different methods are being used to distribute the energy use of the different energy products on actual sectors. Some are based on very old assumptions and surveys that need to be updated. This is also the case for the electricity use, and the use of district heating.

9.4. Industry

- There is a need for an update of the calculations of emissions from consumption of halocarbons and SF_6 from 2003 and onwards as a result of the introduction of taxation and refund schemes. Statistics Norway will conduct a project in 2005 that will prepare new methodologies for calculation of emissions of HFCs and PFC used in products and processes. Focus will be on new and improved import/export data from customs statistics and revision of emission factors based on feedback from users and scientists. The aim of the project is to implement a fully revised and improved methodology for emissions in 2004 and onwards.
- Emissions from large point sources are reported from the companies to the Norwegian Pollution Control Authority. Over the last years the quality of this reporting has improved, especially for greenhouse gases, SO_2, NO_X and NMVOC. Because of the focus on CO_2 and emission trading the companies have evaluated their time series on emission figures and reported consistent emission figures back to 1992 or 1990. For heavy metals and POPs the time series seldom are consistent. Emissions of these components are difficult to measure and reporting of annual figures by the companies is often based on a limited number of measurements. Since the emission levels are varying from hour to hour and day to day, this gives a large variation in annual reported emissions. For use in national emission inventories the time series on national level must be consistent. To achieve this the companies either have to correct their time series if they have conducted more accurate measurements for a year or they discover errors in previously reported data or the Norwegian Pollution Control Authority/Statistics Norway have to make a corrected time series. Up to now Statistics Norway have done these correction. We think it would be an advantage if the companies themselves made such corrections and reported revised and consistent time series to the Norwegian Pollution Control Authority, the same way this have been done for CO_2.

9.5. Solvent and other product use

- The inventory used for calculating emissions of NMVOC from solvents is based on a study made in 1995. This means that reduced emissions as a consequence of the EU VOC-directive is not reflected in the inventory, which can lead to an overestimation of this emission source. Solvents and other product use is the second most important NMVOC source in Norway. It is therefore important to prioritise a revision of the solvents model.

9.6. Agriculture

- Emission of methane from enteric fermentation is now calculated with a simple Tier 1 methodology using IPCC default emission factors. Since this is an important emission source that is defined as a key category, Tier 2 methodology should be employed.
- It is a great uncertainty connected to the calculations of N_2O from agricultural soils. The calculations are based on a simple Tier 1 methodology, which results in that some efforts made to reduce the emissions are not catched up in the calculations, as for example changes in soil cultivation practices. The country specific methodology for calculating the N_2O emission from crop residues also needs to be reviewed and better documented.

References

Aakra, Å. and M.A. Bleken (1997): *N_2O Emissions from Norwegian Agriculture as Estimated by the IPCC Methodology*, Departement of Biotechnological Sciences, Ås: Norwegian University of Life Sciences.

Aardenne, J.A., Kroeze, C., and Hordijk, L. (1998): Analysis of the uncertainties in the IPCC default method for estimating N_2O emissions from agricultural soils, Discussion paper submitted for an expert group meeting on managing uncertainty in national greenhouse gas inventories.

Aker Engineering (1992): *Direct Hydrocarbon Gas Emissions from Production and Riser Platforms*

Aspmo, R. (1986): Forurensning fra landbruket - ressurser på avveier, Landbruksforlaget.

Bang, J. (1993): *Utslipp fra dieseldrevne anleggsmaskiner, arbeidsredskaper, traktorer og lokomotiver* (Emissions from diesel-powered construction machinery, tools, tractors and locomotives), Oslo: National Institute of Technology.

Bang, J. (1996): Utslipp av NMVOC fra fritidsbåter og bensindrevne motorredskaper (Emissions of NMVOC from leisure craft and gasoline-powered equipment), Oslo: National Institute of Technology.

Bang, J., K. Flugsrud, G. Haakonsen, S. Holtskog, S.Larssen, K.O.Maldum, K. Rypdal og A. Skedsmo (1999): *Utslipp fra veitrafikk i Norge. Dokumentasjon av beregningsmetode, data og resultater* (Emissions from road traffic in Norway - documentation of a calculation method, data and results). Report 99:04, Oslo: The Norwegian Pollution Control Authority.

Barlaz, M. (2004): National Council for Air and Stream Improvment USA, *Technical Bulletin* no. **872**, March 2004.

Benestad C. (2000): Personal information, E-mail dating 30/10-2000.

Bergfald & Co as (2000): Emissions of methane from coal mining at Svalbard. (Only in Norwegian).

Bolstad, T. (1994): *Utskilling av nitrogen og fosfor i gjødsel og urin frå husdyr i Norge* (Nitrogen and phosphorus in manure and urine from domestic animals in Norway), Department of animal science, Ås: Norwegian University of Life Sciences.

Bremmer, H.J., L.M. Troost, G. Kuipers, J. de Koning J and A.A. Sein (1994): *Emission of dioxins in the Netherlands,* Bilthoven: National institute of public health and enviromental protection (RIVM).

Brink, R. M. M. v. d. (1996): *Deeltjesemissie door wegverkeer;emissiefactoren, deeltjesgrootteverdeling en chemische samenstelling* (Particle emissions from road traffic; emission factors, particle size distribution and chemical composition), Bilthoven: National institute of public health and enviromental protection (RIVM).

Brock C.A ., A. Döpelheuer, A. Petzol and F. Schröder (1999): In situ observations and model calculations of black carbon emissions by aircraft at cruise altitude. *Journal of Geophysical Research* Vol **104**. No D18, 22,171-22,181.

Bækken (1993): Miljøvirkninger av vegtrafikkens asfalt og dekkslitasje (Environmental effects of the asphalt paving and tyre wear from road traffic), rapport O-92090, Oslo: Norsk institutt for vannforskning.

Claesson, S. and S. Steinbeck (1991): *Växtnäring, hushålling - miljø* (Plant nutrients, their management and the environment), Speciella skrifter 41, Uppsala: Agricultural University of Sweden (SLU).

Dämmgen, U., Lüttich, M., Döhler, H., Eurich-Menden,B. and B. Osterburg (2002): GAS-EM - A Procedure to Calculate Gaseous Emissions from Agriculture. *Landbauforschung Völkenrode **52***, 19-42.

Daasvatn L., K. Flugsrud, H. Høie, K. Rypdal, T. Sandmo (1992): Modell for beregning av nasjonale utslipp til luft. Dokumentasjon (Model for calculation of national air emissions. Documentation), Interne notater 92/17, Statistics Norway.

Daasvatn, L., K. Flugsrud, O.K. Hunnes and K. Rypdal (1994): Beregning av regionaliserte utslipp til luft. Beskrivelse av modell og metoder for estimering (Calculation of emissions to air on a regional basis. Description of a model and estimation methods), Notater 94/16, Statistics Norway.

Directorate for Health (1990): Retningslinjer for inneluftkvalitet (Guidelines for indoor air quality). Helsedirektoratets utredningsserie 6/90.

Döpelheuer, A. and M. Lecht (1998): *Influence of engine performance on emission characteristics*. RTO AVT Symposium on "Gas Turbine Engine Combustion, Emissions and Alternative Fuels". NATO Research and Technology Organization. RTO Meeting Proceedings. 14.

ECETOC (1994): *Ammonia Emissions to Air in Western Europe,* ECETOC Technical report No. 62, Brussels: European Centre for Ecotoxicology and Toxicology of Chemicals.

EEA (1996): *EMEP/Corinair. The Atmospheric Emission Inventory Guidebook*. First edition, Copenhagen: European Environmental Agency.

EEA (1997): *Copert II. Computer programme to calculate emissions from road transport*. *Methodology and emission factors*, Topic report 1997, Copenhagen: European Environmental Agency.

EEA (2001): Emission Inventory Guidebook, 3rd Edition. A joint EMEP/CORINAIR Production, Copenhagen: European Environmental Agency.

Eggleston, Gorißen, Joumard, Rijkeboer, Samaras and Zierock (1991): *CORINAIR Working Group on Emission Factors for Calculating 1990 Emissions from Road Traffic. Volume 1: Methodology and Emission Factors,* Final report, December 1991.

Eikeland (2002): Personal information, E-mail dating 29.05.2002. Elkem@elkem.no

EPA (1986): *Ferro-alloy Industry Particulate Emissions: Source Category Report*, Report no EPA/600/7-86/039, U.S. Environmental Protection Agency.

EPA (1998): *Locating and Estimating Airmissions From Sources of Polycyclic Organic Matter.* EPA-454/R-98-014, U.S. Environmental Protection Agency.

EPA (2002): *Compilation of air pollutant emission factors. Fifth edition, AP-42, Volume 1, Stationary Point & Area Sources, Update 2001 & Update 2002*, U.S. Environmental Protection Agency.

Erlandsen K., J.L. Hass and K.Ø. Sørensen (2002): Norwegian Economic and Environment Accounts (NOREEA) Project Report - 2001, Documents 2002/15, Statistics Norway.

EU (2002): Final Technical Report of the SACS2 project, issued 30. Aug. 2002, EU project NNE-1999-00521.

Evans, F. (2000): Personal information, telephone call 20/11-00, Oslo: Norwegian Institute of Wood Technology.

Evensen, R. (1997a): Personal information, telephone call 11/12 1997. Bærum: ViaNova.

Evensen, R. (1997b): Note for Johnny Johansen. 14/12 1997. Bærum: ViaNova.

FAO (2002): FAOSTAT database, http://apps.fao.org.

Finstad, A., G.Haakonsen, E.Kvingedal and K.Rypdal (2001): *Utslipp til luft av noen miljøgifter i Norge - Dokumentasjon av metode og resultater* (Emissions of some hazardous chemicals to air in Norway - Documentation of methodology and results), Report 2001/17, Statistics Norway.

Finstad, A., G. Haakonsen and K. Rypdal (2002a): *Utslipp til luft av dioksiner i Norge - Dokumentasjon av metode og resultater* (Emissions to air of dioxins in Norway - Documentation of methodology and results) , Report 2002/7, Statistics Norway.

Finstad, A., K. Flugsrud and K. Rypdal (2002b): *Utslipp til luft fra norsk luftfart* (Emissions to air from Norwegian air traffic), Report 2002/8, Statistics Norway.

Finstad, A., and K. Rypdal (2003): *Utslipp til luft av kobber, krom og arsen i Norge - Dokumentasjon av metode og resultater* (Emissions to air of copper, chromium and arsenic in Norway - Documentation of methodology and results), Report 2003/7, Statistics Norway.

Finstad, A., G. Haakonsen and K. Rypdal (2003): *Utslipp til luft av partikler i Norge - Dokumentasjon av metode og resultater* (Emissions to air of particles in Norway - Documentation of methodology and results), Report 2003/15, Statistics Norway.

Finstad A., K. Flugsrud, G. Haakonsen and K. Aasestad (2004): Vedforbruk, fyringsvaner og svevestøv.

Undersøkelse om vedforbruk og fyringsvaner i Trondheim og Bergen 2003 (Use of wood for heating, heating habits and particulate matters. Survey of use of wood for heating and heating habits in Trondheim and Bergen 2003), Report 2004/24, Statistics Norway.

Flugsrud K., and K. Rypdal (1996): *Utslipp til luft fra innenriks sjøfart, fiske og annen sjøtrafikk mellom norske havner* (Emissions to air from domestic shipping, fisheries and other maritime traffic between Norwegian ports). Report 96/17, Statistics Norway.

Flugsrud, K., E. Gjerald, G. Haakonsen, S. Holtskog, H. Høie, K. Rypdal, B. Tornsjø and F. Weidemann (2000): *The Norwegian Emission Inventory. Documentation of methodology and data for estimating emissions of greenhouse gases and long-range transboundary air pollutants,* Report 2000/1, Statistics Norway.

Flugsrud K. and K. Rypdal (2001): Sensitivity Analysis as a Tool for Systematic Reductions in GHG Inventory Uncertainties. *Environmental Policy and Science.* **Vol 4/2-3**, 117-135.

Fontelle, J.P. (2002): Personal information (e-mail correspondance), April 2002, CITEPA.

Fyns Amt (2000): *Estimeret beregning for årlig dioxinemission på 8 anlæg i Fyns Amt* (Estimated calculation for yearly dioxin emissions on 8 plants in Fyns Amt). Report 15.420. dk-TEKNIK Fredericia, May 2000.

Geological Society of London Memoir (under publishing): 4D seismic imaging of an injected CO2 plume at the Sleipner field, central North Sea.

Gundersen, G. I. and O. Rognstad (2001): *Lagring og bruk av husdyrgjødsel* (Storage and use of manure), Reports 2001/39, Statistics Norway.

Hansen, E. (2000): *Substance flow analysis for dioxins in Denmark*, Environmental project No 570 2000, Danish Environmental Protection Agency, Danish Ministry of the Environment.

Hassel, Jost, Weber, Dursbeck, Sonnborn and Plettau (1994): *Abgas-Emissionsfaktoren von Pkw in der Bundesrepublik Deutschland.* Berichte 8/94. Umweltbundesamt (UBA) 1994.

Haukeland J.V., A. Skogli and I. Stangeby (1999): *Reisevaner i Norge 1998* (Travel habits in Norway 1998), Report 418/1999, Oslo: Institute of Transport Economics (TØI).

Hedalen T. (1994): *Vegslitasje - partikkelstørrelses-fordeling* (Road abrasion - particle size distribution), Report no. STF36 A94011, Trondheim: Institute of Social Research in Industry (SINTEF) Bergteknikk.

Hedalen, T. and T. Myran (1994): *Vegstøvdepot i Trondheim - partikkelstørrelsesfordeling, kjemisk og mineralogisk sammensetning* (Road dust depot in Trondheim - particle size distribution, chemical and mineralogic composition), STF36 A94037, Trondheim: Institute of Social Research in Industry (SINTEF) Bergteknikk.

Hutchings, N.J., Sommer, S.G., Andersen, J.M. and W.A.H. Asman (2001): A detailed ammonia emission inventory for Denmark. *Atmospheric Environment* ***35***, 1959-1968.

Haakonsen, G., K. Rypdal and B. Tornsjø (1998): Utslippsfaktorer for lokale utslipp - PAH, partikler og NMVOC (Emission factors for local emissions - PAH, particles and NMVOC), Notater 98/29, Statistics Norway.

Haakonsen, G. (2001): Beregninger av utslipp til luft av klimagasser. En gjennomgang av arbeidsprosess og dokumentasjon (Calculations of emissions to air of greenhouse gases. A review of the work process and documentation). Notater 2001/77, Statistics Norway.

Haakonsen, G. and E. Kvingedal (2001):*Utslipp til luft fra vedfyring i Norge. Utslippsfaktorer, ildstedsbestand og fyringsvaner* (Emissions to air from combustion of wood in Norway), Report 2001/36, Statistics Norway.

IMC (2000): *Seam Gas Content Analysis.* Technical Services Limited.

IPCC (1997a): Greenhouse Gas Inventory. Workbook. IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2, London: Intergovernmental Panel on Climate Change.

IPCC (1997b): Greenhouse Gas Inventory. Reference Manual. Revised 1996. IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3, London: Intergovernmental Panel on Climate Change.

IPCC (2001): Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. J. Penman et. al. (eds.), Hayama, Japan: IPCC National Greenhouse Gas Inventories Programme, Technical Support Unit.

Jebsens miljøteknikk (1991): Undersøkelse av utslipp av støv, PAH, CO, SO_2 og tyngre organiske forbindelser fra et motstrøms og et ordinært trommelblandeverk for asfalt.

Jordforsk (1998): *Report from the monitoring of nutrients in 1997* (Authors: Vagstad, N., M. Bechmann, P. Stålnacke, H.O. Eggestad and J. Deelstra), Ås: Centre for Soil and Environmental Research.

Jordforsk (2004): Personal information (e-mail correspondance) Arne Grønlund, Centre for Soil and Environmental Research, February 2004.

Karlsson M.L., P.A. Wallin and L. Gustavsson (1992): *Emissioner från biobrensle-eldade anläggningar mellan 0,5 och 10 MW* (Emissions from biofuel plants between 0,5 and 10 MW), SP report 1992:46, Borås: Swedish National Testing and Research Institute.

Larssen, S. (1985): *Støv fra asfaltveier. Karakterisering av luftbåret veistøv. Fase 1: Målinger i Oslo, våren 1985* (Dust from asphalt roads. Characterization of air carried road dust. Phase 1: Measurements in Oslo, spring 1985), O-8431, Kjeller: Norwegian Institute for Air Research (NILU).

Lloyd's Register (1995): Marine Exhaust Emissions Research Programme, London: Lloyd's Register of Shipping.

Lunnan et al. (1991): Skog og skogproduksjon i Norge som virkemiddel mot CO_2-opphoping i atmosfæren (Forest and forest production in Norway as a way of reducing CO_2 accumulation in the atmosphere), *Skogforsk* **6**, Norwegian Forest Research Institute.

Misselbrook T.H, Van Der Weerden, T.J., Pain, B.F., Jarvis, S.C., Chambers, B.J., Smith, K.A., Phillips, V.R, and T.G.M. Demmers (2000): Ammonia emission factors for UK agriculture. *Atmospheric Environment* **34**, 871-880.

Morken, J. (1994): *Ammoniakktap fra husdyrrom og gjødsellager* (Losses of ammonia from livestock housing and manure storage facilities), ITF report no. 13/94, Department of Agricultural Engineering, Ås: Norwegian University of Life Sciences.

Morken, J. (2003a): Personal information, Department of Agricultural Engineering, Norwegian University of Life Sciences.

Morken, J. (2003b): Evaluering av ammoniakkutslippsmodellen (Evaluation of the ammonia emission model), internal note, Department of Agricultural Engineering, Norwegian University of Life Sciences.

Morken, J. and L. Nesheim (2004): Utnytting og tap av næringsstoff i husdyrgjødsel - framtidige utfordringar, *Grønn kunnskap* Vol. 8 Nr. 3-2004, 51-64.

NIJOS (2000): *Skog 2000: statistikk over skogforhold og -ressurser i Norge* (Forest 2000: Statistics of forest conditions and resources in Norway), Ås: National Institute of Land Inventory.

NILU/NIVA (1995): *Materialstrømsanalyse av PAH, 1995* (Material flow analysis of PAHs, 1995), Report O-92108, Kjeller and Oslo: Norwegian Institute for Air Research (NILU) and Norwegian institute for Water research (NIVA).

Norsk Hydro (1995): Personal information, Kaarstad, Norsk Hydro.

NPD (2001): *Forskrift om måling av petroleum for fiskale formål og for beregning av CO2-avgift* (Regulation on measurements of petroleum for fiscal purposes and for the calculation of the CO2 tax), 1. november 2001, Oslo: Oljedirektoratet (OD), http://www.npd.no/regelverk/r2002/frame_n.htm

NPRA (1995a): *Undersøkelse av vegvedlikehold og kjøreforhold - vinteren 1994/1995. Del I: Samlet fremstilling og analyser av undersøkelsene i perioden 1990 - 94* (Investigation of road maintenance and driving circumstances -Winter 1994/1995. Part I: Summary description and analyses of the investigations in the period 1990-94), Nr. 95-333, Norwegian Public Roads Administration.

NPRA (1995b): *Undersøkelse av vegvedlikehold og kjøreforhold - vinteren 1994/1995. Del II: Statistikkhefte for undersøkelsene i perioden 1990 - 94* (Investigation of road maintenance and driving circumstances -Winter 1994/1995. Part II: Statistical booklet about the investigations in the period 1990-94). Nr. 95-334, Norwegian Public Roads Administration.

NPRA (1996): *Veg-grepsprosjektet; Delprosjekt 5.15: Samfunnsøkonomiske konsekvenser; Dokumentasjon av beregningsmodell* (The road grip project; Part project 5.15: Social economic consequences; Documentation of calculation modell), Internal report no. 1918, Norwegian Public Roads Administration.

NPRA (1997): *Veg-grepsprosjektet: Samlerapport; Konklusjoner, forslag til ny veg-grepspolitikk og resultater* (The road grip project: Summary report; Conclutions, proposals for new road grip politics and results), Internal report no. 1994, Norwegian Public Roads Administration.

NPRA (1998): *Undersøkelse av vegvedlikehold og kjøreforhold - vinteren 1997/98 Landssammenstilling* (Investigation of road maintenance and driving circumstances -Winter 1997/98, Country collocation), STF22 A98561, Norwegian Public Roads Administration.

