Greenhouse Gas Emissions in Norway 1990-2001

Reporting according to the UNFCCC guidelines

TA-1976/2003
ISBN 82-7655-219-6

Preface

The United Nations Framework Convention on Climate Change (UNFCCC), adopted in 1992 and entered into force in 1994, requires Parties to report emissions from sources and removals by sinks of greenhouse gases on an annual basis.

In compliance with the above requirement, Norway has prepared the present National Inventory Report (NIR) for the year 2003. The report has been prepared to be in accordance with the UNFCCC Reporting Guidelines on Annual Inventories adopted in November 1999 by decision 3/CP.5. However, it has been additionally adjusted to accommodate as far as possible the new Guidelines adopted in November 2002 by decision 18/CP.8 first to be valid in 2004. The methodology used in the calculation of emissions is in accordance with the revised IPCC 1996 Guidelines for emission inventories as elaborated by the IPCC Good Practice Guidance and approved by the UNFCCC. The responsibility for reporting on the national inventory system lies with the Norwegian Pollution Control Authority (SFT), a directorate under the Norwegian Ministry of Environment. Statistics Norway (SN) has been the principle contributor to the preparation of the report.

SFT, Oslo, April 2003

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National Inventory Report

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Executive Summary

Background

The 1992 United Nations Framework Convention on Climate Change (UNFCCC) requires that Parties report annually on their greenhouse emissions by sources and removals by sinks. In response to this requirement for 2003, Norway has prepared the present emission National Inventory Report (NIR).

This report presents the national inventory of greenhouse gas (GHG) emissions and removals from 1990 to 2001. The components covered are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), tetrafluoromethane (CF_4), hexafluoroethane (C_2F_6), octafluoropropane (C_3F_8)sulphur hexafluoride (SF_6) and HFCs (i.e. HFC-134a, HFC-125, HFC-143a, HFC-23, HFC-32, HFC-152a and HFC227ea).

The report and the associated Common Reporting Format (CRF) tables are prepared to be in accordance with the UNFCCC Reporting Guidelines on Annual Inventories. The methodology used in the calculation of emissions are harmonised with the Guidelines for National Greenhouse Gas Inventories and those of the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories published by the Intergovernmental Panel on Climate Change (IPCC). According to these guidelines country specific methods have been used where appropriate and where they give more accurate emission data. The methodology is described in detail in the report SN/SFT 2000 ("The Norwegian Emission Inventory"). However, since 2002 both elements of the inventory and the efficiency of the processes involved have been improved substantially. These aspects are discussed to a certain extent here. A full description of the improved inventory system will be documented in a comprehensive report to be submitted to the UNFCCC in the 2004 round of reporting.

CRF tables are submitted for the years 1990 and 1998-2001. For the years 1991 to 1997 emission figures do exist but are available in another electronic format than that required by the UNFCCC. Norway plans to submit a complete set of CRF tables for all years in the next round of reporting.

With regard to the Land Use Change and Forestry sector (LUCF), the IPCC is currently preparing a "Good Practice Guidance" report due later this year. We are aware of the fact that the current reporting of this sector has some limitations, but it will be improved when the IPCC report is finalised. The next NIR will most likely contain updated LUCF figures calculated with the new methodology.

Summary of national emission and removal related trends

In 2001, the **total emissions of greenhouse gases**, measured as CO_2–equivalents, were about 56.2 million tonnes. From 1990 to 2001 the emissions increased by 8 per cent. Table 1 below shows the overall trend in the total emissions by gas during the period 1990-2001, and preliminary emission figures for 2002. We see from the table that the emissions dropped slightly from 1990 to 1992, but then increased quite steadily until 1999, apart from a small interruption in 1995. The downward trend in the early 1990s was primarily due to decreased consumption of gasoline and fuel oils as well as reduced production of metals. The low

economic activity during that time and the CO_2 tax, which was implemented with effect from 1991, contributed to this development. The growth in total emissions since 1992 can mainly be explained by general economic growth over the period, which has resulted in increased CO_2 emissions, in particular in the oil and gas extraction sector and the transport sector. This trend has to some degree been counteracted by decreased emissions of PFCs and SF6 from aluminium and magnesium plants. From 1999 to 2000 the emissions decreased a little, primarily because the winter season in 2000 was quite mild, with resulting reduced consumption of fuel for heating. Furthermore, a tax on petrol was introduced in 2000, and this led to a temporary reduction in fuel stock-in-trade that year. From 2000 to 2001 the total emissions rose again, by 1.6 per cent, and they are now back at the same level as in 1999.

Table 1. Emissions and removals of greenhouse gases for the years 1990-2001 and preliminary figures for 2002. Mill tonnes CO_2–equivalents. Source: SN/SFT

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002***	**1990-2001**
CO_2	34.9	33.2	34.0	35.7	37.4	37.5	40.7	40.9	41.1	41.6	41.1	41.6	40.3	19 %
CH_4	6.4	6.5	6.6	6.7	6.8	6.9	7.0	7.0	6.9	6.9	7.0	7.0	6.9	9 %
N_2O	5.5	5.3	4.7	5.0	5.1	5.2	5.2	5.1	5.4	5.7	5.5	5.6	5.9	1 %
PFC	3.0	2.5	2.0	2.0	1.7	1.6	1.4	1.4	1.3	1.1	0.9	1.0	1.1	-66 %
SF_6	2.2	2.1	0.7	0.7	0.9	0.6	0.6	0.5	0.7	0.8	0.9	0.8	0.3	-65 %
HFC	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.4	
Total - without LUCF	**52.0**	**49.7**	**48.0**	**50.2**	**51.9**	**51.8**	**54.9**	**55.1**	**55.5**	**56.2**	**55.7**	**56.2**	**54.8**	**8 %**
LUCF	-9.8	-11.9	-13.4	-13.7	-15.8	-15.7	-17.6	-16.5	-17.6	-17.8	-18.7	-19.0	-	99 %