NTI (2000): *Fokus på tre*, Nr. **21**, Norwegian Institute of Wood Technology.

OLF (1991): OLF Environmental Programme. Emissions to air. Report Phase I - Part A, Stavanger: Norwegian Oil Industry Association.

OLF (1993): OLF Environmental Programme. Phase II. Summary Report. March 1993, Stavanger: Norwegian Oil Industry Association.

OLF (1994): Anbefalte retningslinjer for utslippsberegning. Identifisering, kvantifisering og rapportering av forbruks- og utslippsdata fra aktiviteter i norsk oljevirksomhet (Recommended guidelines for emission calculations. Identification, quantification and reporting of data on consumption and emissions from activities in the Norwegian oil and gas sector), Stavanger: Norwegian Oil Industry Association.

OLF (2004): Veiledning til Vedlegg til Opplysningspliktforskriften; Krav til rapportering fra offshore petroleumsvirksomhet på norsk kontinentalsokkel. (Recommended guidelines for reporting from activities at the Norwegian oil and gas sector.), Novatech as December 2004.

Olivier, J.G.J. (1991): *Inventory of aircraft Emissions: A review of Recent Literature*, Report no. 736 301 008, Bilthoven: National Institute of Public Health and Environmental Protection

Parma, Z., Vosta J., Horejs J., Pacyna J.M. and D. Thomas (1995): *Atmospheric Emission Inventory Guidelines for Persistent Organic Pollutants (POPs),* Prague, The Czech Republic: Report for External Affairs Canada.

Petersen, S.O. and J.E. Olesen (2002): Greenhouse gas Inventories for Agriculture in the Nordic Countries. Proceedings from an international workshop, Helsingør, Denmark 24-25 January 2002, *DIAS report Plant Production* no. **81.**

Rideng, A. (2001): *Transportytelser i Norge 1946-2000* (Transport performance in Norway 1946-2000), Report 515/2001, Oslo: Institute of Transport Economics.

Rosland, A. (1987): Utslippskoeffesienter. Oversikt over koeffesienter for utslipp til luft og metoder for å beregne disse (Emission factors. Overview of factors for emissions to air and methods of calculating them), Oslo: Norwegian Pollution Control Authority (SFT).

Rypdal, K. (1993): *Anthropogenic Emissions of the greenhouse gases CO_2, CH_4 and N_2O in Norway,* Reports 93/24, Statistics Norway.

Rypdal, K. (1995a): *Løsemiddelbalanse for Norge* (Solvent balance for Norway), Report 95:02, Oslo: Norwegian Pollution Control Authority (SFT).

Rypdal, K. (1995b): *Anthropogenic Emissions of SO_2, NO_x, NMVOC and NH_3 in Norway*, Reports 95/12, Statistics Norway.

Rypdal, K. and T. Mykkelbost (1997): Utslippsfaktorer for miljøgifter (Emission factors for hazardous chemicals), Internal notes 25.06.1997, Statistics Norway.

Rypdal, K. and L-C. Zhang (2000): *Uncertainties in the Norwegian Greenhouse Gas Emission Inventory*, Report 2000/13, Statistics Norway.

Rypdal, K. and L-C. Zhang (2001): *Uncertainties in Emissions of Long-Range Air Pollutants*, Report 2001/37, Statistics Norway.

Rypdal, K. (2001): CO_2 emission estimates for Norway. Methodological difficulties, Documents 2001/14, Statistics Norway.

Schøning, P. (1992): *Ressursregnskap for skog 1987-1991 : dokumentasjon av metode og resultater* (Resource accounts for forestry 1987-1991: Documentation of method and results), Internal notes 92/15, Statistics Norway.

Sérié, E. and R. Joumard (1996): *Proposition of modelling of cold start emissions for road vehicles.* MEET Project, INRETS report LEN 9624, December 1996.

SFT (1990): Klimagassregnskap for Norge. Beskrivelse av utslippsmengder, drivhusstyrke og utslippsfaktorer. Bidrag til den interdepartementale klimautredningen (Greenhouse gas inventory for Norway. Emission figures, global warming potentials and emission factors. Contribution to the interministerial climate report.), Oslo: Norwegian Pollution Control Authority.

SFT (1992): *Biologiske nitrogenfjerningsprosesser - en kilde til lystgassutslipp?* (Biological nitrogen removal processes - a source of nitrogen oxide emissions), Report 92:27, Oslo: Norwegian Pollution Control Authority.

SFT (1993): *Utslipp fra veitrafikken i Norge. Dokumentasjon av beregningsmetode, data og resultater* (Emissions from road traffic in Norway - Method for estimation, input data and emission estimates), Report 93:12, Oslo: Norwegian Pollution Control Authority.

SFT (1996): *Utslipp ved håndtering av kommunalt avfall* (Emissions from municipal waste management), Report 96:16 (Authors: Sandgren J., A. Heie, and T. Sverud), Oslo: Norwegian Pollution Control Authority.

SFT (1999a): *Evaluation of uncertainty in the Norwegian emission inventory*, Report 99:01 (Author: K. Rypdal), Oslo: Norwegian Pollution Control Authority.

SFT (1999b): *Calculations of emissions of HFCs and PFCs in Norway. Tier 2 method*, Report 99:03 (Author: Hans T. Haukås, Sigurd Holtskog, and Marit Viktoria Pettersen), Oslo: Norwegian Pollution Control Authority.

SFT (1999c): *Utslipp fra vegtrafikk i Norge. Dokumentasjon av beregningsmetode, data og resultater* (Emissions from road traffic in Norway - Method for estimation, input data and emission estimates), Report 99:04 (Updated SFT report 93:12, Author: Bang, J., K. Flugsrud, G. Haakonsen, S. Holtskog, S. Larssen, K.O. Maldum, K. Rypdal and A. Skedsmo), Oslo: Norwegian Pollution Control Authority.

SFT (1999d): *Materialstrømsanalyse av SF_6. Beregning av potensielt og faktisk utslipp over tid* (Material flow analysis of SF_6. Calculation of potential and actual emissions over time), Report 99:14, Oslo: Norwegian Pollution Control Authority.

SFT (1999e): *Beregningsmodell for utslipp av metangass fra norske deponier* (Model for estimation of CH_4 from landfills in Norway), Report 99:16 (Author: Frøiland Jensen J.E., Williksen T. and J. Bartnes at Norconsult), Oslo: Norwegian Pollution Control Authority.

SFT (1999f): PAH-utslipp til sjø og luft fra aluminiumsverkene på Lista, Karmøy og Mosjøen, (Elkem Aluminium, Teknologisk institutt, SINTEF, NIVA), Notat, Norwegian Pollution Control Authority.

SFT (2001a): *Harmonized Quantification and Reporting Procedures (HARP-HAZ Prototype),* Report 1789/2001, Oslo: Norwegian Pollution Control Authority.

SFT (2001b): Units for dioxins (dioxins.doc). Personal information C. Benestad, 13 March 2001, Norwegian Pollution Control Authority.

SFT (2005a): *Methane emissions from solid waste disposal sites*, TA- 2079/2005, ISBN 82-7655-246-3, Oslo: Norwegian Pollution Control Authority. http://www.sft.no/publikasjoner/luft/2079/ta2079.pdf

SFT (2005b): *National Inventory Report 2005, Norway, Greenhouse Gas Emissions 1990-2003 Reported According to the UNFCCC Reporting Guidelines*, TA-2097/2005, ISBN 82-7655-258-7, Oslo: Norwegian Pollution Control Authority. http://www.sft.no/publikasjoner/luft/2097/ta2097.pdf

SINTEF (1995): *Round robin test of a wood stove-emissions*, SINTEF Report STF12 F95012 (Author: Karlsvik, E.), Trondheim: SINTEF (Institute of Social Research in Industry).

SINTEF (1998a): *Emisjonsfaktorer for CO_2-utslipp fra sementproduksjon i Norge for 1990 og 1997* (Emission factors for CO_2 emissions from cement production in Norway for 1990 and 1997), SINTEF Report STF66 A98511 (Authors: Andersen, T. and K.H.Karstensen), Oslo: SINTEF (Institute of Social Research in Industry).

SINTEF (1998b): *Omregningsfaktorer for CO_2-utslipp fra metallurgisk industri og sementproduksjon. Delprosjekt 1. CO_2-utslipp fra forskjellige typer reduksjonsmaterialer* (Conversion factors for CO_2 emissions from metal manufacturing and cement production. Part 1. CO_2 emissions from various types of reducing agents), Revised edition, SINTEF Report STF24 A98550 (Author: Raaness, O.), Trondheim: SINTEF (Institute of Social Research in Industry).

SINTEF (1998c): *Omregningsfaktorer for CO_2-utslipp fra metallurgisk industri og sementproduksjon. Delprosjekt 2. Produksjon av ferrosilisium og silisiummetall i Norge* (Conversion factors for CO_2 emissions from metal manufacturing and cement production. Part 2. Production of ferro silicon and silicon metal in Norway), Revised edition, SINTEF Report STF24 A98537 (Author: Monsen, B.), Trondheim: SINTEF (Institute of Social Research in Industry).

SINTEF (1998d): *Omregningsfaktorer for CO_2-utslipp fra metallurgisk industri og sementproduksjon. Delprosjekt 3. Produksjon av ferromangan, silikomangan og ferrokrom i Norge* (Conversion factors for CO_2 emissions from metal manufacturing and cement production. Part 3. Production of ferro manganese, silicon manganese and ferro chromium in Norway), ST24 A98548 (Authors: Monsen, B. and S.E. Olsen), Trondheim: SINTEF (Institute of Social Research in Industry).

SINTEF (1998e): *Omregningsfaktorer for CO_2-utslipp fra metallurgisk industri og sementproduksjon. Delprosjekt 4. Utslipp av CO_2 ved produksjon av silisiumkarbid og kalsiumkarbid* (Conversion factors for CO_2 emissions from metal manufacturing and cement production. Part 4. CO_2 emissions from production of silicon carbide and calcium carbide), SINTEF Report STF24 A98549 (Authors: Raaness, O. and S. Olsen), Trondheim: SINTEF (Institute of Social Research in Industry).

SINTEF (1998f): *Omregningsfaktorer for CO_2-utslipp fra metallurgisk industri og sementproduksjon. Delprosjekt 5. Produksjon av magnesium* (Conversion factors for CO_2 emissions from metal manufacturing and cement production. Part 5. Magnesium production), SINTEF Report STF24 A98574 (Authors: Olsen, K., T. Støre and R. Tunold), Trondheim: SINTEF (Institute of Social Research in Industry).

SINTEF and Det Norske Veritas (2004): *Hvitbok om klimagassutslipp fra norsk landbasert prosessindustri* (White book about greenhouse gas emissions from Norwegian land based process industry), SINTEF Report STF24A03501, DNV Report 2002-1609, Revised February 2004.

SLB (1998): *Metallemission från trafiken i Stockholm- Slitasje av bromsbelägg (*Metal emissions from the traffic in Stockholm- Brake wear). Report 2:98, Stockholm: Stockholms luft- och bulleranalys.

Statistics Norway/SFT (2000): *Verification of the Norwegian Emission Inventory comparing emission intensity values with similar countries,* Report 2000:1736 (Authors: Haakonsen G., S. Holtskog, E. Kvingedal, K. Rypdal and B. Tornsjø at Statistics Norway), Oslo: Statistics Norway and Norwegian Pollution Control Authority.

Statistics Norway (2001): *Natural resources and the environment 2001. Norway*, Statistical Analyses 47, Statistics Norway.

Statistics Norway (2002): Sample Survey of agriculture and forestry 2001, Statistics Norway.

Statistics Norway (2003): Standard Industrial Classification (SIC2002), internet version only, http://www3.ssb.no/stabas/ItemsFrames.asp?ID=3152101&Language=en&VersionLevel=classversion&MenuChoice=Language

Sternbeck J., Sjödin, Å. and Andrèasson, K. (2001): *Spridning av metaller från vägtrafik,* Report B1431, Stockholm: IVL Swedish Environmental Research Institute.

Sundstøl, F. and Z. Mroz (1988): *Utskillelse av nitrogen og fosfor i gjødsel og urin fra husdyr i Norge* (Nitrogen and phosphorus in manure and urine from domestic animals in Norway) (*see Bolstad 1994*), Report no. 4 from the project "Agricultural policy and environmental management", Ås: Norwegian University of Life Sciences.

TI (1991): *Tiltak 11. Reduksjon av VOC-utslipp fra totaktsmotorer. Rapport utarbeidet av Teknologisk Institutt for Statens Forurensningstilsyn* (Reduction of VOC-emissions from two stroke engines), Oslo: National Institute of Technology.

Tine BA (2003): http://org.tine.no/nokkeltall.cfm

TNO (1992): *Emission Factors Manual Parcom-Atmos. Emission factors for air pollutants 1992,* Report 92-235, Institute of Enviromental and Energy Technology.

TNO (2002): CEPMEIP Database, www.mep.tno.nl

Tornsjø, B. (1998): *Emissions of greenhouse gases in Norway - estimated by the default IPCC methodologies and the Norwegian national inventory model,* Report 98:06, Oslo: Norwegian Pollution Control Authority.

Tornsjø, B. (2001): *Utslipp til luft fra innenriks sjøfart, fiske og annen sjøtrafikk mellom norske havner.* (Emissions to Air from Fishing Fleet and Sea Traffic between Norwegian Harbours), Report 2001/6, Statistics Norway.

UMB (2001): Expert judgement by Department of Animal Science, Ås: Norwegian University of Life Sciences

UN-ECE (2002): Control Techniques For Preventing And Abating Emissions Of Ammonia EB.AIR/WG.5/1999/8/Rev.1.

7th Greenhouse Gas Control Technologies Conference (2004): *Recent time-lapse seismic data show no indication of leakage at the Sleipner CO2-injection site*, 7th Greenhouse Gas Control Technologies Conference (GHGT7), Vancouver 2004.

Appendix A

Abbreviations

Pollutants

GHG	greenhouse gases
CO_2	Carbon dioxide
CH_4	Methane
N_2O	Nitrous oxide
PFCs	Perfluorocarbons
HFCs	Hydrofluorocarbons
SF_6	Sulphur hexafluoride
SO_2	Sulphur dioxide
NO_X	Nitrogen oxides
NH_3	Ammonia
CO	Carbon monoxide
(NM)VOC	(Non-methane) volatile organic compounds
TSP	Total suspended particulates
HM	heavy metals
Pb	Lead
Cd	Cadmium
Hg	Mercury
As	Arsenic
Cr	Chromium
Cu	Copper
POPs	persistent organic pollutants

Other

BOD	Biological oxygen demand
CLRTAP	Convention on Long-Range Transboundary Air Pollution
COZSTORE	Continuation project following SACS
CRB	Crop residue burned
CRF	Common Reporting Format
DOC	Degradable organic carbon
EEA	European Environment Agency
EPA	U.S. Environmental protection agency
GIS	Gas-insulated switchgear
INKOSYS	Register at the SFT with data and information on point sources
IPCC	Intergovernmental Panel on Climate Change
Jordforsk	Norwegian Centre for Soil and Environmental research
LPG	Liquid Petroleum Gas
LTO	Landing Take off
NFR	Nomenclature For Reporting
NILF	Norwegian Agricultural Economics Research Institute
NILU	Norwegian Institute for Air Research
NIVA	Norwegian Institute for Water Research
NPD	Norwegian Petroleum Directorate
NPRA	Norwegian Public Roads Administration
OECD	Organisation for Economic Co-operation and Development
OLF	Norwegian Oil Industry Association
PRODCOM	PRODucts of the European COMmunity
QA/QC	Quality Assurance and Quality Control
RVP	Reid vapour pressure
SACS	Saline aquifer carbon dioxide storage project
SFT	Norwegian Pollution Control Authority
SINTEF	Institute of Social Research in Industry
SPS	Specific wear of studded tyres
SWDS	Solid waste disposal sites
TNO	Institute of Environmental and Energy Technology
UNECE	United nations - Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
VPU	Vapour recovery units

Appendix B

Emission factors

In the calculations the numbers are used with the highest available accuracy. In this tables though, they are only shown rounded off, which i some cases can lead to the result that the exceptions looks the same as the general factors.

For road traffic this general view of the emission factors only includes last years factors and not all time series.

In the tables for stationary combustion, dotted cells indicate combinations of fuel and source without consumption.

A description of the sector codes used in the tables is given in Appendix F.

CO_2, SO_2 and heavy metals - Stationary and mobile combustion

Table B1. General emission factors for CO_2, SO_2 and heavy metals

	CO_2	SO_2[1]	Pb	Cd	Hg	As	Cr	Cu
	tonne/tonne	kg/tonne	g/tonne	g/tonne	g/tonne	g/tonne	g/tonne	g/tonne
Coal	2.52	**16**[2]	*0.2*[2]	*0.003*[2]	*0.05*[2]	*0.089*[2]	*0.065*[2]	*0.087*[2]
Coke	3.19	**18**	*0.2*[2]	*0.003*[2]	*0.05*[2]	*0.089*[2]	*0.065*[2]	*0.087*[2]
Petrol coke	3.59	**18**	0.2	0.003	0.05	0.089	0.065	0.087
Motor gasoline	3.13	**0.1**	**0.03**[3]	0.01	0	0.05	0.05	1.7
Aviation gasoline	3.13	**0.4**	675.7	0.01	0	0.05	0.05	1.7
Kerosene (heating)	3.15	**0.3**	0.07	0.01	0.03	0.05	0.04	0.05
Jet kerosene	3.15	**0.3**	0.07	0.01	0.03	0.05	0.05	0.05
Auto diesel	3.17	**0.192**[4]	0.1	0.01	0.05	0.05	0.05	1.7
Marine gas oil/diesel	3.17	**2**	0.1	0.01	0.05	0.05	0.04	0.05
Light fuel oils	3.17	**0.8**	0.1	0.01	0.05	0.05	0.04	0.05
Heavy distillate	3.17	**4.6**	0.1	0.01	0.05	0.05	0.04	0.05
Heavy fuel oil	3.2	**14**[5]	1	0.1	0.2	0.057	1.35	0.53
Natural gas (1000 Sm^3)	***2.34***	0	0.00025	0.002	0.001	0.004	0.021	0.016
LPG	3	0	0	0	0	0.004	0.021	0.016
Refinery gas	2.8	0	0	0	0	0.004	0.021	0.016
Blast furnace gas	1.571	0	0	0	0	0.004	0.021	0.016
Fuel gas	2.5	0	0	0	0	0.004	0.021	0.016
Landfill gas	0.275	**0.019**	0	0	0	0.004	0.021	0.016
Fuel wood	0	**0.2**	0.05	0.1	0.0084	0.159	0.152	0.354
Wood waste	0	**0.37**	0.05	0.1	0.0084	0.159	0.152	0.354
Black liquor	0	**0.37**	0.05	0.1	0.0084	0.159	0.152	0.354
Municipal waste	0.251	**1.4**	**0.00304**	**0.00015**	**0.00016**	0.022	0.001	0.000985
Special waste	3.2	**9.2**	14	0.6	0.2	1	31	25

[1] Apply 2003 to petroleum products; the factors changes yearly, in accordance with changes in the sulphur content in the products.

[2] Apply to industry.

[3] From 1997 - considerably higher earlier years. Earlier used factors are not shown in this Appendix.

[4] Apply to road traffic.

[5] Stationary combustion.

Numbers in italics have exceptions for some sectors, see Table B2. Bold numbers are different for different years, see Table B3, B4 and B5.

Source: Norwegian Petroleum Industry Association, Rosland (1987), SFT (1990), SFT (1996), Finstad et al. (2001) and Finstad et al. (2003).

Table B2. Exceptions from the general emission factors for heavy metals: Solid fuels in small stoves

	Pb g/tonne	Cd g/tonne	Hg g/tonne	As g/tonne	Cr g/tonne	Cu g/tonne
Coal	2.5	0.15	0.3	1.2	0.9	1.2
Coke	2.5	0.15	0.3	1.2	0.9	1.2

Table B3. Time series for variable emission factors for SO_2 (kg/tonne)

Years	V11 Motor gasoline	V13 Kerosene (heating)	V14 Jet kerosene	V15 Auto diesel				V17 Marine gas oil/diesel	V18 Light fuel oils	V19 Heavy distillate	V20 Heavy fuel oil (LS-oil)	V20 Heavy fuel oil (NS-oil)
	General	General	General	General	M.1A3B.1 Passenger cars	M.1A3B.2 Light duty vehicles	M.1A3B.3 Heavy duty vehicles	General	General	General	General	General
1980	1	0.2	0.2	6.6	.	.	.	6.6	6.6	15	19	46
1987	0.7	0.4	0.4	4.4	.	.	.	4.4	4.4	9	19	44
1989	0.6	0.4	0.4	3.4	.	.	.	3.4	3.4	7.6	18.2	40
1990	0.6	0.3	0.3	3.2	.	.	.	3.2	3.2	6	17	39.4
1991	0.6	0.38	0.38	2.8	.	.	.	2.8	2.8	4.6	16.8	43.6
1992	0.6	0.32	0.32	2.6	.	.	.	2.6	2.6	4.4	16.4	42.6
1993	0.6	0.42	0.42	2.2	.	.	.	2.2	2.2	4.4	16.2	45.8
1994	0.6	0.36	0.36	1.4	.	.	.	1.4	1.4	4.2	14.2	44.8
1995	0.24	0.46	0.46	1.4	.	.	.	1.4	1.4	4.6	11.8	43.4
1996	0.22	0.46	0.5	1.2	.	.	.	1.2	1.2	3.8	12.6	46.6
1997	0.16	0.46	0.46	1.2	.	.	.	1.2	1.2	3.8	12.6	47.2
1998	0.16	0.42	0.42	0.8	.	.	.	1.8	1.8	4.2	12.4	42.8
1999	0.22	0.32	0.32	0.6	.	.	.	1.6	1.6	4.4	12.8	39
2000	0.18	0.36	0.36	1.4	0.33491	0.33491	0.33491	1.8	1.8	4.6	14.4	31
2001	0.18	0.46	0.46	0.8	0.20628	0.20628	0.20628	1.8	1.8	4.8	13.2	44.4
2002	0.2	0.32	0.32	0.6	0.15161	0.15161	0.15161	1.6	1.2	4.8	12	43.8
2003	0.1	0.3	0.3	0.8	0.19998	0.19998	0.19998	2	0.8	4.6	14	44.2

Table B4. Time series for variable emission factors for heavy metals, stationary combustion g/tonne

			1990-1991			1992-		
Sector	Source	Fuel	Pb	Cd	Hg	Pb	Cd	Hg
General	S.03	V51	0.0085	0.00047	0.00035	0.00304	0.00015	0.00016

Table B5. Time series for variable emission factors for natural gas, tonne CO_2/1000 Sm^3 natural gas

Sector	Source	Fuel	Component	1995	1996	1997	1998	1999	2000	2001	2002	2003
231110	S.02	V31	CO_2	2.29	2.3	2.3	2.31	2.5	2.48	2.47	2.45	2.45
231110	S.1B2C	V31	CO_2	2.42	2.34	2.34	2.34	2.48	2.52	2.42	2.47	2.34

Aviation - CH_4, N_2O, NO_x, NMVOC, CO, particles and PAH

Table B6. General emission factors for aviation

Source	Fuel	CH_4 kg/tonne	N_2O kg/tonne	NO_x kg/tonne	NMVOC kg/tonne	CO kg/tonne	NH3 kg/tonne	TSP, PM10, PM2.5 kg/tonne	PAH g/tonne	PAH-OSPAR g/tonne	PAH-4 g/tonne	Dioxin ug/tonne
M.1A3A.111 Jet/turboprop 0-100 m	V14 Jet kerosene	***0.1854***	0.1	***6.8543***	***1.6684***	***18.7643***	0	0.025	*0.54*	0.02	0.005	0.06
M.1A3A.112 Jet/turboprop 100-1000 m	V14 Jet kerosene	***0.0304***	0.1	***13.2081***	***0.2732***	***2.0361***	0	0.025	*0.32*	*0.02*	*0.005*	0.06
M.1A3A.12 Jet/turboprop cruise	V14 Jet kerosene	0	0.1	***12.1063***	***0.5693***	***3.0802***	0	0.007	*0.29*	*0.02*	*0.005*	0.06
M.1A3A.211 Helicopter 0-100 m	V14 Jet kerosene	*3.2*	0.1	*6.67*	*28.8*	*36.6*	0	0.025	*0.54*	0.02	0.005	0.06
M.1A3A.212 Helikopter 100-1000 m	V14 Jet kerosene	*3.2*	0.1	*6.67*	*28.8*	*36.6*	0	0.025	*0.32*	*0.02*	*0.005*	0.06
M.1A3A.22 Helicopter cruise	V14 Jet kerosene	0	0.1	*6.67*	*32*	*36.6*	0	0.007	*0.29*	*0.02*	*0.005*	0.06
M.1A3A.311 Small aircrafts 0-100 m	V12 Aviation gasoline	3.61	0.1	0	32.5	898.7	0	0.025	*0.54*	0.02	0.005	2
M.1A3A.312 Small aircrafts 100-1000 m	V12 Aviation gasoline	1.55	0.1	3.61711	13.95	932.5	0	0.025	*0.32*	*0.02*	*0.005*	2
M.1A3A.32 Small aircrafts cruise	V12 Aviation gasoline	0	0.1	2.92	19.48	926	0	0.007	*0.29*	*0.02*	*0.005*	2

Numbers in italics have exceptions for some sectors, see Table B7, and bold numbers are different for different years, see Table B8.

Source: IPCC (2001), Finstad et al. (2001) and Finstad et al. (2002b).

Table B7. Exceptions from the general factors for aviation

Component	Emission factor	Fuel		Source	Sectors
CH_4	0.35	V14	Jet kerosene	M.1A3A.111-112, M1A3A.211-212	247520
NO_x	13.51	V14	Jet kerosene	M.1A3A.111, M1A3A.211	247520
NO_x	13.29	V14	Jet kerosene	M.1A3A.112, M1A3A.212	247520
NO_x	11.7	V14	Jet kerosene	M.1A3A.12, M.1A3A.22	247520
NMVOC	7.43	V14	Jet kerosene	M.1A3A.111, M1A3A.211	247520
NMVOC	7.36	V14	Jet kerosene	M.1A3A.112, M1A3A.212	247520
NMVOC	4.3	V14	Jet kerosene	M.1A3A.12, M.1A3A.22	247520
CO	23.67	V14	Jet kerosene	M.1A3A.111, M1A3A.211	247520
CO	23.15	V14	Jet kerosene	M.1A3A.112, M1A3A.212	247520
CO	20.9	V14	Jet kerosene	M.1A3A.12, M.1A3A.22	247520
PAH	0.18	V12, 14	Aviation gasoline, jet kerosene	M.1A3A.111, M1A3A.211, M1A3A.311	236203
PAH	0.05	V12, 14	Aviation gasoline, jet kerosene	M.1A3A.112, M1A3A.212, M1A3A.312	236203
PAH	0.1	V12, 14	Aviation gasoline, jet kerosene	M.1A3A.12, M.1A3A.22, M.1A3A.32	236203
PAH-OSPAR, PAH-4	0	V12, 14	Aviation gasoline, jet kerosene	M.1A3A.112, M.1A3A.12, M1A3A.212, M.1A3A.22, M1A3A.312, M.1A3A.32	236203

Table B8. Time series for variable emission factors for aviation

			CH_4			NO_x			NMVOC			CO		
Sector	Source	Fuel	1980-1992	1993-1997	1998-	1980-1992	1993-1997	1998-	1980-1992	1993-1997	1998-	1980-1992	1993-1997	1998-
General	M.1A3A.111	V14	0.1558	0.2014	0.1854	6.0256	7.2	6.8543	1.4022	1.8	1.6684	11.1046	17.5	18.7643
	M.1A3A.112	V14	0.0255	0.033	0.0304	11.6111	13.9041	13.2081	0.2296	0.2969	0.2732	1.2049	1.8951	2.0361
	M.1A3A.12	V14	0	0	0	10.6633	12.0612	12.1063	1.0224	0.6599	0.5693	3.4502	3.2676	3.0802
236203	M.1A3A.111	V14	0.1567	0.3361	0.3927	6.7254	8.118	7.6891	1.4104	3.0253	3.534	11.5571	17.2131	18.9539
	M.1A3A.112	V14	0.0257	0.055	0.0672	12.9597	15.6432	15.6189	0.231	0.4954	0.605	1.254	1.8677	2.9777
	M.1A3A.12	V14	0	0	0	10.6633	11.5718	11.333	1.0224	3.5046	0.50178	3.4502	6.2931	1.70096
660000	M.1A3A.111	V14	0.1567	0.3361	0.3927	6.7254	8.118	7.6891	1.4104	3.0253	3.534	11.5571	17.2131	18.9539
	M.1A3A.112	V14	0.0257	0.055	0.0672	12.9597	15.6432	15.6189	0.231	0.4954	0.605	1.254	1.8677	2.9777
	M.1A3A.12	V14	0	0	0	10.6633	11.5718	11.333	1.0224	3.5046	0.50178	3.4502	6.2931	1.70096

Road traffic - CH_4, N_2O, NO_x, NMVOC, CO, NH_3, particles and PAH

Table B9. General emission factors for road traffic

Source	Fuel	CH_4 kg/tonne	N_2O kg/tonne	NO_x kg/tonne	NMVOC kg/tonne	CO kg/tonne	NH3 kg/tonne	TSP, PM10 kg/tonne	PM2.5 kg/tonne	PAH g/tonne	PAH-OSPAR g/tonne	PAH-4 g/tonne	Dioxin ug/tonne
M.1A3B.1 Passenger car	V11 Motor gasoline	**1.1755**	**1.43147**	**9.96201**	**15.739**	**125.514**	**1.35375**	**0.16854**	**0.16854**	**1.000068**	**0.445696**	**0.125624**	**0.1**
	V15 Auto diesel	**0.05674**	**0.20742**	**6.84545**	**1.72326**	**9.05492**	**0.02229**	**1.76795**	**1.69273**	4.366809	2.382979	0.446809	0.1
	V31 Naturgass	0.261	0.0255	0.871	0.0653	1.69	0	0.122	0.122	0.0153	0.00085	0	0.05
	V32 LPG	0.195	0.213	4.61	1.78	13.4	0.973	0.0745	0.0745	0	0	0	0.06
M.1A3B.2 Other light duty cars	V11 Motor gasoline	**0.65492**	**0.74042**	**8.99486**	**11.4871**	**102.539**	**0.71934**	**0.12733**	**0.12733**	**1.000068**	**0.445696**	**0.125624**	**0.1**
	V15 Auto diesel	**0.06816**	**0.15151**	**6.13565**	**2.01701**	**11.4397**	**0.01352**	**1.54065**	**1.47509**	4.366809	2.382979	0.446809	0.1
M.1A3B.3 Heavy duty vehicles	V11 Motor gasoline	**1.10077**	**0.04448**	**29.4414**	**18.1644**	**96.0699**	**0.07749**	**0.10023**	**0.10023**	1.994992	0.997496	0.21	**0.1**
	V15 Auto diesel	**0.11468**	**0.12624**	**26.5508**	**2.77258**	**7.10601**	**0.00292**	**1.06066**	**0.99569**	**3.563499**	**1.78175**	**0.428321**	0.1
	V31 Naturgass	4.29	0.0255	11.8	1.073	2.51	0	0.122	0.122	0.0153	0.00085	0	0.05
M.1A3B.41 Moped	V11 Motor gasoline	**5.85474**	**0.05855**	**2.73767**	**367.532**	**699.883**	**0.05306**	**0.13956**	**0.13956**	2	0.53	0.08	**0.1**
M.1A3B.42 Motorcycle	V11 Motor gasoline	**4.93893**	**0.05142**	**7.00757**	**127.746**	**710.504**	**0.05095**	**0.14498**	**0.14498**	2	0.53	0.08	**0.1**

Bold numbers are different for different years, but only the 2003 data are shown in this Appendix.

Source: SFT (1999c), Bang (1993) and Finstad et al. (2001).

Navigation (M.1A3D) - CH_4, N_2O, NO_x, NMVOC, CO, particles and POPs

Table B10. General emission factors for navigation

	CH_4 kg/tonne	N_2O kg/tonne	NO_x kg/tonne	NMVOC kg/tonne	CO kg/tonne	NH3 kg/tonne	TSP, PM10 kg/tonne	PM2.5 kg/tonne	PAH g/tonne	PAH-OSPAR g/tonne	PAH-4 g/tonne	Dioxin ug/tonne
V17 Marine gas oil/diesel, V18 Light fuel oils, V19 Heavy distillate, V20 Heavy fuel oil	*0.23*	*0.08*	***67.9***	*2.4*	***2.9***	0	***0.7***	***0.665***	1.6	0.26	0.04	4
V31 Natural gas (1000 Sm^3)	40.029	0	7.407	0.814	2.143	0	0.018	0.018	0.0153	0.00085	0	0.05

Numbers in italics have exceptions for some sectors, see Table B11, and bold numbers are different for different years, see Table B12.

Source: Flugsrud and Rypdal (1996), Tornsjø (2001), Finstad et al. (2001), Finstad et al. (2002a) and Finstad et al. (2003).

Table B11. Exceptions from the general factors for navigation

Component	Emission factor (kg/tonne)	Fuel		Sector
CH_4	0.8	V17	Marine gas oil/diesel	231120
CH_4	1.9	V20	Heavy fuel oil	231120
N_2O	0.02	V17	Marine gas oil/diesel	231120
NO_x	**71.8072**	V17, 18, 19, 20	Marine gas oil/diesel, light fuel oils, heavy distillate, heavy fuel oil	230510
NO_x	**79.4**	V17, 18, 19, 20	Marine gas oil/diesel, light fuel oils, heavy distillate, heavy fuel oil	231110
NO_x	70	V17, 18, 19	Marine gas oil/diesel, light fuel oils, heavy distillate	231120
NO_x	**70**	V20	Heavy fuel oil	231120
NO_x	63.1	V17, 18, 19, 20	Marine gas oil/diesel, light fuel oils, heavy distillate, heavy fuel oil	247520
NMVOC	**1.4**	V17, 18, 19, 20	Marine gas oil/diesel, light fuel oils, heavy distillate, heavy fuel oil	230510
NMVOC	**2.3**	V17, 18, 19, 20	Marine gas oil/diesel, light fuel oils, heavy distillate, heavy fuel oil	247520
NMVOC	2.3	V17, 18, 19, 20	Marine gas oil/diesel, light fuel oils, heavy distillate, heavy fuel oil	231110
NMVOC	5	V17, 18	Marine gas oil/diesel, light fuel oils	231120
NMVOC	**5**	V19, 20	Heavy distillate, heavy fuel oil	231120
CO	7.9	V17, 18, 19, 20	Marine gas oil/diesel, light fuel oils, heavy distillate, heavy fuel oil	230510
CO	**1.6**	V17, 18, 19, 20	Marine gas oil/diesel, light fuel oils, heavy distillate, heavy fuel oil	231110
CO	7	V17, 18, 19, 20	Marine gas oil/diesel, light fuel oils, heavy distillate, heavy fuel oil	231120
CO	2.3	V17, 18, 19, 20	Marine gas oil/diesel, light fuel oils, heavy distillate, heavy fuel oil	247520
TSP, PM10	0.5	V17, 18, 19, 20	Marine gas oil/diesel, light fuel oils, heavy distillate, heavy fuel oil	230510, 231120, 247520
TSP, PM10	**0.9**	V17, 18, 19, 20	Marine gas oil/diesel, light fuel oils, heavy distillate, heavy fuel oil	231110
PM2.5	**0.863**	V17, 18, 19, 20	Marine gas oil/diesel, light fuel oils, heavy distillate, heavy fuel oil	231110
PM2.5	0.5	V17, 18, 19, 20	Marine gas oil/diesel, light fuel oils, heavy distillate, heavy fuel oil	230510
PM2.5	0.48	V17, 18, 19, 20	Marine gas oil/diesel, light fuel oils, heavy distillate, heavy fuel oil	231120, 247520

Table B12. Time series for variable emission factors for navigation

		NO_x						NMVOC						CO		TSP, PM10			PM2.5		
Sector	Fuel	1980-1992	1980-1997	1993-1997	1998-1999	1998-	2000-	1980-1990	1980-1997	1980-1998	1991-1997	1998-	1999-	1980-1997	1998-	1980-1997	1993-1997	1998-	1980-1997	1993-	1998-
General	V17-20		65.2			67.9								3.1	2.9	0.6		0.7	0.57		0.665
23510	V17-20		71.1		70.3		71.8072			1.5			1.4								
231110	V17-20		74.6			79.4								2	1.6	0.87		0.9	0.8265		0.863
231120	V19,20							6.4			5										
231120	V 20	65		70																	
247520	V17-20								2.2			2.3									

Other mobile sources including railways - CH_4, N_2O, NO_x, NMVOC, CO, NH_3, particles and POPs

Table B13. General emission factors for other mobile sources

		CH_4 kg/ tonne	N_2O kg/ tonne	NO_x kg/ tonne	NMVOC kg/ tonne	CO kg/ tonne	NH_3 kg/ onne	TSP, PM10 kg/tonne	PM2.5 kg/ tonne	PAH g/tonne	PAH-OSPAR g/tonne	PAH-4 g/ tonne	Dioxin ug/ tonne
M.1A3C Railway	V15 Auto diesel	0.18	1.2	47	4	11	0	3.8	3.8	3.3	0.53	0.08	0.1
M.1A3E.21 Small boats 2 stroke	V11 Motor gasoline	5.1	0.02	6	240	415	0	8	8	2	0.53	0.08	**0.1**
M.1A3E.22 Small boats 4 stroke	V11 Motor gasoline	1.7	0.08	12	40	1000	0	1	1	2	0.53	0.08	**0.1**
	V15 Auto diesel	0.18	0.03	54	27	25	0	4	4	3.3	0.53	0.08	0.1
M.1A3E.31 Motorized equipment 2 stroke	V11 Motor gasoline	*6*	0.02	**2**[1]	500	700	0	8	8	2	0.53	0.08	**0.1**
M.1A3E.32 Motorized equipment 4t	V11 Motor gasoline	*2.2*	*0.07*	10	110	1200	0	1	1	2	0.53	0.08	**0.1**
	V15 Auto diesel	*0.17*	1.3	*50*	*6*	*15*	0.005	*4*	*3.8*	3.3	0.53	0.08	0.1
	V18 Light fuel oils	0.17	1.3	*50*	*6*	*15*	0.005	*7.1*	*6.75*	0.08	0.08	0.08	0.1

M.1A3E.1 Snow scooter has the same emission factors as M.1A3B.41 Moped, see Table B9.

Bold numbers are different for different years. [1]Before 1995 the emission factor was 1.3.

Numbers in italics have exceptions for some sectors, see Table B14 and Table B15.

Sources: Bang (1993), SFT (1999c), Finstad et al. (2001), Finstad et al. (2002a) and Finstad et al. (2003).