* Preliminary figures

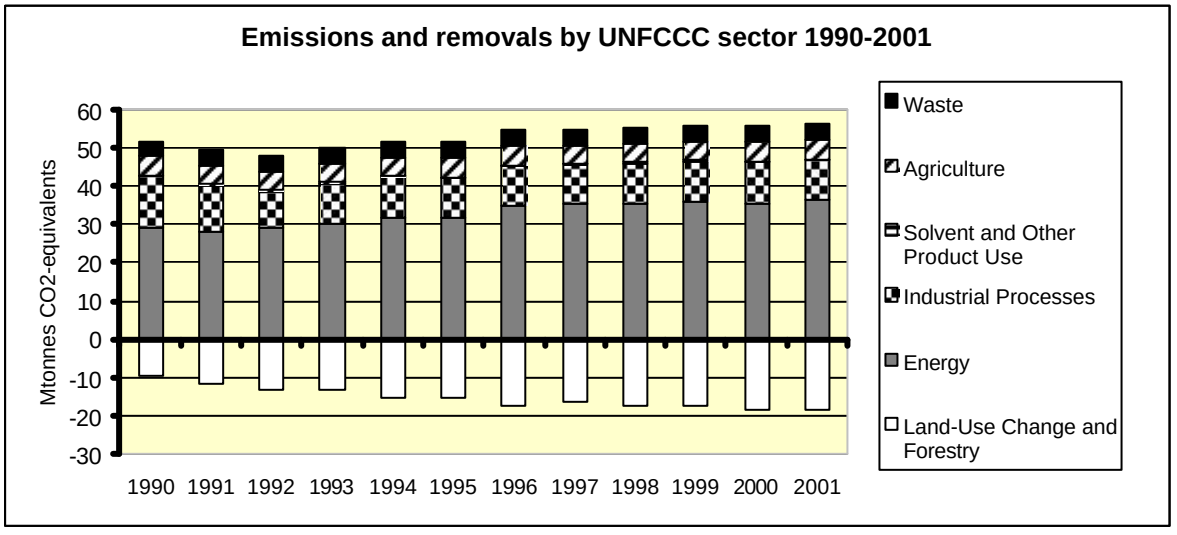


Figure 1. Emissions and removals of greenhouse gases by UNFCCC sector in Norway during the period 1990-2001. Source: SN/SFT

Preliminary calculations of the GHG emissions in 2002 indicate a decrease of 2.5 per cent since 2001. This downward trend is primarily a result of close-downs and reductions in the ferroalloy- and magnesium industry, reduced flaring in the oil and gas extraction sector and

reduced domestic navigation. The reduction outweighs increased emissions from road traffic and from the production of fertiliser as well as from aluminium production and from the consumption of HFCs.

The **emissions of CO_2** were 41.6 million tonnes in 2001. This is approximately 1 per cent higher than in 2000 and 19 per cent above the emission level in 1990. The emissions of CO_2 in Norway originate primarily from industrial sources related to oil and gas extraction and the production of metals as well as the transport sector. The generation of electricity is almost exclusively hydroelectric, thus the energy related emissions are dominated by industrial sources. The increase from 1990 to 2001 is a result of rising emissions in most of the major sources. However, the main reason is the growth in oil- and gas production, including transport of natural gas in pipelines, and higher emissions from the transport sector. This is a consequence of general economic growth over the period. CO_2 accounted for 74 per cent of the total GHG emissions in Norway in 2001. Emissions related to production of electricity in the oil and gas extraction sector increased by 56 per cent from 1990 to 2001. Both emissions from road vehicles and from domestic shipping were increased by 19 per cent during this period. The overall emissions from industrial processes have increased by 12 per cent from 1990 to 2001. Within this sector, the emissions from chemical production increased by as much as 60 per cent due to the launch of a new methanol plant in 1997, while emissions from metal production increased by 20 per cent.

The **emissions of CH_4** amounted to 332 ktonnes in 2001. Waste treatment and agriculture are the main sources of methane in Norway, contributing 89 per cent to the total CH_4 emissions. Other sources are combustion and evaporation/leakage in the oil and gas industry, which accounted for 11 per cent of the national total in 2001. The total methane emissions had a slow increase of 9 percent over the period 1990-2001. This is due to small increases in the amounts emitted from both the oil- and gas industry and from landfills. The emissions from the agricultural sector are dominated by releases from enteric fermentation. The overall emissions from this sector have decreased by 1 per cent over the period 1990-2001. CH_4 contributed 12 per cent to the total Norwegian GHG emissions in 2001.

In 2001, the anthropogenic **emissions of N_2O** were estimated to be 18 ktonnes. Agriculture and chemical industry (production of fertiliser) are the two main sources, contributing with respectively 51 and 30 per cent to the total N_2O emissions in 2001. Another source which is becoming more and more important is transport, because of increased use of catalytic converters in mobile sources. In 2001 these emissions accounted for 12 per cent of the total N_2O emissions. From 1990 to 2001 the overall emissions increased by only 1 per cent. The emissions trend is mainly influenced by variations in activity in the fertiliser industry. These emissions decreased in the beginning of the 1990s due to changes in the production process, while there was a moderate increase in the following years due to increased production volumes. The steadily rising emissions from road traffic are also contributing to the emission trend. Emissions from agriculture have been rather stable over the period. The overall contribution of N_2O to the total GHG emissions was 10 per cent in 2001.

The **emissions of PFCs** (CF_4 and C_2F_6) from the Norwegian aluminium plants were calculated to be approximately 1 million tonnes CO_2 equivalents in 2001. The emissions have followed a steady downward trend since 1990, with an overall reduction of 67 per cent during the period. This is due to improved technology and process control, which has led to a reduction in the amount of PFC emitted per tonne aluminium from 3.49 to 0.99 tonnes CO_2 equivalent. PFCs may be used as substitutes for ozone depleting substances (ODS). Only one

compound, C_3F_8 (PFC-218), is used for this purpose in Norway. The actual emissions of C_3F_8 amounted to 0.4 ktonnes of CO_2 equivalents in 2001. PFCs contributed less than 2 per cent to the national total GHG emissions in 2001.

The **emissions of SF_6** were estimated at approximately 0.8 million tonnes CO_2 equivalents in 2001. The main source of SF_6 emissions in Norway is magnesium production, where the gas is used to cover the surface of liquid magnesium to prevent it from oxidising, and released to air after use. This source accounted for 83 per cent of the total SF_6 emissions in 2001. SF_6 used in electrical equipment is the second most important source contributing 9 per cent to the total emissions. In the period 1990-1997, the overall emissions were reduced by 75 per cent as a result of reduced production levels for magnesium in addition to improved production routines. From 1997 to 2000 emissions increased by 40 per cent, due to increased production. Since 2000 the emissions decreased again, by 14 per cent, mainly due to reduced production. During the whole period 1990-2001, the emissions decreased by 65 per cent. In 2001, the contribution of SF_6 to the total GHG emissions was 1.4 per cent.

The actual **emissions of HFCs** in Norway were about 0.29 million tonnes CO_2-equivalents in 2001, and they increased by 26 per cent from 2000. The emissions in 1990 were insignificant. The application category refrigeration and air conditioning contributed by far the largest fraction to the HFC emission total. The emissions from the other categories foam and foam blowing, fire extinguishing equipment, solvents and aerosol propellants were only minor in comparison. As the phasing out of CFCs, HCFCs and halons continues, a further strong growth in the consumption of HFCs is expected in the years to come. The contribution of HFCs to the total emissions figure was less than 1 %.