Table B14. Exceptions from the general factors for greenhouse gases and precursors for other mobile sources

Component	Emission factor (kg/tonne)	Fuel		Source	Sectors
CH_4	6.2	V11	Motor gasoline	M.1A3E.31 Motorized equipment 2 stroke	230100
CH_4	3.7	V11	Motor gasoline	M.1A3E.32 Motorized equipment 4 stroke	230100
CH_4	7.7	V11	Motor gasoline	M.1A3E.31 Motorized equipment 2 stroke	230200
CH_4	8.1	V11	Motor gasoline	M.1A3E.31 Motorized equipment 2 stroke	330000
CH_4	5.5	V11	Motor gasoline	M.1A3E.32 Motorized equipment 4 stroke	330000
CH_4	0.18	V15	Motor gasoline	M.1A3E.32 Motorized equipment 4 stroke	330000
N_2O	0.08	V11	Motor gasoline	M.1A3E.32 Motorized equipment 4 stroke	231000-233720
NO_x	54	V15, 18	Auto diesel, light fuel oils	M.1A3E.32 Motorized equipment 4 stroke	230100
NO_x	52	V15, 18	Auto diesel, light fuel oils	M.1A3E.32 Motorized equipment 4 stroke	230200
NO_x	47	V15, 18	Auto diesel, light fuel oils	M.1A3E.32 Motorized equipment 4 stroke	231300-231400, 236010
NO_x	48	V15, 18	Auto diesel, light fuel oils	M.1A3E.32 Motorized equipment 4 stroke	232640, 247520
NO_x	46	V15, 18	Auto diesel, light fuel oils	M.1A3E.32 Motorized equipment 4 stroke	234500
NMVOC	7.2	V15, 18	Auto diesel, light fuel oils	M.1A3E.32 Motorized equipment 4 stroke	230100
NMVOC	5.7	V15, 18	Auto diesel, light fuel oils	M.1A3E.32 Motorized equipment 4 stroke	230200
NMVOC	4	V15, 18	Auto diesel, light fuel oils	M.1A3E.32 Motorized equipment 4 stroke	231300-231400,236010
NMVOC	4.8	V15, 18	Auto diesel, light fuel oils	M.1A3E.32 Motorized equipment 4 stroke	232640, 247520
NMVOC	3.8	V15, 18	Auto diesel, light fuel oils	M.1A3E.32 Motorized equipment 4 stroke	234500
CO	25	V15, 18	Auto diesel, light fuel oils	M.1A3E.32 Motorized equipment 4 stroke	230100
CO	20	V15, 18	Auto diesel, light fuel oils	M.1A3E.32 Motorized equipment 4 stroke	230200
CO	11	V15, 18	Auto diesel, light fuel oils	M.1A3E.32 Motorized equipment 4 stroke	231300-231400, 236010
CO	17	V15, 18	Auto diesel, light fuel oils	M.1A3E.32 Motorized equipment 4 stroke	234500
CO	18	V15, 18	Auto diesel, light fuel oils	M.1A3E.32 Motorized equipment 4 stroke	247520

Table B15. Exceptions from the general factors for other pollutants for other mobile sources

Component	Emission factor (kg/tonne)	Fuel		Source	Sectors
TSP, PM10	7.1	V15	Auto diesel	M.1A3E.32 Motorized equipment 4 stroke	230100-230200
TSP, PM10	3.8	V15, 18	Auto diesel, light fuel oils	M.1A3E.32 Motorized equipment 4 stroke	231300-231400, 236010
TSP, PM10	4.2	V15, 18	Auto diesel, light fuel oils	M.1A3E.32 Motorized equipment 4 stroke	232640
TSP, PM10	5.3	V15, 18	Auto diesel, light fuel oils	M.1A3E.32 Motorized equipment 4 stroke	234500
TSP, PM10	5.4	V15, 18	Auto diesel, light fuel oils	M.1A3E.32 Motorized equipment 4 stroke	247520
PM2.5	6.75	V15	Auto diesel	M.1A3E.32 Motorized equipment 4 stroke	230100-230200
PM2.5	3.61	V15, 18	Auto diesel, light fuel oils	M.1A3E.32 Motorized equipment 4 stroke	231300-231400, 236010
PM2.5	3.99	V15, 18	Auto diesel, light fuel oils	M.1A3E.32 Motorized equipment 4 stroke	232640
PM2.5	5.04	V15, 18	Auto diesel, light fuel oils	M.1A3E.32 Motorized equipment 4 stroke	234500
PM2.5	5.13	V15, 18	Auto diesel, light fuel oils	M.1A3E.32 Motorized equipment 4 stroke	247520

Table B16. Time series for variable emission factors for other mobile sources

Fuel	Component	1980-1990	1991	1992	1993	1994	1995	1996	1997-
V11 Gasoline	Dioxin	1.32	1.11	0.95	0.69	0.25	0.23	0.11	0.1

CH_4 - Stationary combustion

Table B17. General emission factors, kg CH_4/tonne fuel

Source	V01 Coal	V02 Coke	V03 Petrol coke	V41 Fuel wood	V42 Wood waste	V43 Black liquor	V44 Wood pellets	V45 Wood briquettes	V04 Char-coal	V31 Natural gas	V33 Re-finery gas	V34 Blast fur-nace gas	V36 Land-fill gas	V35 Fuel gas	V32 LPG	V13 Kero-sene (heating)	V17 Marine gas oil/ diesel	V18 Light fuel oils	V19 Heavy dis-tillate	V20 Heavy fuel oil	V51 Muni-cipal waste	V52 Special waste
S.01 Direct-fired furnaces	0.028	0	0	.	.	.	.	.	.	*0.05*	0.054	0.054	.	*0.05*	.	.	0.016	.	0.04	0.04	.	0.04
S.02 Gas turbines	.	.	.	.	.	.	.	.	.	0.91	.	.	.	.	.	.	0	.	.	.	.	.
S.03 Boilers	*0.28*	0.28	0.28	.	0.25	0.25	0.25	0.25	.	*0.2*	0.24	0.24	0.24	0.24	0.17	0.17	*0.4*	*0.4*	*0.4*	*0.4*	*0.23*	*0.4*
S.04 Small stoves	8.4	8.4	.	5.3	.	.	5.3	.	8.4	.	.	.	.	.	0.24	0.3	.	0.4	0.4	.	.	.
S.1B2C Flares	.	.	.	.	.	.	.	.	.	0.24	0.28	.	0.37	.	.	.	.	.	.	.	.	.

Numbers in italics have exceptions for some sectors, see Table B18.

Source: IPCC (1997b), SFT (1996), SINTEF (1995) and OLF (1994).

Table B18. Exceptions from the general factors for CH_4, stationary combustion (kg CH_4/tonne fuel)

Emission factor	Fuel		Source	Sectors
0	V31, 35	Natural gas (1000 Sm^3), fuel gas	S.01 Direct fired furnaces	232640-232650
0.085	V31	Natural gas (1000 Sm^3)	S.01 Direct fired furnaces	232416
0.03	V01	Coal	S.03 Boilers	231000, 231110, 232320, 232340, 234010-234040
0.1	V17, 18, 19, 20, 52	Fuel oils incl. spezial waste	S.03 Boilers	231000-234040 (Industry incl. power supply)
0.0425	V31	Natural gas (1000 Sm^3)	S.03 Boilers	231000, 231110, 232320, 232340, 234010-234040

N_2O - Stationary combustion

Table B19. General emission factors. kg N_2O/tonne fuel

Source	V01 Coal	V02 Coke	V03 Petrol coke	V41 Fuel wood	V42 Wood waste	V43 Black liquor	V44 Wood pellets	V45 Wood briquettes	V04 Char-coal	V31 Natural gas (1000 Sm^3)	V33 Re-finery gas	V34 Blast furn-ace gas	V36 Land-fill gas	V35 Fuel gas	V32 LPG	V13 Kero-sene (heating)	V17 Marine gas oil/ diesel	V18 Light fuel oils	V19 Heavy dis-tillate	V20 Heavy fuel oil	V51 Munici-pal waste	V52 Special waste
S.01 Direct-fired furnaces	0	0	0	.	.	.	.	.	.	*0.02*	0.024	0.024	0.024	0.024	.	.	0.03	.	0.03	0.03	.	0.03
S.02 Gas turbines	.	.	.	.	.	.	.	.	.	0.019	.	.	.	.	.	.	0.024	.	.	.	.	.
S.03 Boilers	0.04	0.04	0.04	.	0.005	0.005	0.07	0.07	.	0.004	0.005	0.005	0.005	0.005	0.03	0.03	0.03	0.03	0.03	0.03	0.035	0.03
S.04 Small stoves	0.04	0.04	.	0.032	.	.	0.032	.	0.04	.	.	.	.	.	0.03	0.03	.	0.03	0.03	.	.	.
S.1B2C Flares	.	.	.	.	.	.	.	.	.	*0.02*	0.024	.	0.002	.	.	.	.	.	.	.	.	.

Numbers in italics have exceptions for some sectors, see Table B20.

Source: IPCC (1997b), SFT (1996) and OLF (1994).

Table B20. Exceptions from the general factors for N_2O. Stationary combustion (kg N_2O/1000 Sm^3 natural gas)

Emission factor	Fuel		Source	Sectors
0.017	V31	Natural gas	S.01 Direct-fired furnaces	232416
0.06	V31	Natural gas	S.1B2C Flares	231120

NO_x - Stationary combustion

Table B21. General emission factors. kg NO_x/tonne fuel

Source	V01 Coal	V02 Coke	V03 Petrol coke	V41 Fuel wood	V42 Wood waste	V43 Black liquor	V44 Wood pellets	V45 Wood briquettes	V04 Char-coal	V31 Natural gas (1000 Sm^3)	V33 Re-finery gas	V34 Blast furn-ace gas	V36 Land-fill gas	V35 Fuel gas	V32 LPG	V13 Kero-sene (heating)	V17 Marine gas oil/ diesel	V18 Light fuel oils	V19 Heavy dis-tillate	V20 Heavy fuel oil	V51 Munici-pal waste	V52 Special waste
S.01 Direct-fired furnaces	16	20	20	.	.	.	.	.	.	*5.95*	5.4	5.4	.	5.4	.	.	70	.	*5*	*5*	.	5
S.02 Gas turbines	.	.	.	.	.	.	.	.	.	***6.27***	.	.	.	.	.	.	16	.	.	.	.	.
S.03 Boilers	*3*	*3*	3.4	.	0.9	0.9	1.3	1.3	.	2.55	*3*	*3*	0.01	*3*	2.3	3	*2.5*	*2.5*	*2.5*	*4.2*	1.365	*4.2*
S.04 Small stoves	*3*	*3*	.	**0.981**	.	.	1.1	.	1.4	.	.	.	.	.	2.3	2.5	.	2.5	2.5	.	.	.
S.1B2C Flares	.	.	.	.	.	.	.	.	.	12	7	.	0.17	.	.	.	.	.	.	.	.	.

Numbers in italics have exceptions for some sectors, see Table B22, and bold numbers are different for different years, see Table B23.

Source: Rosland (1987).

Table B22. Exceptions from the general factors for NO_x. Stationary combustion (kg NO_x /tonne fuel)

Emission factor	Fuel		Source	Sectors
24	V19, 20, 52	Heavy distillate, heavy fuel oil, special waste	S.01 Direct-fired furnaces	231009, 232650
6.13	V31	Natural gas (1000 Sm^3)	S.01 Direct-fired furnaces	232416
9.5	V19, 20	Heavy distillate, heavy fuel oil	S.01 Direct-fired furnaces	232640
8.68124	V31	Natural gas (1000 Sm^3)	S.02 Gas turbines	231110
3	V17, 18, 19	Fuel oils	S.03 Boilers	231000-233720
4.5	V01	Coal	S.03 Boilers	231000-233720
3.4	V02	Coke	S.03 Boilers	231000-233720
5	V20, 52	Heavy fuel oil, special waste	S.03 Boilers	231000-233720
2.9	V35	Fuel gas	S.03 Boilers	232411-232470, 232710-232740
0.01	V34	Blast furnace gas	S.03 Boilers	234010-234040
1.4	V01, 02	Coal, coke	S.04 Small stoves	330000

Table B23. Time series for variable emission factors for NO_x. Stationary combustion (kg NO_x /tonne fuel)

Sector	Source	Fuel	1980-1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000-
General	S.04	V41	0.98241	0.981	0.98235	0.98236	0.98231	0.981	0.98239	0.98234	0.98213	0.981	0.981
231110	S.02	V31	8.22299	8.17156	8.23417	8.44355	8.61688	8.87385	9.12833	9.18543	9.52767	9.0867	8.68124

NMVOC - Stationary combustion

Table B24. General emission factors. kg NMVOC/tonne fuel

Source	V01 Coal	V02 Coke	V03 Petrol coke	V41 Fuel wood	V42 Wood waste	V43 Black liquor	V44 Wood pellets	V45 Wood briquettes	V04 Char-coal	V31 Natural gas (1000 Sm^3)	V33 Re-finery gas	V34 Blast furnace gas	V36 Land-fill gas	V35 Fuel gas	V32 LPG	V13 Kero-sene (heating)	V17 Marine gas oil/ diesel	V18 Light fuel oils	V19 Heavy dis-tillate	V20 Heavy fuel oil	V51 Munici-pal waste	V52 Special waste
S.01 Direct-fired furnaces	0	0	0	.	.	.	.	.	.	*0*	0.1	*0*	.	*0*	.	.	5	.	*0.3*	*0.3*	.	*0.3*
S.02 Gas turbines	.	.	.	.	.	.	.	.	.	0.24	.	.	.	.	.	.	0.03	.	.	.	.	.
S.03 Boilers	*1.1*	0.6	0.6	.	*1.3*	0	1.3	1.3	.	0.085	0.1	*0.1*	0	*0.1*	*0.1*	0.4	*0.4*	*0.4*	*0.4*	0.3	0.7	0.3
S.04 Small stoves	*1.1*	0.6	.	**6.93**	.	.	6.501	.	10	.	.	.	.	.	0.1	*0.4*	.	0.4	0.4	.	.	
S.1B2C Flares	.	.	.	.	.	.	.	.	.	*0.06*	13.5	.	0	.	.	.	.	.	.	.	.	.

Numbers in italics have exceptions for some sectors, see Table B25, and bold numbers are different for different years, see Table B26.

Source: Rosland (1987) and SFT (1996).

Table B25. Exceptions from the general factors for NMVOC. Stationary combustion (kg NMVOC/tonne fuel)

Emission factor	Fuel		Source	Sectors
0	V 19, 20, 52	Heavy distillate, heavy fuel oil, special waste	S.01 Direct-fired furnaces	231009, 232650
0.1	V34	Blast furnace gas	S.01 Direct-fired furnaces	231009
0.085034	V31	Natural gas (1000 Sm^3)	S.01 Direct-fired furnaces	232416
0.9	V19, 20	Heavy distillate, heavy fuel oil	S.01 Direct-fired furnaces	232640
0.8	V01	Coal	S.03 Boilers	231000-233720
0	V32, 34, 35, 42	LPG, blast furnace gas, fuel gas, wood waste	S.03 Boilers	231000-233720, 232110, 232411-232470, 234010-234040
0.6	V17, 18, 19	Fuel oils	S.03 Boilers	330000
10	V01	Coal	S.04 Small stoves	330000
0.6	V13	Kerosene (heating)	S.04 Small stoves	330000
0.02	V31	Natural gas (1000 Sm^3)	S.1B2C Flares	231120

Table B26. Time series for variable emission factors for NMVOC. Stationary combustion (kg NMVOC/tonne fuel)

Sector	Source	Fuel	1980-1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
General	S.04	V41	6.90376	6.90333	6.90374	6.90374	6.90373	6.90333	6.90375	6.90374	6.9082	6.91237	6.91689	6.92141	6.92615	6.92615

CO - Stationary combustion

Table B27. General emission factors. kg CO/tonne fuel

Source	V01 Coal	V02 Coke	V03 Petrol coke	V41 Fuel wood	V42 Wood waste	V43 Black liquor	V44 Wood pellets	V45 Wood briquettes	V04 Char-coal	V31 Natural gas (1000 Sm^3)	V33 Re-finery gas	V34 Blast furn-ace gas	V36 Land-fill gas	V35 Fuel gas	V32 LPG	V13 Kero-sene (heating)	V17 Marine gas oil/ diesel	V18 Light fuel oils	V19 Heavy dis-tillate	V20 Heavy fuel oil	V51 Munici-pal waste	V52 Special waste
S.01 Direct-fired furnaces	0	0	0	.	.	.	.	.	.	0	0	*0*	.	*0*	.	.	5	.	*0.2*	*0.2*	.	*0.2*
S.02 Gas turbines	.	.	.	.	.	.	.	.	.	1.7	.	.	.	.	.	.	0.7	.	.	.	.	.
S.03 Boilers	3	3	3	.	*15*	0	15	15	.	0	0	0	0	0	*0.5*	2	*2*	*2*	*2*	*0.4*	2.8	*0.4*
S.04 Small stoves	*3*	*3*	.	**122.2**	.	.	2.6	.	100	.	.	.	.	.	0.5	*2*	.	2	2	.	.	.
S.1B2C Flares	.	.	.	.	.	.	.	.	.	*1.5*	*0*	.	0.04	.	.	.	.	.	.	.	.	.

Numbers in italics have exceptions for some sectors, see Table B28, and bold numbers are different for different years, see Table B29.

Table B28. Exceptions from the general factors for CO. Stationary combustion (kg CO/tonne fuel)

Emission factor	Fuel		Source	Sectors
0	V 19, 20, 52	Heavy distillate, heavy fuel oil, special waste	S.01 Direct-fired furnaces	231009, 232640, 232650
0.01	V34	Blast furnace gas	S.01 Direct-fired furnaces	231009
0.2	V20. 52	Heavy fuel oil, special waste	S.03 Boilers	231000-233720
0	V32, 42	LPG, wood waste	S.03 Boilers	231000-233720, 232110
6.5	V17, 18, 19	Fuel oils	S.03 Boilers	330000
100	V01, 02	Coal, coke	S.04 Small stoves	330000
6.5	V13	Kerosene (heating)	S.04 Small stoves	330000
1.7	V31	Natural gas (1000 Sm^3)	S.1B2C Flares	232320

Table B29. Time series for variable emission factors for CO. Stationary combustion (kg CO/tonne fuel)

Sector	Source	Fuel	1980-1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
General	S.04	V41	149.108	149.21	149.113	149.112	149.116	149.21	149.11	149.114	144.631	140.217	135.721	131.225	126.729	126.566

NH_3 - Stationary combustion

Table B30. General emission factors. kg NH_3/tonne fuel

Source	V01 Coal	V02 Coke	V03 Petrol coke	V41 Fuel wood	V42 Wood waste	V43 Black liquor	V44 Wood pellets	V45 Wood briquettes	V04 Char-coal	V31 Natural gas (1000 Sm^3)	V33 Re-finery gas	V34 Blast furn-ace gas	V36 Land-fill gas	V35 Fuel gas	V32 LPG	V13 Kero-sene (heating)	V17 Marine gas oil/ diesel	V18 Light fuel oils	V19 Heavy dis-tillate	V20 Heavy fuel oil	V51 Munici-pal waste	V52 Special waste
S.04 Small stoves	.	.	.	0.066	.	.	0.066	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
All other sources	0	0	0	.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Particulate matter - Stationary combustion

Table B31. General emission factors. kg particle component/tonne fuel

Compo-nent	Source	V01 Coal	V02 Coke	V03 Petrol coke	V41 Fuel wood	V42 Wood waste	V43 Black liquor	V44 Wood pellets	V45 Wood briquettes	V04 Char-coal	V31 Natural gas (1000 Sm^3)	V33 Re-finery gas	V34 Blast furn-ace gas	V36 Land-fill gas	V35 Fuel gas	V32 LPG	V13 Kero-sene (heating)	V17 Marine gas oil/ diesel	V18 Light fuel oils	V19 Heavy dis-tillate	V20 Heavy fuel oil	V51 Munici pal waste	V52 Special waste
TSP	S.01 Direct-fired furnaces	*1.6*	1.6	1.6	.	.	.	.	.	.	0.122	0.144	0.144	.	0.144	.	.	0.286	.	*)	*)	.	*5.68*
TSP	S.02 Gas turbines	.	.	.	.	.	.	.	.	.	0.122	.	.	.	.	.	.	0.286	.	.	.	.	.
TSP	S.03 Boilers	*1.6*	1.6	1.6	.	*0.22*	0	0.216	0.216	.	0.122	0.144	0.144	0.144	0.144	0.136	0.296	0.286	0.286	*)	*)	***0.05***	*5.68*
TSP	S.04 Small stoves	4.2	2.85	3.5	**31.54**	.	.	1.1	.	2.4	.	.	.	.	.	0.136	*0.3*	.	0.3	.	.	.	.
TSP	S.1B2C Flares	.	.	.	.	.	.	.	.	.	0.002	0.144	.	0.144	.	.	.	.	.	.	.	.	.
PM10	S.01 Direct-fired furnaces	*1.14*	1.14	1.14	.	.	.	.	.	.	0.122	0.144	0.144	.	0.144	.	.	0.143	.	*)	*)	.	*4.87*
PM10	S.02 Gas turbines	.	.	.	.	.	.	.	.	.	0.122	.	.	.	.	.	.	0.143	.	.	.	.	.
PM10	S.03 Boilers	*1.14*	1.14	1.14	.	*0.22*	0	0.216	0.216	.	0.122	0.144	0.144	0.144	0.144	0.136	0.148	0.143	*0.15*	*)	*)	***0.05***	*4.87*
PM10	S.04 Small stoves	2.8	1.71	2.1	**31.54**	.	.	1.1	.	2.4	.	.	.	.	.	0.136	*0.16*	.	0.155	.	.	.	.
PM10	S.1B2C Flares	.	.	.	.	.	.	.	.	.	0.002	0.144	.	0.144	.	.	.	.	.	.	.	.	.
PM2.5	S.01 Direct-fired furnaces	*0.82*	0.82	0.82	.	.	.	.	.	.	0.122	0.144	0.144	.	0.144	.	.	0.036	.	*)	*)	.	*3.2*
PM2.5	S.02 Gas turbines	.	.	.	.	.	.	.	.	.	0.122	.	.	.	.	.	.	0.036	.	.	.	.	.
PM2.5	S.03 Boilers	*0.82*	0.82	0.82	.	*0.22*	0	0.216	0.216	.	0.122	0.144	0.144	0.144	0.144	0.136	0.037	*0.12*	*0.12*	*)	*)	***0.05***	*3.2*
PM2.5	S.04 Small stoves	0.86	0.86	1.05	**31.54**	.	.	1.1	.	2.4	.	.	.	.	.	0.136	*0.12*	.	0.119	.	.	.	.
PM2.5	S.1B2C Flares	.	.	.	.	.	.	.	.	.	0.002	0.144	.	0.144	.	.	.	.	.	.	.	.	.