Overview of source and sink category emission estimates and trends

The **Energy sector** accounts for about 2/3 of the total Norwegian greenhouse gas emissions. Road traffic and offshore gas turbines (electricity generation and pumping of natural gas) are the largest single contributors, while coastal navigation and energy commodities used for the production of raw materials are other major sources. During most of the 1990s and until 2001, energy related emissions have been increasing, mainly due to higher activity in the offshore- and transport sector. From 1990 to 2001 the increase in emissions from the energy sector was 24 per cent.

The second most important sector with regard to the size of emissions of greenhouse gases in Norway is **industrial processes**. This sector accounts for 20 per cent of the total national emissions of greenhouse gases. Production of raw materials is the main source of process-related industrial emissions of both CO_2 and other greenhouse gases such as N_2O (fertiliser production), SF_6 (magnesium foundries) and PFCs (aluminium production). From 1992 onwards these emissions have been relatively stable, with the downward trend of PFCs emissions being counterbalanced by rising emissions of CO_2.

Agriculture is a sector contributing 9 per cent to the total emissions of greenhouse gases. Unlike other sectors, it has experienced a reduction over the period 1990-2001, which amounted to 4 per cent. Agricultural practices mainly result in emissions of methane and nitrous oxide, as well as indirect emissions of CO_2. The largest sources in this sector are N_2O from soil processes and CH_4 from enteric fermentation.

The sector **solvent and other product use** accounts for only 0.2 per cent of the total emissions of greenhouse gases in the country. This contribution has been more or less unchanged since 1990.

In 2001, CO_2 emissions from **international marine and aviation bunkers** amounted to 3.6 million tonnes. These emissions are not included in the national totals, but reported separately as required. From 1990 to 2001, the CO_2 emissions from ships in international traffic increased by as much as 83 per cent, while CO_2 emissions related to international aviation increased by 47 per cent over the same period. The reason for this increase is simply a growth in traffic. Aircraft are more fuel efficient now than they were earlier in the period, which means that the growth in international air traffic has been even higher than what is indicated by the growth in emissions.

In the sector **land-use change and forestry**, the gross increment of carbon in Norwegian forests was estimated at 35.4 million tonnes of CO_2 in 2001. A total of 16.4 million tonnes CO_2 was emitted due to harvesting or depletion, which resulted in a net removal of 19 million tonnes CO_2. The sequestration of CO_2 in forest soil and harvested wood products is not included in this figure. The net sink increased by 0.7 million tonnes from 2000 to 2001. The net removal of CO_2 in 2001 may be compared with the total emissions of greenhouse gases. As much as about 37 per cent of the emissions are offset by CO_2 uptake due to forest regrowth. This considerable accumulation is due to a large increment in the standing volume of forests.

Precursors and SO_2

Nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOC) and carbon monoxide (CO) are not greenhouse gases, but they have an indirect effect on the climate through their influence on greenhouse gases; ozone in particular. Sulphur dioxide (SO_2) has also an indirect impact on climate, as it increases the level of aerosols with a subsequent cooling effect. Therefore, emissions of these gases are also included in the inventory.

NO_x emissions decreased by about 1 per cent from 1990 to 2001, primarily because of stricter emission regulations with regard to road traffic, which counteracted increased emissions from oil and gas production and from navigation. The emissions of NMVOC experienced an increase of 28 per cent in the same period, mainly because of the rise in oil production. Emissions of CO have decreased by 37 per cent over the period 1990-2001. This can primarily be explained by new emissions standards for motor vehicles. With regard to emissions of SO_2, they were reduced by 52 per cent from 1990 to 2001. This can mainly be explained by a reduction in sulphur content of all oil products and lower process emissions from ferroalloy and aluminium production and refineries.

Chapter 1. Introduction

1.1 Background

The 1992 United Nations Framework Convention on Climate Change (UNFCCC) was ratified by Norway on 9 July 1993 and entered into force on 21 March 1994. One major commitment under the Convention is that Parties are required to report on their national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, using methodologies agreed upon by the Conference of the Parties to the Convention (COP).

The greenhouse gases in question are: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Sulphur hexafluoride (SF_6). The agreed methodologies for emission reporting are those described in the documents on reporting guidelines on annual inventories, which are published and updated periodically by the UNFCCC secretariat.

With the adoption of the Kyoto Protocol in 1997, Norway is faced with the requirement to restrict the increase of its collective greenhouse gas emissions to not more than 1 per cent from the 1990 level by the commitment period 2008-2012. Norway ratified the Kyoto Protocol on 30 May 2002.

In compliance with its reporting requirements, Norway has submitted to the UNFCCC national emission inventory reports on an annual basis since 1993. Furthermore, since the introduction of annual technical reviews of the national inventories by independent expects experts in 2000, Norway has undergone two desk reviews, in 2000 and 2001 respectively, and one in-depth country review held in Oslo in October 2002.

The present report together with the associated CRF tables is Norway's contribution to the 2003 round of reporting under the Convention and covers emissions in the period 1990-2001. It has been prepared in accordance with the UNFCCC Reporting Guidelines on Annual Inventories adopted in 1999 by decision 3/CP.5. However, the report has been additionally adjusted to accommodate as far as possible the new Guidelines adopted in November 2002 by decision 18/CP.8 first to be valid in 2004 The methodology used in the calculation of emissions is according to the revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories as elaborated by the IPCC Good Practice Guidance.

With regard to the Land Use Change and Forestry sector (LUCF), the IPCC is currently preparing a "Good Practice Guidance" report due later this year. We are aware of the fact that the current reporting of this sector has some limitations, but it will be improved when the IPCC report is finalised. The next NIR will most likely contain updated LUCF figures calculated with the new methodology.

1.2 Institutional arrangement

The major actors in the reporting of national GHG emissions to the UNFCCC are the Norwegian Pollution Control Authority (SFT) and Statistics Norway (SN). The flow of information and distribution of responsibilities between the two institutions is depicted in Figure 2.