Numbers in italics have exceptions for some sectors, see Table B33, and bold numbers are different for different years, see Table B34.

General emission factors for all sources for heavy distillate and heavy fuel oil are given in Table B32 for all years.

Source: Finstad et al. (2003).

Table B32. General particle emission factors for heavy distillate and heavy fuel oil for all sources. Factors dependent on sulphur content (kg particle component /tonne fuel)

Fuel	Compo-nent	1980-1981	1982	1983	1984	1985-1986	1987-1988	1989	1990	1991	1992	1993	1994	1995	1996-1997	1998	1999	2000-2003
V19	TSP	1.3761	1.05766	1.18504	1.05766	1.05766	0.99398	0.90481	0.80291	0.71375	0.70101	0.70101	0.68828	0.71375	0.6628	0.68828	0.70101	0.71375
	PM10	1.18305	0.90929	1.01879	0.90929	0.90929	0.85453	0.77788	0.69028	0.61362	0.60267	0.60267	0.59172	0.61362	0.56982	0.59172	0.60267	0.61362
	PM2.5	0.77055	0.59224	0.66356	0.59224	0.59224	0.55658	0.50665	0.44959	0.39967	0.39253	0.39253	0.3854	0.39967	0.37114	0.3854	0.39253	0.39967
V20	TSP	1.4644	1.4644	1.5216	1.3501	1.4873	1.4644	1.4187	1.3501	1.3386	1.3157	1.3043	1.1899	1.0527	1.0984	1.087	1.1099	1.2014
	PM10	1.25899	1.25899	1.30816	1.16066	1.27866	1.25899	1.21966	1.16066	1.15083	1.13116	1.12133	1.023	0.905	0.94433	0.9345	0.95417	1.03283
	PM2.5	0.82528	0.82528	0.85751	0.76082	0.83817	0.82528	0.7995	0.76082	0.75438	0.74149	0.73504	0.67058	0.59324	0.61902	0.61257	0.62546	0.67703

Numbers in italics have exceptions for some sectors, see Table B33, and bold numbers are different for different years, see Table B34.

Source: Finstad et al. (2003).

Table B33. Exceptions from the general factors for particles. Stationary combustion

Emission factor (kg TSP/tonne)	Emission factor (kg PM10/tonne)	Emission factor (kg PM2.5/tonne)	Fuel		Source	Sectors
4.06	2.4	1.4	V52	Special waste	S.01 Direct-fired furnaces	231000-233720
5.45	3.54	1.45	V01	Coal	S.01 Direct-fired furnaces	234040
4.2	2.8	0.86	V01	Coal	S.03 Boilers	230100
.	0.143 (V18)	0.036 (V17, 18)	V17, 18	Light fuel oils	S.03 Boilers	231000-233720
4.06	2.4	1.4	V52	Special waste	S.03 Boilers	231000-233720
0	0	0	V42	Wood waste	S.03 Boilers	232110
5.45	3.54	1.45	V01	Coal	S.03 Boilers	234040
0.5	0.5	0.5	V51	Municipal waste	S.03 Boilers	259000
0.3	0.155	0.119	V13	Kerosene (heating)	S.04 Small stoves	330000

Table B34. Time series for variable emission factors for particles. Stationary combustion (kg particle component /tonne fuel)

Sector	Source	Fuel	1980-1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
General	S.04	V41	38.863	38.863	39.2432	38.8664	38.8752	38.8892	39.2432	38.8902	38.9096	37.4323	36.1885	34.6611	33.0773	31.5401	31.5401
General	S.03	V51	0.2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05

POPs (Persistent Organic Pollutants) - Stationary combustion

Table B35. General emission factors for PAH

Component	Source	V01 Coal	V02 Coke	V03 Petrol coke	V41 Fuel wood	V42 Wood waste	V43 Black liquor	V44 Wood pellets	V45 Wood briquettes	V04 Char-coal	V31 Natural gas (1000 Sm^3)	V33 Re-finery gas	V34 Blast furn-ace gas	V36 Land-fill gas	V35 Fuel gas	V32 LPG	V13 Kero-sene (heating)	V17 Marine gas oil/ diesel	V18 Light fuel oils	V19 Heavy dis-tillate	V20 Heavy fuel oil	V51 Municipal waste	V52 Special waste
PAH	S.01 Direct-fired																						
g/tonne	furnaces	0.17	0.17	0.17	.	0.018	0.018	.	.	.	0.015	0.018	0.018	.	0.018	.	.	1.6	.	0.015	0.015	.	0.015
PAH	S.02 Gas																						
g/tonne	turbines	.	.	.	.	.	.	.	.	.	0.015	.	.	.	.	.	.	1.6	.	.	.	.	.
PAH	S.03																						
g/tonne	Boilers	0.46	0.46	0.46	.	0.018	0.018	0.16	0.16	.	0.015	0.018	0	0.018	0.018	0.018	0.007	*0.01*	*0.01*	0.015	0.015	*2.5*	0.015
PAH	S.04 Small																						
g/tonne	stoves	39.9	27.8	27.8	38.8	.	.	38.8	.	39.9	.	.	.	.	0.039	0.039	.	1.01	.	.	.	.	.
PAH	S.1B2C																						
g/tonne	Flares	.	.	.	.	.	.	.	.	.	0.015	0.018	.	0.018	.	.	.	.	.	.	.	.	.
PAH-OSPAR	S.01 Direct-fired																						
g/tonne	furnaces	0.02	0.02	0.02	.	.	.	.	.	.	9E-04	0.001	0.001	.	0.001	.	.	0.26	.	0.004	0.004	.	0.004
PAH-OSPAR	S.02 Gas																						
g/tonne	turbines	.	.	.	.	.	.	.	.	.	9E-04	.	.	.	.	.	.	0.26	.	.	.	.	.
PAH-OSPAR	S.03																						
g/tonne	Boilers	0.16	0.16	0.16	.	0.061	0.061	0.061	0.061	.	9E-04	0.001	0.001	0	0.001	0.001	8E-04	*0*	*0*	0.004	0.004	*0.7*	0.004
PAH-OSPAR	S.04 Small																						
g/tonne	stoves	18	13.4	13.4	6.8	.	.	6.8	.	18	.	.	.	.	0.007	0.007	.	0.57	.	.	.	.	.
PAH-OSPAR	S.1B2C																						
g/tonne	Flares	.	.	.	.	.	.	.	.	.	9E-04	0.001	.	0	.	.	.	.	.	.	.	.	.
PAH-4	S.01																						
g/tonne	Direct-fired furnaces	0	0	0	.	.	.	.	.	.	0	0	0	.	0	.	.	0.04	.	4E-04	4E-04	.	4E-04
PAH-4	S.02 Gas																						
g/tonne	turbines	.	.	.	.	.	.	.	.	.	0	.	.	.	.	.	.	0.04	.	.	.	.	.
PAH-4	S.03																						
g/tonne	Boilers	0.024	0.024	0.024	.	0.016	0.016	0.016	0.016	.	0	0	0	0	0	0	1E-04	1E-04	1E-04	4E-04	4E-04	*0.03*	4E-04
PAH-4	S.04 Small																						
g/tonne	stoves	2.6	0.4	0.4	2.5	.	.	2.5	.	2.6	.	.	.	.	.	0	0	.	0.003	.	.	.	.
PAH-4	S.1B2C																						
g/tonne	Flares	.	.	.	.	.	.	.	.	.	0	0	.	0	.	.	.	.	.	.	.	.	.

Numbers in italics have exceptions for some sectors, see Table B36, and bold numbers are different for different years, see Table B37.

Source: Finstad et al. (2001).

Table B35. General emission factors for dioxin

Component	Source	V01 Coal	V02 Coke	V03 Petrol coke	V41 Fuel wood	V42 Wood waste	V43 Black liquor	V44 Wood pellets	V45 Wood briquettes	V04 Char-coal	V31 Natural gas (1000 Sm^3)	V33 Re-finery gas	V34 Blast furn-ace gas	V36 Land fill gas	V35 Fuel gas	V32 LPG	V13 Kerosene (heating)	V17 Marine gas oil/ diesel	V18 Light fuel oils	V19 Heavy dis-tillate	V20 Heavy fuel oil	V51 Munici pal waste	V52 Special waste
	S.01 Direct-fired																						
Dioxin	furnaces	1.6	1.6	1.6	.	.	.	.	.	.	0.05	0	0	.	0	.	.	4	.	0.1	0.1	.	4
Dioxin	S.02 Gas																						
ug/tonne	turbines	.	.	.	.	.	.	.	.	.	0.05	.	.	.	.	.	.	4	.	.	.	.	.
Dioxin	S.03																						
ug/tonne	Boilers	1.6	1.6	1.6	.	1	1	1	1	.	0.05	0	0	0	1	*0.06*	0.1	0.1	*0.1*	*0.1*	*0.1*	0.02	4
Dioxin	S.04 Small																						
ug/tonne	stoves	10	10	10	5.9	.	.	5.9	.	1E-05	.	.	.	.	.	0.06	0.06	.	0.2	.	.	.	.
Dioxin	S.1B2C																						
ug/tonne	Flares	.	.	.	.	.	.	.	.	.	0.05	0	.	0	.	.	.	.	.	.	.	.	.

Numbers in italics have exceptions for some sectors, see Table B36.

Source: Finstad et al. (2002a).

Table B36. Exceptions from the general factors for POPs. Stationary combustion

Emission factor (g PAH/tonne)	Emission factor (g PAH-OSPAR/tonne)	Emission factor (g PAH-4/tonne)	Emission factor (ug dioxin/tonne)	Fuel		Source	Sectors
0.0008	0.0005	.	.	V17, 18	Fuel oils	S.03 Boilers	231000-233720
.	.	.	0.2	V18, 19	Heavy distillate, heavy fuel oil	S.03 Boilers	330000
0.75	**0.2**	**0.01**	.	V51	Municipal waste	S.03 Boilers	234040

Table B37. Time series for variable emission factors for PAH. Stationary combustion

			1980-1994			1995-		
Sector	Source	Fuel	Emission factor (g PAH/tonne)	Emission factor (g PAH-OSPAR/tonne)	Emission factor (g PAH-4/tonne)	Emission factor (g PAH/tonne)	Emission factor (g PAH-OSPAR/tonne)	Emission factor (g PAH-4/tonne)
General	S.03	V51	2.5	0.7	0.03	0.75	0.2	0.01

Source: NILU/NIVA (1995)/ Karlsson et al. (1992).

Appendix C

Activity data and emission figures

StatBank Norway is a service operated by Statistics Norway where you may select scope and content of each table, and then may export the result in various formats to your own PC. For air emissions you find data for:

- Emissions to air, summary data (1973-2004).
- Emissions to air, by source and fuel (1980-2003).

The StatBank is found at: http://statbank.ssb.no//statistikkbanken/default_fr.asp?PLanguage=1

Reported air emission data for Norway, and the activity data used in the calculations, is given at the homepage to the European Environment Information and Observation Network (EIONET):

- Data for greenhouse gases reported to the UNFCCC: http://cdr.eionet.eu.int/no/un/UNFCCC/
- Data for long-range transboundary air pollutants reported to the ECE: http://cdr.eionet.eu.int/no/un/CLRTAP/

Appendix D

Uncertainty estimates for single sources

Greenhouse gases

Table D1. Summary of standard deviation and probability density of activity data

IPCC source category	Pollutant source	Standard deviation (2σ). %	Density shape	Source/Comment
1A1, 1A2	Gas combustion	± 4	Normal	Directorate of oil and gas
1A1, 1A2, 1A3, 1A4	Oil combustion (total)	± 3	Normal	Spread in data.
1A1	Waste combustion - Energy industries	± 5	Normal	Expert judgement
1A2, 1A4	Waste combustion - Other sectors	± 30	Lognormal	Expert judgement
1A1, 1A2, 1A4	Wood combustion - All sectors	± 30	Lognormal	Expert judgement
1A2	Coal and coke combustion- Industry	± 5	Normal	Spread in data
1A3b, 1A3e	Oil, road/off-road/catalytic/non-catalytic	± 20	Normal	Comparisons of data
1A3a	Oil combustion - Aviation	± 20	Normal	Expert judgement
1A3d	Oil combustion - Shipping	± 10	Normal	Comparisons of data
1A4b	Coal and coke combustion - Residential	± 20	Normal	Expert judgement
1B1a	Mining of coal	± 3	Normal	Expert judgement
1B2a and b	Extraction of oil and gas	± 3	Normal	Expert judgement
1B2a	Loading of crude oil	± 3	Normal	Expert judgement
1B2c	Flaring of natural gas	± 4	Normal	As combustion of gas
2A1	Cement production	± 3	Normal	Expert judgement
2B1	Ammonia production	± 3	Normal	Expert judgement
2B2	Nitric acid production	-	-	Measured value
2B4	Carbide production	± 3	Normal	Expert judgement
2C1, 2C2, 2C3	Metal production	± 5	Normal	Expert judgement
2F	HFCs in products	-	-	See emission factor
2F	SF_6 in products	-	-	See emission factor
4A, 4B	Animal population	± 5-10	Normal	Expert judgement
4D	Agricultural soils - Fertiliser use	± 5	Normal	Agriculture authorities
4D	Agricultural soils - Manure use	± 20	Normal	Expert judgement
4D	Agricultural soils - Other activities	± 50	Lognormal	Expert judgement
6A	Solid waste disposal	± 20	Normal	Expert judgement
6B	Waste water treatment	± 25	Normal	Expert judgement

Table D2. Summary of standard deviation and probability density of emission factors

IPCC source category	Pollutant source	Standard deviation (2σ). %	Density shape	Source/Comment
1A1, 1A2	CO_2 - Gas combustion	± 7	Normal	The Norwegian Petroleum Directorate
1A1, 1A2, 1A3, 1A4	CO_2 - Oil combustion	± 3	Normal	Spread in data
1A1, 1A2, 1A4	CO_2 - Coal combustion	± 7	Normal	Spread in data
1A1, 1A2, 1A4	CO_2 - Coke combustion	± 7	Normal	Spread in data
1A1, 1A2, 1A4	CO_2 - Waste combustion	± 30	Normal	Spread in data
1A1, 1A2, 1A4	CH_4 - Wood, coal, waste combustion	-50 - +100	Lognormal	Spread in data
1A3	CH_4 - Oil combustion. Road traffic	-50 - +100	Lognormal	Spread in data. Expert judgement
1A1, 1A2, 1A4	CH_4 - Oil combustion. Other	-50 - +100	Truncated N	Spread in data
1A3	N_2O - Oil combustion. Road traffic	-66 - +200	Beta	Spread in data. Expert judgement
1A1, 1A2, 1A4	N_2O - Oil combustion. Other	-66 - +200	Beta	Spread in data. Expert judgement. IPCC (1997)
1B2c	CO_2 - Flaring	± 10	Normal	As combustion of gas
1B1a	CH_4 - Coal mining	-50 - +100	Lognormal	Expert judgement. IPCC (1997)
1B2a, 1B2b	CH_4 - Oil & gas extraction, refineries	-50 - +100	Lognormal	Expert judgement
1B2a	CH_4 - Oil loading	± 40	Lognormal	Oil company
1B2c	CH_4 - Flaring	-50 - +100	Lognormal	As combustion of gas
1B2c	N_2O - Flaring	-66 - +200	Beta	As combustion of gas
2A1	CO_2 - Cement production	± 7	Normal	Spread in data. IPCC (1997)
2B1	CO_2 - Ammonia production	± 7	Normal	Expert judgement
2B2	N_2O - Nitric acid production	± 7	Normal	Plants' estimate. Continuos measurements
2B4	CO_2 - Carbide production	± 10	Normal	Spread in data
2C1, 2C2, 2C3	CO_2 - Metal production	± 7	Normal	Spread in data
2C4	SF_6 - Metal production	± 5	Normal	Expert judgement. Consumption of chemical
2C3	PFCs - Metal production	-30 - +50	Lognormal	Plants estimate
2F	HFCs from product use	± 50	Lognormal	Expert judgement
2F	SF_6 from product use	± 60	Lognormal	Expert judgement
4A	CH_4 - Enteric fermentation	± 25	Normal	IPCC (1997)
4B	CH_4 - Animal waste	± 25	Normal	IPCC (1997)
4D	N_2O - Agricultural soils	2 orders of magnitude	Lognormal	Expert judgement
6A	CH_4, CO_2 - Landfilled solid waste	± 30	Lognormal	SFT (1999a)
6B	CH_4 - Waste water treatment	± 70	Lognormal	Expert judgement

Table D3. Uncertainties in emission level. Each gas and total GWP weighted emissions

1990	μ (mean)	Fraction of total emissions	Relative standard deviation (σ/μ)	Uncertainty 2σ (% of mean)
Total	52 mill. tonnes	1	0.103	21
CO_2	35 mill. tonnes	0.67	0.017	3
CH_4	317 ktonnes	0.12	0.111	22
N_2O	18 ktonnes	0.11	0.960	200
HFC	0.13 tonnes	0.00	0.251	50
PFC	390 tonnes	0.05	0.203	40
SF_6	95 tonnes	0.04	0.026	5
2010*	μ (mean)	Fraction of total emissions	Relative standard deviation	Uncertainty 2σ (% of mean)
Total	63 mill. tonnes	1	0.084	17
CO_2	48 mill. tonnes	0.76	0.018	4
CH_4	286 ktonnes	0.10	0.098	20
N_2O	19 ktonnes	0.09	0.852	170
HFC	580 tonnes	0.02	0.255	50
PFC	185 tonnes	0.02	0.202	40
SF_6	21 tonnes	0.01	0.043	9

* Projected data with uncertainties as if they were historical.

Table D4. Uncertainty of emission trend. 1990-2010*

	% change $((\mu_{2010}-\mu_{1990})*100/\mu_{1990})$	Relative standard deviation $(\sigma/(\mu_{2010}-\mu_{1990}))$	Uncertainty 2σ (%-point of change)
Total	21	0.107	4
CO_2	36	0.066	5
CH_4	-10	-0.785	16
N_2O	10	0.652	13
HFC	-	0.250	-
PFC	-51	-0.193	20
SF_6	-77	-0.024	4

* Projected values with uncertainties as if they were historical.

Long-range transboundary air pollutants

Table D5. Summary of expert judgements of uncertainties in point sources

Production type	Number of plants	Pollutant	Emission determination method and uncertainty evaluation	Assessment (average)
Pulp and paper	6	SO_2	Continuous emission measurements and estimations from sulphur content of fuel. Diffuse emissions of sulphur compounds when producing sulphite pulp. The latter has a higher uncertainty than both the measured and estimated stack emissions.	± 4 %
Oil refineries	2 (3)	SO_2	Continuous emission measurements and estimations from sulphur content of fuel.	± 5 %
		NO_x	Based on measurements and calculations.	± 10 %
		NMVOC	Combination of point measurements and calculations. Emissions are variable with possibilities of systematic errors. Emissions from loading of products have lower uncertainty than the fugitive. Differences between the refineries due to different technology, products and operations.	± 45 %
Petrochemical industries and gas terminal	4	NO_x	Annual measurements and/or calculations	± 7 %
		NMVOC	Several emission points. Difficult to measure properly and high variability. Uncertainty is in any case lower than for the refineries as mostly gas is handled (high demand for security).	± 25 %
Cement	2	SO_2	Continuous measurements and annual measurements/calculations. High variability as cement plants incinerates special waste.	± 12 %
		NO_x	Continuous measurements and annual measurements/calculations. High variability as cement plants incinerates special waste.	± 12 %
Ammonia and fertiliser	2	NO_x	Continuous/weekly measurements.	± 7 %
		NH_3	Several emission points. Several measurements performed each year. Low variability.	± 10 %
Silicon carbide (SiC)	3	SO_2	Emissions are estimates based on consumption and sulphur content of coke. The sulphur content is measured independently for every delivery. There is, however, uncertainty connected to the end products and degree of oxidation and definition applied, so reporting can seem inconsistent.	± 20 %
Ferroalloys	16	SO_2	Emissions are estimates based on consumption and sulphur content of coke and the sulphur in products. The sulphur content is measured independently for every delivery. The sulphur content of products are measured regularly, but shows small variability.	± 2 %
		NO_x	Estimates using emission factors. Emission factors are based on measurements. Emission factors are, however, only available for some types of ferroalloys and emissions are not estimated for the others.	± 10-20 %*
Aluminium	8	SO_2	Monthly measurements (covering emissions from stack and ceiling)	± 7 %
		NO_x	Emissions are estimated based on emission factors (see Table 4).	-
Waste incineration	8	SO_2	Annual representative measurements. Variable emissions due to the waste fraction incinerated.	± 7 %
		NO_x	Annual representative measurements.	± 10 %

* Additional uncertainty due to possible incomplete reporting.