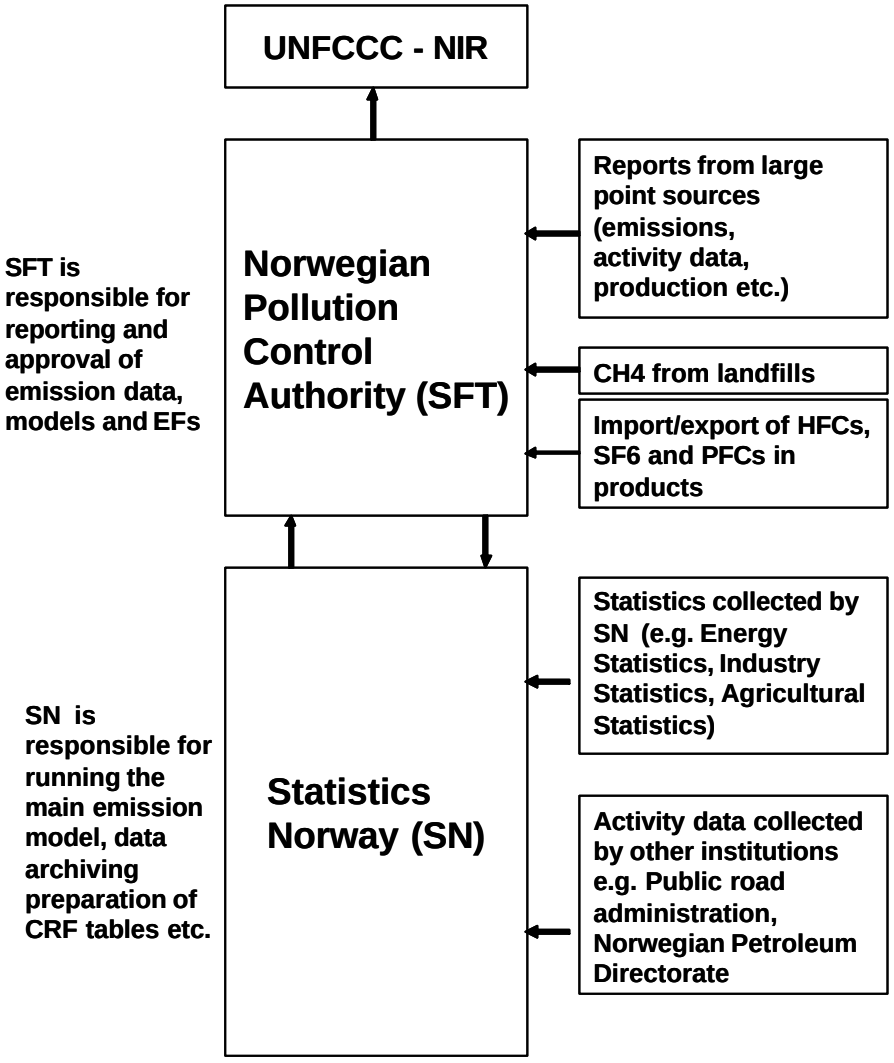


Figure 2. Information flow in the Norwegian emission inventory system under reporting to the UNFCCC.

SFT is responsible for the reporting to the UNFCCC, while SN has the responsibility for most of the emission calculations described below.

In addition to the overall responsibility for reporting, SFT is responsible for the approval of emission data, models and emission factors. Additional responsibilities include the supply of:

- emission factors for all sources
- measured emission data from large industrial plants based on individual company reports submitted to SFT on a regular basis
- emissions of CH_4 from landfills estimated by a model operating at SFT
- import and export data of HFCs, PFCs and SF_6.

In the context of emission reporting to the UNFCCC, Statistics Norway is responsible for:

- the collection of activity data
- the operation and further development of models for emission estimation and
- the production of CRF tables.

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

1.3 The process for inventory preparation

The Norwegian emission reporting system depends largely on the efficient operation of a general emission inventory 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). With only one exception (i.e. the SFT model calculating emissions from landfills), these models are operated by Statistics Norway. Their structure is described in detail in the reports SN/SFT 2000 and SFT 1999b.

Data and information on point sources are recorded at SFT 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 enterprise 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 SN with data from INKOSYS relevant for the preparation of the national emission inventory.

Data collection, processing and storage

SN collects the bulk of data necessary to run the general emission model, namely, activity levels, emission factors, aggregated results from the side models and emission figures for point sources.

The collected data are subjected to the QA/QC routines described in Section 1.6. They are subsequently 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 model output includes emission figures in the required CRF format.

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

Since the last round of reporting under the UNFCCC, the main emission model has undergone substantial restructuring and modifications in order to enable efficient and timely processing, especially in terms of automatic control, treatment of long time series and recording of all changes performed during the inventory preparations. The new version of the model will be fully documented in a comprehensive report currently prepared by SN, which is to be finalised in the second half of 2003.

1.4 Methodologies and data sources used

The estimation methods of all greenhouse gases are harmonised with the current IPCC Guidelines for National Greenhouse Gas Inventories and are in accordance with IPCC's Good Practice Guidance. National specific estimation methodologies have been used when they better illustrate Norwegian conditions as recommended in Good Practice Guidance. The methodology, emission factors, activity data and measurements used in the Norwegian inventory model are described in the report SN/SFT 2000 ("The Norwegian Emission Inventory"), but are to be presented in a more elaborative updated document scheduled for submission to the UNFCCC in the next round of reporting (see also Section 1.3).

Since 2000, methodologies for the estimation of emissions from aviation and shipping have been updated and described in two separate reports (SN 2001a – "Emissions to Air from Fishing Fleet and Sea Traffic between Norwegian Harbours" and SN 2002 – "Emissions to Air from Norwegian Air Traffic"). In addition, smaller refinements have been made also for other sources. These are noted in the CRF tables addressing the issue of recalculations.

The emissions in the Norwegian emission inventory are calculated by a four-dimensional cube model, with the axes components, technical emission sources, emission carriers (e.g. fuels) and economic sectors. This model includes the greenhouse gases CO_2, CH_4 and N_2O and in addition the precursors NO_X, SO_2, NMVOC, CO and some other gases such as heavy metals and particles. Thus, emissions can be listed by a multitude of combinations of fuels, sources and sectors. Emissions from combustion are calculated by combining the fuel consumption distributed on emission sources and economic sectors with fuel-, source-, sector- and pollutant specific emission factors. Whenever measured emissions are available, these are used instead of the calculated figures. Aggregated emission factors are input to the main emission model. Non-combustion emissions are estimated by combining activity data with emission factors through more complicated calculations. They are then fitted into the cube model by an appropriate emission carrier, emission source and economic sector. Emissions from road traffic, methane from landfills and emissions of HFC, PFC and SF_6 from products are calculated by side models, and are incorporated into the main model along with emissions from point sources collected by SFT.

The calculations of greenhouse gas emissions measured as CO_2 equivalents are based on data on global warming potentials (GWP) for the different GHG, calculated for a time horizon of 100 years, from IPCC's Second Assessment Report from 1995.

In 2002 Statistics Norway started developing the emission model further. The principle goal has been to facilitate the QA/QC and reporting procedures primarily with regard to Norway's international obligations. The main features of the model are kept. However, there have been extensive changes in the parameter structure and a substantial increase in the amount of input data (especially activity data) fed into the model.

The emission estimation methodologies are being developed continuously. SN and SFT have carried out several studies on specific emission sources, e.g. emissions from road, sea, and air transport, emissions from landfills as well as emissions of HFCs and SF_6. Usually, such projects are connected to an evaluation of emission reduction measures. An important element in SN's work is to increase the environmental relevance of the statistical system. As far as possible, data collection relevant to the emission inventories is integrated into other surveys and statistics.

The data sources used in the Norwegian inventorying activities are outlined in the following:

- *Activity levels* – these are mostly taken from official statistical sources available internally in SN and other material available from external sources (see also Section 1.2). When such information is not available, research reports are used or extrapolations are made from expert judgements.
- *Emission factors* – these are taken primarily from reports on Norwegian conditions and are either estimated from measurements or taken from special investigations. However, international default data are used in cases where emission factors are highly uncertain (e.g. N_2O from agriculture, and CH_4 and N_2O from stationary combustion) or when the source is insignificant in relation to other sources.
- *Aggregated results from the side models* – The operation of these side models requires various sets of additional parameters pertinent to the emission source at hand. These data sets are as far as possible taken from official registers, public statistics and surveys, but some are based on assumptions.
- *Emission figures for point sources* – For large industrial plants these are figures reported to the SFT by the plants (based on measurements or calculations at the plants).

1.5 Key source categories

According to the IPCC definition, key sources are those that add up to 90 per cent of total uncertainty in level and/or trend. In the Norwegian Emission Inventory key source categories are 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 Annex 1, which is based upon the work by Rypdal and Zhang described in the report SN 2000.

The key source 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. Correlations are taken into consideration in the analysis. 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. Furthermore, emission factors and activity

data can be assessed separately. In addition, the Tier 1 method may identify sources that are not actually key sources according to Tier 2 (SN 2001e).

1.6 The national QA/QC plan

1.6.1 Background

Norway has not yet implemented a formal QA/QC or verification plan. However, several checks are formalised. In general terms these include:

- A stepwise procedure in the preparation of the final national emission inventory, including recalculations to ensure time-series consistency
- Checking of the data and relevant information collected by SFT and SN and follow up of discrepancy issues
- Quality control of the emission estimates through comparison with corresponding figures calculated earlier and consistency checks with figures for neighbouring years.

The above issues are elaborated in the following sections.

In recent years a lot of effort has been dedicated in the design and implementation of an effective QA/QC procedure which could address not only the issue of accuracy but also timeliness, especially in connection with the national obligations to international agreements.

Recognising that focus has traditionally been on controlling the final quality of products rather than processes or input data, Statistics Norway started a Total Quality Management (TQM) project in 2001, aiming at the broadening of the quality concept. One principal goal was to account for the need to meet the deadlines in the international reporting of emission data.

For this task a project team was established. The team members were representatives of the users of the emission inventory data, the input data providers and other experts involved at different stages in the inventorying work. The team looked first at the flow of information in the national inventory system, presented in Figure 3, in order to identify critical process variables ("bottlenecks") and their implications. Energy data for the manufacturing industry were found to be the most critical variable both in terms of contribution to the total and delays in their preparation.

To improve the situation the inventory team decided to involve the key data providers more actively in the inventory preparation process by:

- clearly informing them about the use of their submissions
- making them aware of the importance of their contribution and its implication on the work of the UN Conventions
- inviting them to adjust their internal time schedule in order to meet deadlines essential for the broader national inventory work.

The team did also identify problems with the inventory model itself. In particular, the model was not designed to handle long time series, rendering recalculations a time consuming task. Furthermore, the model structure did not facilitate automatic checking of the input data. Since manual inspection was the common way to check the vast quantity of input data, many errors would not be detected before model runs were completed and the output tables checked. This resulted in time-consuming model re-runs. Moreover, such a control method often left many errors undiscovered, since these are more difficult to trace in the results than in the input data.

To deal with these deficiencies, Statistics Norway designed a new emission model in 2002/2003, which:

- makes automatic controls easy
- handles long time series better
- registers all changes made into the inventory system (including time and responsible person).

A full documentation of the model will be available in the second half of 2003.

1.6.2 Procedure followed in the preparation of the national emission inventory

The Norwegian emission inventory is produced in several steps. Preliminary estimates are first produced three months after the end of the inventory year (for SO_2 six months later). These data 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 subjected to quality control. The "final" update takes place 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 due to smaller or larger methodological changes or refinements.

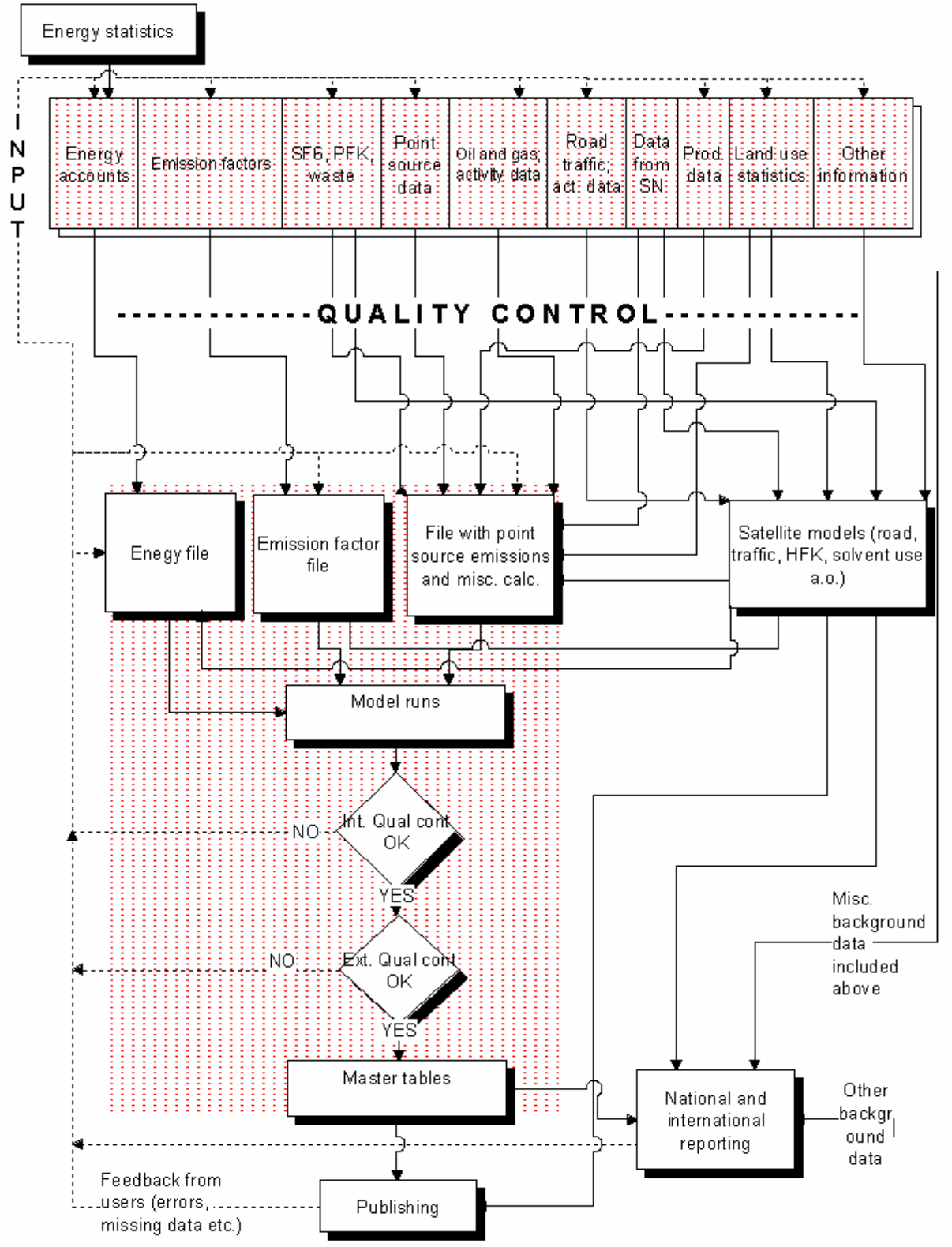


Figure 3. Processes involved in the Norwegian emission inventory work. Source: Haakonsen (2001)