Table D6. Summary of standard deviation and probability density of activity data

SNAP category	Pollutant source	Important for	Standard deviation (2σ). %	Density shape	Source/Comment
01, 02, 03	Gas combustion	NO_x	± 4	Normal	Directorate of oil and gas
01, 02, 03, 07, 08	Oil combustion (total)	SO_2, NO_x	± 3	Normal	Spread in data.
0102	Waste combustion - Energy industries	SO_2, NO_x, NMVOC	± 5	Normal	Expert judgement
0202	Coal and coke combustion - Residential	SO_2, NO_x, NMVOC	± 20	Normal	Expert judgement
090201	Waste combustion - Other sectors	SO_2, NO_x, NMVOC	± 30	Lognormal	Expert judgement
01, 02, 03	Wood combustion - All sectors	SO_2, NO_x, NMVOC	± 30	Lognormal	Expert judgement
01, 03	Coal and coke combustion- Industry	SO_2, NO_x, NMVOC	± 5	Normal	Spread in data
07, 08	Oil, road/off-road/catalytic/non-catalytic	SO_2, NO_x, NMVOC, NH_3	± 20	Normal	Comparisons of data
0805	Oil combustion - Aviation	SO_2, NO_x, NMVOC	± 20	Normal	Expert judgement
0804	Oil combustion - Shipping	SO_2, NO_x, NMVOC	± 10	Normal	Comparisons of data
0401	Refineries (throughput)	NMVOC	± 3	Normal	Expert judgement
040301	Aluminium production	NO_x	± 3	Normal	Expert judgement
040302	Ferroalloy production	NO_x	± 3	Normal	Expert judgement
040605	Bread production	NMVOC	± 30	Normal	Expert judgement
040607	Beer production	NMVOC	± 10	Normal	Expert judgement
050202	Loading of crude oil	NMVOC	± 3	Normal	Expert judgement
0505	Gasoline distribution	NMVOC	± 3	Normal	Expert judgement
0601	Solvent use	NMVOC			See emission factor
09	Waste combustion in small scale	SO_2, NO_x, NMVOC	± 50	Lognormal	Expert judgement
090201	Methane incineration (landfills)	NO_x, NMVOC	± 5	Normal	Expert judgement
090204	Flaring of natural gas	NO_x, NMVOC	± 4	Normal	As combustion of gas
090204	"Flaring" of crude oil	SO_2, NO_x, NMVOC	± 10	Normal	Expert judgement
090203/4	Other flaring	NO_x, NMVOC	± 5	Normal	Expert judgement
090207	Incineration of hospital waste	NO_x, NMVOC	± 20	Normal	Expert judgement
090901	Cremation	SO_2, NO_x, NMVOC	± 20	Normal	Expert judgement
10	Animal population	NH_3	± 5-10	Normal	Expert judgement
10	Agricultural soils - Treatment of straw	NH_3			See emission factor
1001	Agricultural soils - Fertiliser use	NH_3	± 5	Normal	Agriculture authorities
1009	Agricultural soils - Manure use	NH_3	± 20	Normal	Expert judgement

Table D7. Summary of standard deviation and probability density of emission factors

SNAP source category	Pollutant source	Standard deviation (2σ). %	Density shape	Source/Comment
01, 02, 03	SO_2 - Oil combustion, general	± 1	Normal	Expert judgement. Oil companies
01, 02, 03	SO_2 - Oil combustion, heavy fuel oil	-50 - +100	Normal	Expert judgement. Oil companies
01, 03	SO_2 - Coal combustion	-50 - +100	Lognormal	Spread in data
01, 03	SO_2 - Wood combustion	-50 - +100	Lognormal	Spread in data
0804	SO_2 - Oil combustion, domestic shipping	± 25	Normal	Expert judgement. Oil companies
01, 02 (+03)	NO_x - Combustion in area sources	± 40-50	Normal	Spread in data
0105	NO_x - Combustion off-shore	± 40	Lognormal	Expert judgement
040301	NO_x - Aluminium production	-50 - +100	Lognormal	Expert judgement
07	NO_x - Road traffic	± 25-30	Normal	Expert judgement, spread in data
0704/0705	NO_x - Motorcycles	± 40	Normal	Expert judgement, spread in data
0801-02, 0806-09	NO_x - Equipment and railways	± 40	Normal	Spread in data
0804	NO_x - Shipping	± 15	Normal	Spread in data
0805	NO_x - Aircraft	± 20	Normal	EEA (2000)
0902	NO_x - Flaring	± 40	Lognormal	Expert judgement
01, 02 (+03)	NMVOC - Combustion in area sources	± 40-50	Normal	Spread in data
0105	NMVOC - Combustion offshore	± 50	Lognormal	Expert judgement
040605/07	NMVOC- Beer and bread production	-50 - +100	Lognormal	EEA (2000)
050201	NMVOC- Oil loading onshore	± 30	Normal	Rypdal (1999), Expert judgement
050202	NMVOC- Oil loading offshore	± 40	Normal	Rypdal (1999), Expert judgement
0505	NMVOC - Gasoline distribution	± 50	Lognormal	EEA (2000)
0601	NMVOC - Solvent use	± 30	Normal	Rypdal (1995a)
0701	NMVOC - Road traffic (gasoline vehicles)	± 40-50	Normal	Expert judgement, spread in data
0703	NMVOC - Road traffic (diesel vehicles)	± 20-30	Normal	Expert judgement, spread in data
0704/0705	NMVOC - Motorcycles	± 40	Normal	Expert judgement, spread in data
0801-02, 0806-09	NMVOC - Equipment and railways	± 40	Normal	Spread in data
0804	NMVOC - Shipping	± 50	Normal	Spread in data
0805	NMVOC - Aircraft	± 25	Normal	EEA (2000)
0902	NMVOC - Flaring	± 50	Lognormal	Expert judgement
07	NH_3 - Road traffic	Factor 3	Lognormal	Expert judgement, spread in data
1001	NH_3 -Agriculture, fertiliser	± 20	Normal	Expert judgement
1005	NH_3 -Agriculture, animal manure	± 30	Normal	Expert judgement
10	NH_3 -Agriculture, treatment of straw	± 5	Normal	Expert judgement

Table D8. Uncertainty in emission level of pollutants. 1990, 1998 and 2010

1990	μ (mean) ktonnes	Relative standard deviation (σ/μ)	Uncertainty 2σ (% of mean)	Uncertainty 2σ (ktonnes)
SO_2	52.7	0.02	4.0	2
NO_x	219.0	0.062	12	27
NMVOC	298.4	0.09	18	54
NH_3	22.9	0.104	21	5
1998	**μ (mean) ktonnes**	**Relative standard deviation (σ/μ)**	**Uncertainty 2σ (% of mean)**	**Uncertainty 2σ (ktonnes)**
SO_2	29.8	0.021	4.2	1
NO_x	224.0	0.062	12	42
NMVOC	344.5	0.105	21	72
NH_3	27.0	0.091	18	5
2010*	**μ (mean) ktonnes**	**Relative standard deviation (σ/μ)**	**Uncertainty 2σ (% of mean)**	**Uncertainty 2σ (ktonnes)**
SO_2	22.0	0.025	5.0	1
NO_x	156.0	0.062	12	19
NMVOC	194.0	0.074	15	29
NH_3	23.0	0.105	21	5

* Projected data with uncertainties as if they were historical.

Table D9. Uncertainties in emission trends 1990-1998 and 1990-2010

	Absolute change (μ_{2010}-μ_{1990})	% change ((μ_{2010}-μ_{1990})*100/μ_{1990})	Relative standard deviation (σ/(μ_{2010}-μ_{1990}))	Uncertainty 2σ (absolute change)	Uncertainty 2σ (%-point of change)
1990-1998					
SO_2	-23.0	-43	-0.04	1.7	3.2
NO_x	+4.8	+2	+3.00	28	13
NMVOC	+43.8	+15	+0.40	35	12
NH_3	+4.1	+18	+0.22	1.8	8.0
1990-2010					
SO_2	-30.7	-58	-0.03	1.8	3.4
NO_x	-62.8	-29	-0.21	26.9	12
NMVOC	-104.9	-35	-0.18	38	13
NH_3	+0.0	0	61.3	3.1	13

* Projected values with uncertainties as if they were historical.

Appendix E

Key category analysis for GHG

This chapter outlines the Tier 2 methodology used to find which sources are key categories in the Norwegian Greenhouse gas emission inventory.

In previous Norwegian National Inventory Report (2003) the key category analysis was based on a work done by Rypdal and Zhang (2000). This report used a tier 2 approach for uncertainty assessment and incorporated Monte Carlo analysis. The current analysis is simplified and uses a tier 1 uncertainty assessment as described in IPCC's Good Practice Guidance (IPCC 2001), equations 7.3-7.4. According to the Good Practice Guidance the key category analysis is a Tier 2 method.

Key categories are identified as the emission sources that add up to 90 per cent of total uncertainty in level and/or trend. This definition of a key category is according to IPCC (2001), which is based on Flugsrud and Rypdal (2001). A Tier 2 analysis for the LULUCF secor has also been performed. The uncertainties of the categories defined from this source are additional to the 90 per cent uncertainties from the other categories.

The key category analysis is performed at the level of IPCC source categories and each GHG from each source category is considered separately with respect to total GWP weighted emissions. The advantage in using a Tier 2 rather than the Tier 1 methodology is that uncertainties are taken into account so the ranking shows where uncertainties can be reduced.

The steps taken to find key categories with respect to level and trend were the determination of uncertainties in input parameters (AD = activity data and EF = emission factors). Uncertainty data were obtained from Rypdal and Zhang (2000) with some modifications. The highest uncertainties from Rypdal and Zhang (2000) could not be used directly, as they would have totally dominated the analysis. These uncertainties were usually associated with emission factors with lognormal probability densities. They were "normalized" by the formula $U^* = ln\ (U + 1)$. The associated emission factors still dominate the analysis more strongly than in Rypdal and Zhang (2000), but the conclusions with respect to the key categories now seem more robust.

Uncertainties of activity data and emissions factors were combined to source uncertainty by the error propagation rule $U_{source} = \sqrt{U_{AD}^2 + U_{EF}^2}$ (IPCC 2001, equation 6.4).

The next step was the use of sensitivity analysis to identify which parameters in the inventory influence most the total GHG emissions in level and in trend. The current method does not take correlations into account. This has partly been handled by aggregating sources with the same emission factors in stationary combustion, categories 1A1, 1A2, and 1A4. However, correlations due to common activity data for several pollutants have not been taken into account. This may lead to an underestimation of the uncertainty importance for such sources.

Compilations of the uncertainty importance elasticity lead to the estimation of uncertainty importance of each input parameter with respect to total level and trend uncertainty. Out of this we get a ranked list of parameters, which add up to 90 per cent of total uncertainty in level and trend. The LULUCF key categories come in addition to this.

The background data on emissions and uncertainties are shown in tables E1 and E2, with regard to LULUCF, which also gives the level of aggregation used in the analysis. The results of the Tier 1 and Tier 2 level analyses are shown in tables E3 and E4 respectively, while the results of the Tier 1 and Tier 2 trend analyses are listed in tables E5 and E6. These tables include key categories from all sectors. A summary of the key categories are given in table E7 for the emissions categories, and a summary for removal key categories are given in table E8.

The key categories identified correspond well with the previous analyses. The major difference is that 2C4 - *SF_6 Used in Aluminum and Magnesium Foundries* is identified as key by the trend analysis. This source has a low uncertainty. However, the major plant using SF_6 were closed in 2002. This leads to an even larger difference between total trend and source trend than in Rypdal and Zhang (2000).

N_2O from agriculture figure more prominently than in Rypdal and Zhang (2000). This is probably due to a different treatment of the very large uncertainty in this source. The source would be identified as key by all reasonable treatments. However, the choice of treatment influences which sources are included by the 90 per cent

threshold. The next sources in the trend analysis were both identified as key in the level analysis. The next sources in the level analysis were 2B2 *Nitric acid production* and 1A3e *Other motorized equipment*.

The other differences between the current analysis and Rypdal and Zhang (2000) have no bearings on the conclusions on key categories. There are some differences in ranking and in whether the sources are identified by the level, trend or both analyses.

CH_4 from coal mining - 1B1a - has been designated key in the previous National Inventory Reports. This source is not identified by the quantitative method. It is included because the national emission factor we use is in an order of magnitude less than IPCC's default factors (not shown in the tables).

No formal analysis of the separate effects of AD and EF uncertainty has been performed. Rypdal and Zhang (2000) concluded that the uncertainty importance of activity data is generally lower than the emission factors. Table E1 shows that this conclusion is still valid. In fact, the only key categories for which activity data are more uncertain than emission factors are CO_2 from mobile combustion (1A3a, 1A3b, 1A3d).

The analyses have been performed for 1990 and 2003 GHG emission data. The main conclusion is that there are few differences in the result for 1990 compared with 2003.

Land-use, Land-use Change and Forestry (LULUCF)

The assessment of key categories should have consequences for methodological choice according to the decision trees of GPG2004. As far as possible higher tier methods should be used for the key categories. Key categories are defined according to the level and trend. For this purpose the assessment is made taking into account also the size and change in non-LULUCF sources of emissions.

Tables E3 – E6 show the results of the Tier 1 and 2 key category analysis performed as described in GPG2004[7], the Tier 2 key categories are summarized in table E8. Uncertainties were not determined by a rigid analysis. There are some differences between the two tiers, Tier 1 level analysis identifies forest converted for settlements, but not forest drained organic soil and cropland histosols. The reason is that the two latter categories have large uncertainties. For the trend analysis there are small difference between the two tiers with respect to the LULUCF categories identified, and the trend analysis do not identify any additional LULUCF categories to those identified in the level analysis. Including LULUCF also influences other key categories identified. However, according to GPG2004 the LULUCF key categories are additional to those identified analyzing the inventory excluding LULUCF. In both analysis, forest remaining forest (all three pools) are among the top key categories.

[7] Tier 1 is based on only the size of emissions/removals and estimate their contribution to the level and trend. In the Tier 2 method the contribution is also multiplied with the relative uncertainty (two standard deviations).

Table E1. Background data for the key category analysis, all sectors except LULUCF

IPCC	Source category	Emissions, 1000 t CO_2-eq.						Uncertainties			
								Activity	Emission factors		
Part 1	CO_2, CH_4, and N_2O	CO_2		CH_4		N_2O			CO_2	CH_4	N_2O
		1990	2003	1990	2003	1990	2003				
1A1, 1A2, 1A4	Stationary Fuel Combustion, Coal/coke	541	546	2	1	1	0	0.05	0.07	0.69	1.10
1A1, 1A2, 1A4	Stationary Fuel Combustion, Gas	7 166	13 385	47	86	18	32	0.04	0.07	0.69	1.10
1A1, 1A2, 1A4	Stationary Fuel Combustion, Oil	6 379	6 540	10	10	81	67	0.03	0.03	0.69	1.10
1A1, 1A2, 1A4	Stationary Fuel Combustion, Wood etc.	.	.	119	163	40	48	0.30	.	0.69	1.10
1A1, 1A2, 1A4	Stationary Fuel Combustion, Waste	100	178	2	4	4	10	0.05	0.30	0.69	1.10
1A3a	Civil Aviation	679	954	0	1	7	9	0.20	0.03	0.69	1.10
1A3b	Road Transportation	7 850	9 576	59	43	92	714	0.20	0.03	0.69	1.10
1A3c	Railways	96	41	0	0	11	5	0.10	0.03	0.69	1.10
1A3d	Navigation	1 929	2 487	4	8	14	19	0.10	0.03	0.69	1.10
1A3e	Other (snow scooters, boats, motorized equipment)	544	646	6	7	40	52	0.20	0.03	0.69	1.10
1A5a	Military - Stationary	62	58	0	0	0	0	0.05	0.05	0.69	1.10
1A5b	Military - Mobile	394	114	0	0	4	1	0.05	0.05	0.69	1.10
1B1a	Coal Mining	0	4	3	33	.	.	0.03	0.69	0.69	.
1B2a	Oil (incl. oil refineries, gasoline distribution)	1 115	1 408	190	301	.	.	0.03	0.34	0.34	.
1B2b	Natural Gas	6	14	16	34	.	.	0.03	0.69	0.69	.
1B2c	Venting and Flaring	1 501	1 294	146	277	4	3	0.04	0.10	0.69	1.10
2A1	Cement Production	653	885	.	.	.	.	0.03	0.07	.	.
2A2	Lime Production	25	44	.	.	.	.	0.03	0.07	.	.
2A3	Limestone and Dolomite Use	20	22	.	.	.	.	0.03	0.07	.	.
2B1	Ammonia Production	500	180	.	.	.	.	0.03	0.07	.	.
2B2	Nitric Acid Production	.	.	.	.	2 062	1 711	0.00	.	.	0.07
2B4	Carbide Production	289	96	21	12	.	.	0.03	0.10	0.69	.
2B5	Other	3	2	1	3	.	.	0.10	0.10	0.69	.
2C1	Iron and Steel Production	201	328	.	.	.	.	0.03	0.07	.	.
2C2	Ferroalloys Production	2 574	2 214	16	12	.	.	0.03	0.07	0.69	.
2C3	Aluminum Production	1 431	1 891	.	.	.	.	0.03	0.07	.	.
2C5	Other	190	83	.	.	.	.	0.10	0.10	.	.
2D2	Food and Drink	20	70	.	.	.	.	0.10	0.10	.	.
3A	Paint Application	37	24	.	.	.	.	0.15	0.20	.	.
3B	Degreasing and Dry Cleaning	8	1	.	.	.	.	0.15	0.20	.	.
3C	Chemical Products, Manufacture and Processing	8	15	.	.	.	.	0.15	0.20	.	.
3D	Other	92	87	.	.	36	41	0.15	0.20	.	1.10
4A1	Cattle	.	.	1 360	1 285	.	.	0.10	.	0.25	.
4A3	Sheep	.	.	260	296	.	.	0.10	.	0.25	.
4A4	Goats	.	.	9	7	.	.	0.10	.	0.25	.
4A6	Horses	.	.	12	19	.	.	0.10	.	0.25	.
4A8	Swine	.	.	17	20	.	.	0.10	.	0.25	.
4A9	Poultry	.	.	1	1	.	.	0.10	.	0.25	.
4B1	Cattle	.	.	215	206	.	.	0.10	.	0.25	.
4B3	Sheep	.	.	24	27	.	.	0.10	.	0.25	.
4B4	Goats	.	.	2	1	.	.	0.10	.	0.25	.
4B6	Horses	.	.	11	18	.	.	0.10	.	0.25	.
4B8	Swine	.	.	23	27	.	.	0.10	.	0.25	.
4B9	Poultry	.	.	19	26	.	.	0.10	.	0.25	.
4B11	Liquid Systems	.	.	.	.	17	17	0.10	.	.	1.10
4B12	Solid Storage and Dry Lot	.	.	.	.	117	125	0.10	.	.	1.10
4B13	Other	.	.	4	4	.	.	0.10	.	0.25	.
4D1	Direct soil emissions	.	.	.	.	1 783	1 730	0.20	.	.	4.62
4D2	Animal production	.	.	.	.	219	222	0.20	.	.	4.62
4D3	Indirect emissions	.	.	.	.	417	410	0.41	.	.	4.62
4F1	Cereals	.	.	24	5	7	1	0.10	.	0.69	1.10
4A10	Other	.	.	54	50	.	.	0.10	.	0.25	.
6A	Solid Waste Disposal on Land	.	.	2 463	2 049	.	.	0.20	.	0.30	.
6B	Wastewater Handling	.	.	20	21	91	110	0.41	.	0.53	1.10
6C	Waste Incineration	0	35	0	0	0	0	0.30	0.30	0.69	1.10
Part 2	HFCs, PFCs, and SF_6	HFC		PFC		SF_6			HFC	PFC	SF_6
		1990	2003	1990	2003	1990	2003				
2C3	Aluminum Production	.	.	3 294	703	.	.	0.03	.	0.41	.
2C4	SF6 Used in Aluminum and Magnesium Foundries	.	.	.	.	2 144	172	0	.	.	0.05
2F	Consumption of Halocarbons and Sulphur Hexafluoride	0	240	.	.	57	60	0	0.41	.	0.47