QA/QC of the emission model input

The national emission model was revised in 2002 in order to facilitate the QA/QC of the input data rather than the emission data only. Input data include emissions reported from large plants, activity data, emission factors and other estimation parameters.

All parameter values are compared with values used in previous years and with any preliminary figures available. Whenever large deviations are detected, the value of the parameter in question 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 suppliers (e.g. NIJOS, OD, VD, various plants etc) are contacted for explanations and possibly corrections.

Activity data are often statistical data. Official statistical data undergo a systematic revision process, which may be manual or, increasingly frequenty, computerised. The revision significantly reduces the number of errors in the statistics used as input to the inventory.

SFT and SN control and verify emission data reported to SFT by industrial enterprises, registered in INKOSYS (see Section 1.3). First SFT checks the data received from these plants, which have then the opportunity to submit new data when errors are discovered. Subsequently, SN makes, where possible, 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 performed every year when an emission calculation for a new year is done. It is then examined whether any detected inconsistencies are due to data or/and methodology changes.

Information about existing sources is collected from guideline material and national and international literature sources. For oil and gas production activities information is collected from administrative sources. When new emission sources appear (for example a new industrial plant) or existing sources are for the first time recognised as a source, SFT delivers all relevant information to SN. This information is then thoroughly checked by two members of the inventory team at SN. All changes in methodologies or data are documented and kept up to date.

Emission data are revised in special projects focusing on particular key sources. These projects are repeated in regular intervals when new information is available. They often involve comparison of emission factors in literature and a rational for the choice of emission factor.

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.

QA/QC of the emission model output

Emission time series are recalculated every year in order to account for methodological changes. Emission data undergo two main types of checks:

Comparison of data with previous year's calculations for the same year
The recalculated emission data for a year is compared with the corresponding figures estimated the year before. For example, CO_2 data calculated for 1990 in 2002 are compared with the 1990 CO_2 data calculated in 2003. 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 emission model.

Comparison of data for a new year with the data calculated for the previous year
Emission data for the last year are compared with data for the previous year to check the consistency and explain any changes in the data behaviour. For example, in 2003 SN/SFT calculated emission data for 2002 for the first time. These data were compared with the 2001 figures for detection of any considerable deviations. Large deviations may often be correct, caused for instance by the shutdown of large industrial plants or the launch of new ones.

The above data comparisons offer several opportunities for detection of gross errors. In addition, findings from the QA/QC on input data are utilised, and when necessary, further checks are initialised.

Finally, where two alternative methodologies are available, emission estimates are often made by both methods and then compared. Such comparisons may reveal errors, suggest improvements and/or indicate uncertainty levels. For instance CO_2 emissions from ferroalloy production is reported from each plant. The emissions are, nevertheless, calculated by SN using two separate methods, one reducing agent based and one production volume based. The calculated emission figures are compared to the reported figures. Large deviations must be explained before proceeding further with the work.

1.6.3 Verification studies

Emission estimates for a source are often compared with estimates performed by a different methodology. In particular, Norway has conducted a study on verification of the Norwegian emission inventory (SFT/SN 2000). The main goals of that work were to investigate the possibility of using statistical data 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 Norwegian emission data are compared with national data for Canada, Sweden and New Zealand. It was 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 funded by the Nordic Council of Ministers was carried out, where emissions of greenhouse gases from the agricultural sector in the national emission inventories were compared with the emissions derived from the IPCC default methodology and the IPCC default factors. A summary of the results of the study is included in Section 6.2 – N_2O emissions from agricultural soils.

1.6.4 Confidentiality issues

Statistics Norway is prohibited by law to disseminate activity data for sources categories where the number of plants involved is three or less. This is the reason for the missing activity data in the case of cement, ammonia and calcium carbide production (see CRF Table 2(I).A-G, Annex 6).

1.7 Uncertainty evaluation

The uncertainty in the Norwegian emission inventory has been investigated systematically in two reports so far (SFT/SN, 1999a and SN, 2000).

In the report SN 2000 the uncertainty in level for the total Norwegian GHG emissions in 1990 is estimated to be 21 per cent. An uncertainty 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 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 in the report SFT 1999a was found to be 11-17 per cent.

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 highest uncertainty. This result is in accordance with what was found in the 2000 report, 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 (SN, 2000) are summarised in the tables presented in Annex 5. 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.

1.8 General assessment of the completeness

In the context of the emission inventorying work, an assessment of the completeness should address the issues of spatial coverage, temporal coverage and sectoral coverage along with all underlying source categories and activities. Confidentiality is an additional element of relevance and has been addressed in Section 1.6.4.

In terms of spatial coverage, the emission reporting under the UNFCCC covers all activities within Norway's jurisdiction.

In the case of temporal coverage, the major point to be addressed is that CRF tables are reported for the years 1990, 1998, 1999, 2000 and 2001. For the years 1991 to 1997 emission figures do exist, but are available in another electronic format than the one presently required by the UNFCCC. Norway plans to submit a complete set of CRF tables for all years in the next round of reporting.

With regard to sectoral coverage, the Norwegian GHG emission inventory includes estimates from all known relevant sources or sinks, with a few exceptions. These are:

- Emissions of N_2O from aerosol propellant used in spray box
- Emissions of CH_4 from agricultural waste
- Emissions/removals of CO_2 from agricultural soils
- Emissions of N_2O from application of industrial and urban wastes on fields
- Emissions/removals of other greenhouse gases than CO_2 from LUCF
- Removals of CO_2 from forest soil.

The reason for not including the above activities in the present submission 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. However, as the national inventory system is being improved, several of the above sources/sinks are expected to be addressed in the near future.

Although notation keys have been used more extensively than in any earlier submission, full coverage has not been possible due to time constraints in the emission inventorying work.

Emissions from the use of feedstocks are in accordance with Good Practice Guidance and 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.

In October 2002 the Norwegian emission inventory system was inspected by an emission review team (ERT) of experts hosted at SFT (in-country review). The team concluded that the national inventory submission was in conformity with the UNFCCC reporting guidelines, and that Norway has an excellent inventory programme that systematically reviews and targets areas of improvement through key source identification. It was also noted that the existing institutional arrangement facilitates consistency in reporting.

With respect to deficiencies and areas for improvement in the Norwegian emission inventory system the ERT addressed the following general points:

a) Need for inclusion into the NIR of supporting information on choices for and sources of emission factors and data to aid explanation of information gaps.

b) Lack of notation keys in some CRF tables

c) Lack of full transparency in the LUCF sector in terms of documenting underlying processes, use of notation keys, values assigned to different parameters, and documentation on the decision-making process.

d) Lack of full CRF time series (in particular for the years 1991-1997)

e) Lack of calculation sheets[1]

[1] According to the UNFCCC reporting guidelines, the NIR should include calculation sheets or equivalent database information on detailed inventory calculations in each sector, for all years from the base year to the year of the current annual inventory submission, containing, *inter alia*, disaggregated national emission factors and activity data underlying the estimates (FCCC/CP/1999/7, paragraph 33(b)). This reporting requirement was, however, dropped from the revised UNFCCC reporting guidelines, which were agreed upon by the Subsidiary Body for Scientific and Technological Advice (SBSTA) at its sixteenth session.

f) Lack of clear indication of methods used in some sectors (e.g. agriculture, waste)

g) Lack of clear indication of the rationale and complexity of the methodologies used

h) Lack of some CRF tables referring to agriculture and LULUCF (Tables 4Bb, 4C, 4E, 5B, 5C and 5D).

With the exception of (e), the ERT recommended that Norway add these elements to future NIRs.

The present report addresses the above points to the extent that that has been possible. In particular, the various sectors are here described in more detail than in last year's report, especially those of agriculture and LUCF. The issue of CO_2 capture and storage, which is of relevance for Norway, is also described for the first time in this report. As mentioned earlier in this section, the use of notation keys is now more extensive than before. Furthermore, Table 4Bb is now completed with data on N_2O emissions from Manure Management. CO_2 emissions from liming of agricultural soils are also this year reported in 4D-Agricultural Soils whilst, according to the Good Practice Guidance, they should be reported under 5D-CO_2 Emissions and Removals from Soil. The reason for this deviation is because these emissions were accounted for under 4D when we published the Norwegian GHG emissions in February this year. So to achieve consistency between the NIR and what we publish nationally, we have reported CO_2 from liming of agricultural soils under category 4D. In next year's NIR this will be corrected.

Chapter 2. Trends in Greenhouse Gas Emissions

2.1 Emission trends for aggregated greenhouse gas emissions

The total amounts of greenhouse gases emitted in Norway during the period 1990-2001 are in the following expressed in terms of contribution by gases (Table 2, Figure 3) and contribution by sources (Table 3, Figure 4).

Tables 2 and 3 present emission figures for all direct greenhouse gases and sectors, respectively, expressed in CO_2 equivalent along with their change indicated for both the time periods 1990-2001 and 2000-2001. The trend in the total national GHG emissions as a function of gas and sector is visualised respectively in Figures 4 and 5.

Table 2. Emissions of greenhouse gases in Norway during the period 1990-2001 without Land Use Change and Forestry. Empty cells indicate emission not occurring. Units: CO_2 and CO_2–equivalents in Mtonnes, CH_4 and N_2O in ktonnes and other gases in tonnes. Source: SN/SFT

	Year												Change	
Gas	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**90-01**	**00-01**
CO_2	34.9	33.2	34.0	35.7	37.4	37.5	40.7	40.9	41.1	41.6	41.1	41.6	19 %	1 %
CH_4	306.3	310.9	315.0	321.1	325.2	327.9	331.7	334.1	328.8	326.8	332.0	332.5	9 %	0 %
N_2O	17.7	17.2	15.0	16.2	16.5	16.8	16.8	16.6	17.5	18.2	17.9	18.0	1 %	0 %
CF_4	441	369	294	290	251	229	214	201	185	164	131	149	-66 %	14 %
C_2F_6	18	14	11	10	9	8	5	8	7	6	5	6	-66 %	20 %
SF_6	92	86	29	30	36	24	24	23	29	35	37	32	-65 %	-14 %
HFC 134a			0.2	1.8	5.4	10.2	17.2	26.2	38.2	50.2	61.1	71.8		18 %
HFC 152a	0.0	0.0	0.0	0.0	0.5	2.4	5.5	9.7	14.7	19.9	25.9	32.9		27 %
HFC 125					0.0	0.0	0.0	0.2	0.3	0.6	20.3	26.9		32 %
HFC 143a					0.0	0.0	0.0	0.2	0.3	0.6	1.0	1.5		45 %
HFC 23									0.1	0.1	0.1	0.1		6 %
HFC 32								2.4	4.8	6.0	7.7	10.2		31 %
HFC 227ea								0.1	0.1	0.2	0.2	0.3		70 %
Total CO_2-eq.	**52.0**	**49.7**	**48.0**	**50.2**	**51.9**	**51.8**	**54.9**	**55.1**	**55.5**	**56.2**	**55.7**	**56.2**	**8 %**	**1 %**

Table 3. Emissions of greenhouse gases by sources and CO_2 removals in Norway during the period 1990-2001. Unit: Mtonnes CO_2-equivalents. Source: SN/SFT

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
Energy	29.3	28.2	29.1	30.3	31.9	31.8	34.8	35.3	35.3	36.0	35.4	36.3
Industrial Processes	13.3	12.0	9.6	10.4	10.6	10.4	10.6	10.3	10.7	10.8	10.8	10.6
Solvent Use	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Agriculture	5.2	5.2	5.1	5.2	5.1	5.2	5.2	5.2	5.2	5.2	5.1	5.0
Waste	4.0	4.0	4.0	4.1	4.1	4.1	4.2	4.2	4.2	4.2	4.2	4.1
LUCF	-9.8	-11.9	-13.4	-13.7	-15.8	-15.7	-17.6	-16.5	-17.6	-17.8	-18.7	-19.0
Total - with LUCF	**42.2**	**37.7**	**34.6**	**36.5**	**36.1**	**36.1**	**37.3**	**38.6**	**37.9**	**38.5**	**36.9**	**37.3**
Total - without LUCF)	52.0	49.7	48.0	50.2	51.9	51.8	54.9	55.1	55.5	56.2	55.7	56.2