Table E2. Background data for the key category analysis for LULUCF

IPCC	Source category	Emissions, 1000 t CO_2-eq.						Uncertainties			
								Acti-	Emission factors		
Part 1	CO_2, CH_4, and N_2O	CO_2		CH_4		N_2O		vity	CO_2	CH_4	N_2O
		1990	2003	1990	2003	1990	2003				
5A1	Forest remaining Forest, Living biomass	-11 579	-19 053						15		
5A1	Forest remaining Forest, Dead biomass	-4 562	-3 904						41		
5A1	Forest remaining Forest, Soil, Drained organic soils	136	144						230		
5A1	Forest remaining Forest, Soil, Other[1]	-1 985	-2 170						25		
5B1	Cropland remaining Cropland, Horticulture, Living biomass, increase	-25	-19						25		
5B1	Cropland remaining Cropland, Horticulture, Living biomass, decrease	11	21						25		
5B1	Cropland remaining Cropland, Reduced tillage, Soil	-	-162						64		
5B1	Cropland remaining Cropland, Histosols, Soil	208	209						110		
5B2	Forest converted to Cropland, Living biomass	84	46						25		
5C1	Grassland remaining Grassland, Histosols, Soil	1 870	1 870						110		
5C2	Cropland converted to Grassland, Horticulture, Living biomass, decrease	-	21						25		
5C2	Cropland converted to Grassland, Soil	-	-0,004						64		
5D1	Wetland remaining Wetland, Peat extraction, Soil	3	3						110		
5E1	Forest converted to Settlements, Living biomass	352	342						41		
5A-II	Forest Drainage					8	8				230
5A1-V	Forest Fires			26	21	1,2	1,0			56	56
5A2-I	Forest Fertilizer					-	0,7				161
5B-IV	Cropland Liming	217	105						10		
5B2-III	Cropland Disturbance					1,2	0,6				230
5D-II	Wetland Drainage					0,04	0,04				230
5G-IV	Other - Liming (Lakes and rivers)	10	18						10		

Table E3. Tier 1 level analysis 1990 and 2003 (including LULUCF). Sources with assessment in bold types are identified as key categories

IPCC Source category	Gas	Source category level assessment, without uncertainty (fraction of total). Per cent.		Cumulative total. Per cent.
		1990	2003	2003
5A1 Forest remaining Forest Living biomass, net change	CO_2	**16.26**	**22.98**	22.98
1A Fuel Combustion Activities (Sectoral Approach) (gas)	CO_2	**10.06**	**16.15**	39.13
1A3b Road Transportation	CO_2	**11.02**	**11.55**	50.68
1A Fuel Combustion Activities (Sectoral Approach) (oil)	CO_2	**8.96**	**7.89**	58.57
5A3 Forest remaining Forest Dead biomass, net change	CO_2	**6.41**	**4.71**	63.28
1A3d Navigation	CO_2	**2.71**	**3.00**	66.28
2C2 Ferroalloys Production	CO_2	**3.62**	**2.67**	68.95
5A4 Forest remaining Forest Soil, net change	CO_2	**2.79**	**2.62**	71.57
6A Solid Waste Disposal on Land	CH_4	**3.46**	**2.47**	74.04
2C3 Aluminium Production	CO_2	**2.01**	**2.28**	76.32
5C1 Grassland remaining Grassland Histosols Soil, net	CO_2	**2.63**	**2.26**	78.58
4D1 Agricultural soils – direct soil	N_2O	**2.50**	**2.09**	80.67
2B2 Nitric Acid Production	N_2O	**2.89**	**2.06**	82.73
1B2a Oil (incl. oil refineries, gasoline dist	CO_2	**1.57**	**1.70**	84.43
1B2c Venting and Flaring	CO_2	**2.11**	**1.56**	85.99
4A1 Cattle	CH_4	**1.91**	**1.55**	87.54
1A3a Civil Aviation	CO_2	**0.95**	**1.15**	88.69
2A1 Cement Production	CO_2	**0.92**	**1.07**	89.76
1A3b Road Transportation	N_2O	**0.13**	**0.86**	90.62
2C3 Aluminium Production	PFCs	**4.63**	**0.85**	91.47
1A3e Other (snow scooters, boats, motorized e	CO_2	**0.76**	**0.78**	92.25
1A Fuel Combustion Activities (Sectoral Approach) (coal/coke)	CO_2	**0.76**	**0.66**	92.91
4D3 Indirect	N_2O	**0.59**	**0.49**	93.40
5E1 Forest converted to Settlementes Living biomass,	CO_2	**0.49**	**0.41**	93.81
2C1 Iron and Steel Production	CO_2	0.28	**0.40**	94.21
1B2a Oil (incl. oil refineries, gasoline dist	CH_4	0.27	**0.36**	94.57
4A3 Sheep	CH_4	**0.37**	**0.36**	94.93
1B2c Venting and Flaring	CH_4	0.21	**0.33**	95.26
2B1 Ammonia Production	CO_2	**0.70**	0.22	95.48
2C4 SF_6 Used in Aluminium and Magnesium Foundries	SF_6	**3.01**	0.21	95.69
1A5b Military - Mobile	CO_2	**0.55**	0.14	95.82
2B4 Carbide Production	CO_2	**0.41**	0.12	95.94

Table E4. Tier 2 level analysis 1990 and 2003 (including LULUCF). All categories listed are identified as key

IPCC Source category	Gas	Source category level assessment, with uncertainty (fraction of total). Per cent.		Cumulative total. Per cent.
		1990	2003	2003
4D1 Agricultural soils – direct soil	N_2O	31.36	28.76	28.76
5A1 Forest remaining Forest 0 Living biomass, net change	CO_2	6.61	10.29	39.05
5C1 Grassland remaining Grassland Histosols Soil, net	CO_2	7.82	7.39	46.44
1A3b Road Transportation	CO_2	6.04	6.97	53.41
4D3 Indirect	N_2O	7.35	6.83	60.24
5A3 Forest remaining Forest Dead biomass, net change	CO_2	7.04	5.70	65.94
1A Fuel Combustion Activities (Sectoral Approach) (gas)	CO_2	2.20	3.88	69.83
4D2 Animal production	N_2O	3.85	3.69	73.51
1A3b Road Transportation	N_2O	0.39	2.87	76.38
5A4 Forest remaining Forest Soil, net change	CO_2	1.89	1.95	78.34
6A Solid Waste Disposal on Land	CH_4	3.38	2.66	81.00
1B2a Oil (incl. oil refineries, gasoline dist	CO_2	1.43	1.71	82.71
4A1 Cattle	CH_4	1.39	1.25	83.95
5A2 Forest remaining Forest Drained organic soils Soil	CO_2	1.19	1.19	85.14
2C3 Aluminium Production	PFCs	5.10	1.03	86.17
1A Fuel Combustion Activities (Sectoral Approach) (Oil)	CO_2	1.03	1.00	87.17
1A3d Navigation	CO_2	0.77	0.93	88.11
5B5 Cropland remaining Cropland Histosols Soil, net change	CO_2	0.87	0.83	88.93
1A3a Civil Aviation	CO_2	*0.52*	0.69	89.63
1B2c Venting and Flaring	CH_4	0.39	0.69	90.32
2C2 Ferroalloys Production	CO_2	0.75	*0.61*	90.93
2C3 Aluminium Production	CO_2	0.41	*0.52*	91.44
1B2c Venting and Flaring	CO_2	*0.62*	*0.50*	91.95
2B2 Nitric Acid Production	N_2O	*0.55*	0.43	92.38

Table E5. Tier 1 trend analysis 1990-2003. (including LULUCF). All categories listed are key categories

IPCC Source category	Gas	Source category trend assessment, with uncertainty (fraction of total). Per cent. 1990-2003	Cumulative total. Per cent. 1990-2003
5A1 Forest remaining Forest 0 Living biomass, net change	CO_2	28.49	28.49
1A Fuel Combustion Activities (Sectoral Approach) (gas)	CO_2	23.07	51.57
2C3 Aluminium Production	PFCs	8.00	59.57
1A3b Road Transportation	CO_2	7.91	67.48
2C4 SF_6 Used in Aluminium and Magnesium Foundries	SF_6	6.18	73.66
1A3d Navigation	CO_2	2.40	76.06
1A Fuel Combustion Activities (Sectoral Approach) (Oil)	CO_2	2.19	78.25
1A3b Road Transportation	N_2O	2.15	80.40
2C3 Aluminium Production	CO_2	1.94	82.33
1B2a Oil (incl. oil refineries, gasoline dist	CO_2	1.29	83.62
5A4 Forest remaining Forest Soil, net change	CO_2	1.14	84.76
1A3a Civil Aviation	CO_2	1.11	85.88
5A3 Forest remaining Forest Dead biomass, net change	CO_2	1.08	86.95
2B1 Ammonia Production	CO_2	0.96	87.91
2A1 Cement Production	CO_2	0.96	88.87
1A5b Military - Mobile	CO_2	0.85	89.73
2F Consumption of Halocarbons and Sulphur Hexafluoride	HFCs	0.82	90.55
6A Solid Waste Disposal on Land	CH_4	0.78	91.33
2B2 Nitric Acid Production	N_2O	0.67	91.99
2B4 Carbide Production	CO_2	0.59	92.58
2C2 Ferroalloys Production	CO_2	0.57	93.15
1A3e Other (snow scooters, boats, motorized equipment)	CO_2	0.49	93.64
2C1 Iron and Steel Production	CO_2	0.49	94.12
1B2c Venting and Flaring	CH_4	0.48	94.61
5C1 Grassland remaining Grassland Histosols Soil, net	CO_2	0.48	95.09

Table E6. Tier 2 trend analysis 1990-2003. (including LULUCF). All categories listed are key categories

IPCC Source category	Gas	Source category trend assessment, with uncertainty (fraction of total). Per cent. 1990-2003	Cumulative total. Per cent. 1990-2003
5A1 Forest remaining Forest Living biomass, net change	CO_2	19.97	19.97
2C3 Aluminium Production	PFCs	15.19	35.16
1A3b Road Transportation	N_2O	11.19	46.36
1A Fuel Combustion Activities (Sectoral Approach) (gas)	CO_2	8.69	55.05
1A3b Road Transportation	CO_2	7.47	62.52
4D1 Agricultural soils – direct	N_2O	5.95	68.48
5C1 Grassland remaining Grassland Histosols Soil, net	CO_2	2.47	70.94
5A3 Forest remaining Forest Dead biomass, net change	CO_2	2.04	72.98
1B2a Oil (incl. oil refineries, gasoline dist	CO_2	2.03	75.01
4D3 Indirect	N_2O	1.78	76.80
1B2c Venting and Flaring	CH_4	1.57	78.37
2F Consumption of Halocarbons and Sulphur Hexafluoride	HFCs	1.55	79.92
2C4 SF_6 Used in Aluminium and Magnesium Foundries	SF_6	1.44	81.37
4D2 Animal production	N_2O	1.42	82.79
5A4 Forest remaining Forest Soil, net change	CO_2	1.33	84.12
6A Solid Waste Disposal on Land	CH_4	1.31	85.44
1A3d Navigation	CO_2	1.17	86.61
1A3a Civil Aviation	CO_2	1.05	87.66
2C3 Aluminium Production	CO_2	0.69	88.35
1B2a Oil (incl. oil refineries, gasoline dist	CH_4	0.68	89.03
5A2 Forest remaining Forest Drained organic soils Soil	CO_2	0.66	89.68
1A Fuel Combustion Activities (Sectoral Approach) (fuel wood)	CH_4	0.65	90.33

Table E7. Summary of identified emission key categories

IPCC Source category		Gas	Level assessment. Per cent. 1990	Level assessment. Per cent. 2003	Trend assessment. Per cent. 2003	Method (Tier) 2003
1A1, 1A2, 1A4	Stationary Fuel Combustion, Gas	CO_2	2.99	5.43	8.64	Tier 2
1A1, 1A2, 1A4	Stationary Fuel Combustion, Oil	CO_2	1.40	1.40		Tier 2
1A3a	Civil Aviation	CO_2	0.71	0.97	0.83	Tier 2
1A3b	Road Transportation	CO_2	8.20	9.75	3.90	Tier 2
1A3b	Road Transportation	N_2O		4.01	13.21	Tier 2
1A3d	Navigation	CO_2	1.04	1.31	0.76	Tier 2
1B2a	Oil (incl. oil refineries, gasoline distribution)	CH_4			0.61	Tier 2 / 3
1B2a	Oil (incl. oil refineries, gasoline distribution)	CO_2	1.95	2.39	1.24	Tier 2
1B2c	Venting and Flaring	CH_4		0.97	1.57	Tier 2
1B2c	Venting and Flaring	CO_2	0.84	0.70	0.72	Tier 2
2B2	Nitric Acid Production	N_2O	0.75		0.73	Tier 2
2C2	Ferroalloys Production	CO_2	1.01	0.85	0.88	Tier 2
2C3	Aluminum Production	CO_2		0.72		Tier 2
2C3	Aluminum Production	PFC	6.92	1.44	22.73	Tier 2
2C4	SF6 Used in Aluminum and Magnesium Foundries	SF_6			2.09	Tier 2
2F	Consumption of Halocarbons and Sulphur Hexafluoride	HFC			1.88	Tier 2
4A1	Cattle	CH_4	1.89	1.74	1.04	Tier 1
4D1	Direct soil emissions	N_2O	42.56	40.22	19.50	Tier 1a
4D2	Animal production	N_2O	5.23	5.16	1.56	Tier 1a
4D3	Indirect emissions	N_2O	9.98	9.55	4.10	Tier 1a
6A	Solid Waste Disposal on Land	CH_4	4.59	3.72	4.47	Tier 2
2A1	Cement Production*	CO_2			0.96	Tier 2
1B1a	Coal mining and handling**	CH_4				Tier 2
	CO_2 capture and storage***	CO_2				CS (Tier 2)**

* Identified as key category because of large contribution to the total emissions (Tier 1).

** Identified key category since national emission factors deviate from IPCC default emission factors.

*** No methodology or category is defined in IPCC Guidelines.

In addition, we have identified the key removal categories in the LULUCF sector as listed below. We have also defined CO_2 capture and storage as an additional key category.

Table E8. Summary of identified removal key categories

IPCC Category		Gas	Level assessment. Per cent. 1990	Level assessment. Per cent. 2003	Trend assessment 1990-2003	Method (Tier) 2003
5A1	Forest land remaining forest land, living biomass	CO_2	6.80	10.53	20.03	Tier 3
5C1	Grassland remaining grassland, soils, histosols	CO_2	8.04	7.57	256	Tier 2**
5A1	Forest land remaining forest land, dead organic matter	CO_2	4.39	3.50	1.31	Tier 3
5A1	Forest land remaining forest land, soils, other*	CO_2	1.94	2.00	1.35	Tier 3
5A1	Forest land remaining forest land, soils, drained organic soils	CO_2	1.23	1.22	0.67	Tier 1
5B1	Cropland remaining cropland, soils, histosols	CO_2	0.89	0.85	-	Tier 2
5E1	Forest converted to settlements, living biomass	CO_2	*Tier 1 only*		-	Tier 2

* "Other" refers to all areas excluding Finnmark county and drained areas.

** Country specific emission factors.

Appendix F

Economic sectors in the Norwegian emission model

The classification is almost identical to that used in the National Accounts. To make the standard sectors more appropriate for emission calculation a few changes have been made, e.g. "Private households" is defined as a sector. The classification is aggregated from the Norwegian *Standard Industrial Classification*, SIC2002 (Statistics Norway 2003). The SIC is identical to the European NACE (rev. 1.1) classification up to the four-digit level. A national level has been introduced at the five-digit level.

All sector numbers in the model have six digits. The first two digits refer to the main sectors of the economy: 23 = private sector, 24 = central government, 25 = local government, 33 = private households, and 66 = foreign activity. For clarity, the two first digits are only included for the first sector listed in each main sector in the table below.

The last four digits are approximate SIC codes. The first two of these always correspond to SIC at the two-digit level. (Exceptions: sectors 235000 and 236500 are aggregates of several SIC divisions). For around two thirds of the sectors, all non-zero digits correspond to SIC. The detailed relationship is shown in the following table, where the sectors are listed with the corresponding SIC codes.

Sector number	SIC code	Sector name
Agriculture and forestry		
230100	01.1-3	Agriculture
0140	01.4-5	Services related to agriculture and forestry
0200	02	Forestry and logging
Fishing		
0510	05.01	Fishing
0520	05.02	Operation of fish farms
Energy sectors		
1000	10.1-2	Coal mining
1110	11.1	Extraction of crude petroleum and natural gas
1200	12	Mining of uranium and thorium ores
2320	23.2 part	Manufacture of refined petroleum products
2330	23.3	Processing of nuclear fuel
2340	11.1	Gas terminal
4010	40.110	Production of electricity
4020	40.120	Distribution of electricity
4030	40.2	Manufacture and distribution of gas
4040	40.3	Steam and hot water supply
Mining/manufacturing		
1120	11.2	Oil drilling
1300	13	Mining of metal ores
1400	14, 10.3	Other mining and quarrying
1510	15.1	Production, processing and preserving of meat and meat products
1520	15.2	Processing and preserving of fish and fish products
1530	15.3	Processing and preserving of fruit and vegetables
1540	15.4	Manufacture of vegetable and animal oils and fats
1550	15.5	Manufacture of dairy products
1560	15.6	Manufacture of grain mill products, starches and starch products
1570	15.7	Manufacture of prepared animal feeds
1580	15.8	Manufacture of other food products
1590	15.9	Manufacture of beverages
1600	16	Manufacture of tobacco products
1700	17	Manufacture of textiles and textile products

Sector number	SIC code	Sector name
Mining/manufacturing (cont.)		
1810	18.1	Manufacture of leather clothes
1820	18.2	Manufacture of other wearing apparel and accessories
1830	18.3	Dressing and dyeing of fur, manufacture of articles of fur
1910	19.1-2	Tanning and dressing of leather, manufacture of luggage, handbags, saddlery and harness
1930	19.3	Manufacture of footwear
2010	20.1	Sawmilling and planing of wood, impregnation of wood
2020	20.2	Manufacture of particle board, fibre board and other panels and boards
2030	20.3	Manufacture of builders' carpentry and joinery
2040	20.4-5	Manufacture of other products of wood
2110	21.11	Manufacture of pulp
2120	21.12	Manufacture of paper and paperboard
2130	21.2	Manufacture of articles of paper and paperboard
2210	22.1	Publishing
2220	22.2	Printing and service activities related to printing
2230	22.3	Reproduction of recorded media
2310	23.1	Manufacture of coke oven products
2322	23.2 part	Manufacture of asphalt
2411	24.11	Manufacture of industrial gases
2412	24.12-13	Manufacture of dyes and pigments and other inorganic basic chemicals
2415	24.15, 24.2	Manufacture of fertilisers, nitrogen compounds and pesticides
2416	24.14, 24.16-17	Manufacture of plastics and synthetic rubber in primary forms, manufacture of other organic basic chemicals
2430	24.3	Manufacture of paints and varnishes, printing ink and mastics
2440	24.4	Manufacture of basic pharmaceutical products and pharmaceutical preparations
2450	24.5	Manufacture of soap and detergents and toilet preparations
2460	24.6	Manufacture of other chemical products
2470	24.7	Manufacture of man-made fibres
2500	25	Manufacture of rubber and plastic products
2610	26.1	Manufacture of glass and glass products
2620	26.2-3	Manufacture of ceramic goods
2640	26.4,6-8	Manufacture of other mineral products
2650	26.5	Manufacture of cement, lime and plaster
2710	27.1-3 except 27.35	Manufacture of basic iron and steel
2720	27.35	Manufacture of ferro-alloys
2730	27.42	Aluminium production
2740	27.4 except 27.42	Other non-ferrous metal production
2750	27.5	Casting of metals
2810	28.1-5	Manufacture of fabricated metal products, except machinery and equipment
2860	28.6	Manufacture of cutlery, tools and general hardware
2870	28.7	Manufacture of other metal products
2910	29.1-2	Manufacture of general purpose machinery
2930	29.3-5	Manufacture of special purpose machinery
2960	29.6	Manufacture of weapons and ammunition
2970	29.7	Manufacture of domestic appliances
3000	30	Manufacture of office machinery and computers
3110	31.1-2	Manufacture of electric motors, generators and transformers, manufacture of electricity distribution and control apparatus
3130	31.3	Manufacture of insulated wire and cable
3140	31.4-6	Manufacture of other electrical apparatus and equipment
3210	32.1-2	Manufacture of electronic components and television and radio transmitters
3230	32.3	Manufacture of television and radio receivers, sound or video recording apparatus
3310	33.1-3	Manufacture of medical and precision instruments
3340	33.4-5	Manufacture of optical instruments, photographic equipment, watches and clocks
3400	34	Manufacture of motor vehicles and parts and accessories for motor vehicles
3510	35.1 except 35.114	Building and repair of ships and boats
3520	35.114	Building and repair of oil platforms

Sector number	SIC code	Sector name
Mining/manufacturing (cont.)		
3530	35.2	Manufacture and repair of railway and tramway locomotives and rolling stock
3540	35.3	Manufacture and repair of aircraft and spacecraft
3550	35.4-5	Manufacture of other transport equipment
3610	36.1	Manufacture of furniture
3620	36.2	Manufacture of jewellery and related articles
3630	36.3-6	Other manufacturing
3710	37.1	Recycling of metal waste and scrap
3720	37.2	Recycling of non-metal waste and scrap
Water supply		
4100	41	Collection, purification and distribution of water
Construction		
4500	45	Construction
Wholesale and retail trade/hotels and restaurants		
5000	50-52	Wholesale and retail trade, repair of motor vehicles and personal and household goods
5500	55	Hotels and restaurants
Transport etc.		
6010	60.1	Transport via railways
6020	60.21	Tramway and suburban transport, other scheduled passenger land transport
6030	60.22	Taxi operation
6040	60.23-24	Other land passenger transport, freight transport by road
6080	60.3	Transport via pipelines
6110	61.101	Ocean transport
6130	61.103-109, 61.2	Inland and coastal water transport
6202	62 part	Domestic air transport
6203	62 part	International air transport
6300	63	Supporting and auxiliary transport activities
6400	64	Post, telecommunications
Financing, insurance, real estate and business services		
6500	65-67	Financial intermediation, insurance
7000	70	Real estate activities
7100	71	Renting of machinery and equipment
7200	72	Computer and related activities
7300	73	Research and development
7400	74	Other business activities
8000	80	Education
8500	85	Health and social work
9000	90	Sewage and refuse disposal, sanitation and similar activities
9100	91	Activities of membership organisations
9200	92	Recreational, cultural and sporting activities
9300	93	Other service activities
9500	95	Private households with employed persons
Central government		
246300	63	Supporting and auxiliary transport activities
7300	73	Research and development
7400	74	Other business activities
7510	75.1, 75.21, 23, 24, 75.3	Public administration
7520	75.22	Defence
8000	80	Education
8500	85	Health and social work
9200	92	Other service activities

Sector number	SIC code	Sector name
Local government		
257510	75.1, 75.25	Public administration
8000	80	Education
8500	85	Health and social work
9000	90	Sewage and refuse disposal, sanitation and similar activities
9200	92, 93.03	Other service activities
Private households		
330000	n.a.	Private household
Foreign activities in Norway		
660000	n.a.	Foreign activities in Norway

Appendix G

Source classifications used in the Norwegian emission inventory

Table G1. Source classifications used in the national emission inventory

Stationary combustion		
Oil and gas extraction		
	Natural gas	
	Flaring	
	Diesel combustion	
	Gas terminals	
Manufacturing and mining		
	Refining	
	Manufacture of pulp and paper	
	Manufacture of mineral products	
	Manufacture of chemicals	
	Manufacture of metals	
	Other manufacturing	
Other industries		
Dwellings		
Incineration of waste and landfill gas		
Process emissions		
Oil and gas extraction		
	Venting, leaks, etc.	
	Oil loading at sea	
	Oil loading, on shore	
	Gas terminals	
Manufacturing and mining		
	Refining	
	Manufacture of pulp and paper	
	Manufacture of chemicals	
	Manufacture of mineral products	
	Manufacture of metals	
		Iron, steel and ferroalloys
		Aluminium
		Other metals
	Other manufacturing	
Petrol distribution		
Agriculture		
Landfill gas		
Solvents		
Road dust		
Other process emissions		
Mobile combustion		
Road traffic		
	Petrol engines	
		Passenger cars
		Other light vehicles
		Heavy vehicles
	Diesel engines	
		Passenger cars
		Other light vehicles
		Heavy vehicles
	Motorcycles, mopeds	
		Motorcycles
		Mopeds
Snow scooters		
Small boats		
Motorized equipment		
Railways		
Air traffic		
	Domestic < 1000 m	
	Domestic > 1000 m	
Shipping		
	Coastal traffic, etc.	
	Fishing vessels	
	Mobile oil rigs, etc.	

Table G2. UNFCCC/CRF and EMEP/NFR source sector categories

CRF		**NFR**	
1A1a	Public Electricity and Heat Production	1A1a	Public Electricity and Heat Production
1A1b	Petroleum Refining	1A1b	Petroleum refining
1A1c	Manufacture of Solid Fuels and Other Energy	1A1c	Manufacture of Solid Fuels and Other

			Energy Industries
1A2a	Iron and Steel	1A2a	Iron and Steel
1A2b	Non-Ferrous Metals	1A2b	Non-ferrous Metals
1A2c	Chemicals	1A2c	Chemicals
1A2d	Pulp, Paper and Print	1A2d	Pulp, Paper and Print
1A2e	Food Processing, Beverages and Tobacco	1A2e	Food Processing, Beverages and Tobacco
1A2f	Other (oil drilling, construction, all other manufacturing industries)	1A2f	Other
1A3a	Civil Aviation		
		1A3aii(i)	Civil Aviation (Domestic, LTO)
		1A3aii(ii)	Civil Aviation (Domestic, Cruise)
1A3b	Road Transportation		
		1A3bi	R.T., Passenger cars
		1A3bii	R.T., Light duty vehicles
		1A3biii	R.T., Heavy duty vehicles
		1A3biv	R.T., Mopeds & Motorcycles
		1A3bvi	R.T., Automobile tyre and brake wear
		1A3bvii	R.T., Automobile road abrasion
1A3c	Railways	1A3c	Railways
1A3d	Navigation	1A3dii	National Navigation
1A3e	Other (snow scooters, boats, motorized equipment)		
		1A3ei	Pipeline compressors
		1A3eii	Other mobile sources and machinery
1A4a	Commercial/Institutional	1A4a	Commercial / Institutional
1A4b	Residential		
		1A4bi	Residential plants
		1A4bii	Household and gardening (mobile)
1A4c	Agriculture/Forestry/Fishing		
		1A4ci	Stationary
		1A4cii	Off-road Vehicles and Other Machinery
		1A4ciii	National Fishing
1A5a	Military - Stationary	1A5a	Other, Stationary (including Military)
1A5b	Military - Mobile	1A5b	Other, Mobile (Including military)
1B1a	Coal Mining	1B1a	Coal Mining and Handling
1B1b	Solid Fuel Transformation	1B1b	Solid fuel transformation
1B2aiii	Transport	1B2ai	Exploration Production, Transport
1B2aiv	Refining/storage	1B2aiv	Refining / Storage
1B2av	Distribution of oil products	1B2av	Distribution of oil products
1B2b	Natural Gas	1B2b	Natural gas
		1B2c	Venting and flaring
1B2c1iii	Venting combined		
1B2c2i	Flaring oil		
1B2c2ii	Flaring gas		
2A1	Cement Production	2A1	Cement Production
2A2	Lime Production	2A2	Lime Production
2A3	Limestone and Dolomite Use	2A3	Limestone and Dolomite Use
		2A7	Other including Non Fuel Mining & Construction
2A7.1	Leca		
2A7.2	Rock wool		
2A7.41	Ore		
2B1	Ammonia Production	2B1	Ammonia Production
2B2	Nitric Acid Production	2B2	Nitric Acid Production
		2B4	Carbide Production
2B4.1	Silicon carbide		
2B4.2	Calcium carbide		
		2B5	Other
2B5.1	Methanol		
2B5.2	Titanium dioxide		
2B5.3	Sulphuric acid		
2B5.4	Plastic		
2B5.5	Explosives		
		2C	Metal Production
2C1	Iron and Steel Production		
2C2	Ferroalloys Production		
2C3	Aluminium Production		
2C5.11	Magnesium		
2C5.12	Nickel		
2C5.13	Zinc		
2C5.2	Anodes		
2D1	Pulp and Paper	2D1	Pulp and Paper
2D2	Food and Drink	2D2	Food and Drink
2G	Other (mines)		
3A	Paint Application	3A	Paint Application
3B	Degreasing and Dry Cleaning	3B	Degreasing and Dry Cleaning
3C	Chemical Products, Manufacture and Processing	3C	Chemical Products, Manufacture and Processing
3D	Other	3D	Other, including products containing HMs and POPs

4A1.1	Dairy cattle		
4A1.2	Non-dairy cattle		
4A3	Sheep		
4A4	Goats		
4A6	Horses		
4A8	Swine		
4A9	Poultry		
4A10.1	Ostrich		
4A10.2	Deer		
4A10.3	Reindeer		
4A10.4	Fur-bearing animals		
		4B	Manure management
4B1.1	Dairy cattle	4B1a	Dairy cattle
4B1.2	Non-dairy cattle	4B1b	Non-dairy cattle
4B3	Sheep	4B3	Sheep
4B4	Goats	4B4	Goats
4B6	Horses	4B6	Horses
4B8	Swine	4B8	Swine
4B9	Poultry	4B9	Poultry
4B10	Anaerobic		
4B11	Liquid Systems		
4B12	Solid Storage and Dry Lot		
4B13	Other	4B13	Other
4D1	Direct soil emissions	4D1	Direct soil emissions
4D2	Animal production		
4D3	Indirect emissions		
		4F	Field burning of agricultural wastes
4F1	Cereals		
4G	Other	4G	Other
5A	Changes in forest and woody biomass		
5D	CO_2 emissions and removals from soil		
5E	Other		
6A	Solid Waste Disposal on Land	6A	Solid Waste Disposal on Land
6B	Wastewater Handling	6B	Wastewater Handling
6C	Waste Incineration	6C	Waste Incineration
6D	Other	6D	Other Waste

Tidligere utgitt på emneområdet

Previously issued on the subject

Norges offisielle statistikk (NOS)

D312 Emissions to Air 1973-2003.

Notater

92/17 Modell for beregning av nasjonale utslipp til luft (Model for calculating national emissions to air).

2000/54 Flugsrud, K. and G. Haakonsen: Utslipp av klimagasser i norske kommuner. En gjennomgang av datakvaliteten i utslippsregnskapet (Greenhouse gas emissions in Norwegian municipalities. A review of data quality in the emission inventory).

2001/77 Haakonsen, G.: Beregninger av utslipp til luft av klimagasser. En gjennomgang av arbeidsprosess og dokumentasjon (Calculations of emissions to air of greenhouse gases. A review of the working process and documentation).

Rapporter (RAPP)

98/22 Utslipp til luft fra utenlandske skip i norske farvann 1996 og 1997 (Emissions to air from foreign shipping in Norwegian waters, 1996 and 1997).

2000/1 Flugsrud, K., E. Gjerald, G. Haakonsen, S. Holtskog, H. Høie, K. Rypdal, B. Tornsjø and F. Weidemann: The Norwegian Emission Inventory. Documentation of methodology and data for estimating emissions of greenhouse gases and long-range transboundary air pollutants.

2000/13 Rypdal, K. and L.-C. Zhang: Uncertainties in the Norwegian Greenhouse Gas Emission Inventory.

2001/6 Tornsjø, B.: Utslipp til luft fra innenriks sjøfart, fiske og annen sjøtrafikk mellom norske havner (Emissions to air from domestic shipping, fishing vessels and other sea traffic between Norwegian ports).

2001/16 Holtskog, S.: Direkte energibruk og utslipp til luft fra transport i Norge 1994 og 1998 (Direct energy use and emissions to air from transport in Norway 1994 and 1998).

2001/17 Finstad, A., G. Haakonsen, E. Kvingedal and K. Rypdal: Utslipp til luft av noen miljøgifter i Norge. Dokumentasjon av metode og resultater (Emissions of some hazardous chemcals to air in Norway. Documentation of a method and results).

2001/36 Haakonsen and E. Kvingedal: Utslipp til luft fra vedfyring i Norge. Utslippsfaktorer, ildstedsbestand og fyringsvaner (Emissions to air from fuelwood use in Norway. Emission factors, numbers of wood-burning stoves and open fireplaces, and heating habits).

2001/37 Rypdal, K. and Li-Chun Zhang: Uncertainties in Emissions of Long-Range Air Pollutants.

2002/7 Finstad, A., G. Haakonsen and K. Rypdal: Utslipp til luft av dioksiner i Norge – Dokumentasjon av metode og resultater (Emissions of dioxins to air in Norway – Documentation of methods and results).

2002/8 Finstad, A. K. Flugsrud and K. Rypdal: Utslipp til luft fra norsk luftfart (Emissions to air from Norwegian air traffic).

2003/7 Finstad, A. and K. Rypdal: Utslipp til luft av kobber, krom og arsen i Norge. Dokumentasjon av metode og resultater (Emissions to air of copper, chromium and arsenic in Norway. Documentation of a method and results).

2003/15 Finstad, A., G. Haakonsen and K. Rypdal: Utslipp til luft av partikler i Norge. Dokumentasjon av metode og resultater (Emissions to air of particles in Norway. Documentation of a method and results).

2004/5 Finstad, A., K. Flugsrud, G. Haakonsen and K. Aasestad: Vedforbruk, fyringsvaner og svevestøv. Resultater fra Folke- og boligtellingen 2001, Levekårsundersøkelsen 2002 og Undersøkelse om vedforbruk og fyringsvaner i Oslo 2002. .(Fuelwood consumption, heating habits and particulate matter. Results of the Population and Housing Census 2001, Survey of Living Conditions 2002 and the 2002 survey of fuelwood consumption and heating habits in Oslo).

2004/27 Flugsrud, K., G. Haakonsen and K. Aasestad: Vedforbruk, fyringsvaner og svevestøv. Undersøkelse om vedforbruk og fyringsvaner i Trondheim og Bergen 2003 (Fuelwood consumption, heating habits and particulate matter. Survey of fuelwood consumption and heating habits in Trondheim and Bergen 2003).

Documents

2001/14 Rypdal, K.: CO2 Emission Estimates for Norway. Methodological Difficulties.

2005/09 Hass, J. L., K. Ø. Sørensen, K. Erlandsen and T. Smith: Norwegian Economic and Environment Accounts (NOREEA). Project Report 2002.

Statistical Analyses (SA)

65 Naturressurser og miljø 2004 (Natural Resources and the Environment 2004, Norwegian edition).

70 Natural Resources and the Environment 2004. Norway.

De sist utgitte publikasjonene i serien Rapporter

Recent publications in the series Reports

2005/3 E. Eng Eibak: Konsumprisindeks for Svalbard 2004. 2005 37s. 155 kr inkl. mva. ISBN 82-537-6722-6

2005/4 B. Olsen: Flyktninger og arbeidsmarkedet 4. kvartal 2003. 2005. 30s. 155 kr inkl. mva. ISBN 82-537-6724-2

2005/5 T.P. Bø. Ulike arbeidskontrakter og arbeidstidsordninger. Rapport fra tileggsundersøkelse til Arbeidskraftundersøkelse (AKU). 2. kvartal 2004. 2005. 33s. 155 kr inkl. mva. ISBN 82-537-6735-8

2005/6 G. Berge, T. Kirkemo, R. Straumann og J.K. Undelstvedt: Ressursinnsats, utslipp og rensing i den kommunale avløpssektoren 2003. 2005. 82s. 180 kr inkl. mva. ISBN 82-537-6737-4

2005/7 E. Ugreniov: Levekår blant alenemødre. 2005. 37s. 155 kr inkl. mva. ISBN 82-537-6745-5

2005/8 B. Halvorsen, B.M. Larsen og R. Nesbakken: pris- og inntektsfølsomhet i ulike husholdningers etterspørsel etter elektrisitet, fyringsoljer og ved. 2005. 38s. 155 kr inkl. mva. ISBN 82-537-6752-8

2005/9 T. Skardhamar: Lovbruddskarrierer og levekår. En analyse av fødselskullet 1977. 2005. 47s. 155 kr inkl. mva. ISBN 82-537-6760-9

2005/10 R.H. Kitterød: Hun jobber, de jobber. Arbeidstid blant par av småbarnsforeldre. 2005. 60s. 180 kr inkl.mva. ISBN 82-537-6775-7

2005/11 M. Mogstad: Fattigdom i Stor-Osloregionen. 2005. 47s. 155 kr inkl. mva. ISBN 82-537-6777-3

2005/12 Å. Cappelen, F. Foyn, T. Hægeland, K.A. Kjesbu, J. Møen, G. Petterson og A. Raknerud: Årsrapport for skastteFUNN-evalueringen - 2004. 2005. 40s. 155 kr inkl. mva. ISBN 82-537-6780-3

2005/13 M. Greaker, P. Løkkevik og M. Aasgaard Walle: Utviklingen i den norske nasjonalformuen fra 1985- til 2004. Et eksempel på bærekraftig utvikling? 2005 44s. 155 kr inkl.mva. ISBN 82-537-6789-7

2005/14 D. Ellingsen og V. Sky: Virksomheter som ofre for økonomisk kriminalitet. 2005. 33s. 155 kr inkl. mva. ISBN 82-537-6805-2

2005/15 O.F. Vaage: Tid til arbeid. Arbeidstid blant ulike grupper og i ulike tidsperioder, belyst gjennom tidsbruksundersøkelsene 1971-2000. 2005. 33s. 155 kr inkl. mva. ISBN 82-537-6807-9

2005/16 J. Epland: Veier inn i og ut av fattigdom: Inntektsmobilitet blant lavinntektshushold. 2005. 36s. 155 kr inkl. mva. ISBN 82-537-6812-5

2005/17 A. Thomassen: Byggekostnadsindeks for veganlegg. Kostnadsundersøkelsen. Vekter og representantvarer 2004. 2005. 45s. 155 kr inkl. mva. ISBN 82-537-6813-3

2005/18 B.M. Larsen og R. Nesbakken: Formålsfordeling av husholdningenes elektrisitetsforbruk i 2001. Sammenligning av formålsfordelingen i 1990 og 2001. 41s. 155 kr inkl. mva. ISBN 82-537-6816-8

2005/19 B.Olsen og M. Thi Van: Funksjonshemmede på arbeidsmarkedet. Rapport fra tilleggsundersøkelse til Arbeidskraftsundersøkelsen (AKU) 4. kvartal 2004. 2005. 71s. 180 kt inkl. mva. ISBN 82-537-6818-4

2005/20 F.R. Aune, T. Bye og P. V Hansen: Et felles norsk-svensk elsertifikatmarked. 2005. 36s. 155 kr inkl. mva. ISBN 82-537-6828-1

2005/21 J. Lyngstad, R. Kjeldstad og E. Nymoen: Foreldreøkonomi etter brudd. Omsorgsforeldres og samværsforeldres økonomiske situasjon 2002. 2005. 164s. 260 kr inkl.mva. ISBN 82-537-6834-6

2005/22 R.H. Kitterød: Når mor og far bor hver for seg. Ansvar og omsorg for barna før og etter bidragsreformen. 2005. 104s. 210 kr inkl. mva. ISBN 82-537-6836-2

2005/23 M. Rønsen: Kontantstøttens langsiktige effekter på mødres og fedres arbeidstilbud. 2005. 39s. 155 kr inkl. mva. ISBN 82-537-6838-9