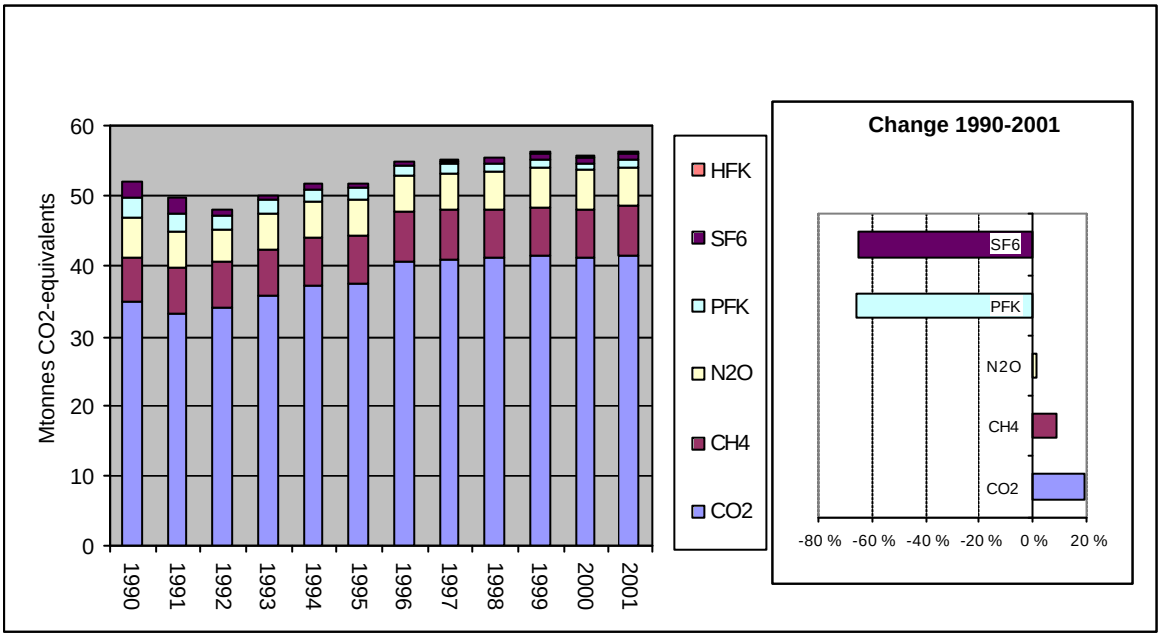


Figure 4. Emissions of greenhouse gases by gas in Norway 1990-2001. (The explosive increase of HFCs between 1990 and 2001 is not displayed in order not to disrupt the figure). Source: SN/SFT

The overall trend first shows a marked decrease between 1990 and 1992 and an increase thereafter with a small interruption in 1995 and 2000. Since 1997 the total emissions have been rather stable except for 2000. In 2001 the emissions amounted to 56.2 million tonnes CO_2 equivalents, thus reaching the 1999 levels, the highest recorded for Norway so far.

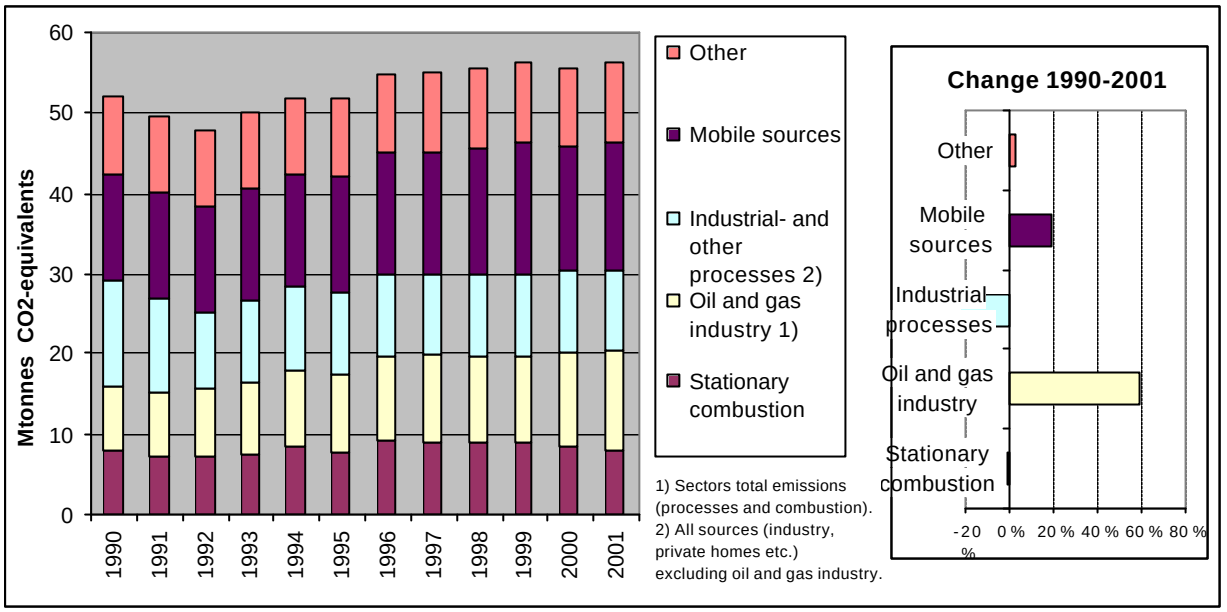


Figure 5. Emissions of greenhouse gases by source in Norway 1990-2001. Source: SN/SFT

The overall increase in emissions from 1990 is mainly due to economic growth in general, which has resulted in higher CO_2 emissions from most sources, but in particular from gas and oil extraction and to a lesser extent from the transport sector and the consumption of oil products in industry. This trend has to some degree been counteracted by decreased emissions of PFCs and SF_6 from aluminium and magnesium plants. The emissions of CH_4 and N_2O have been relatively stable over the same period. By contrast, emissions of HFCs have had an explosive increase since 1990, rising from 0.02 ktonnes CO_2 equivalents of just HFC 152a in 1990 to a total of 292 ktonnes CO_2 equivalents for all HFC components of relevance in Norway in 2001

The downward trend detected in the early 1990's is primarily due to the decreased consumption of gasoline and fuel oils as well as reduced production of metals. Contributors to this development were the low economic activity during that time and the CO2 tax, which was implemented with effect from 1991.

The dip in 2000 corresponds to an emission fall of about 0.9 per cent from the 1999/2001 levels. However, this feature is really an artefact caused by the fact that emissions from transport are calculated on the basis of sales rather than consumption. A mild winter season combined with changes in taxes on petrol and diesel with effect from 1 January 2000 led to a temporary reduction in stock-in-trade of those products with a subsequent reduction in the respective CO_2 emissions.

Emissions increased by 1 per cent between 2000 and 2001. The overall increase between 1990 and 2001 is 8 per cent. This means that Norway will have to reduce its national GHG emissions by 7 per cent in order to achieve the emission target of 1 per cent required by the Kyoto Protocol by the period 2008-2012 if the emissions stabilise at this level. Preliminary calculations of the GHG emissions in 2002 indicate a decrease of 2.5 per cent since 2001. This downward trend is primarily a result of close-downs and reductions in the ferroalloy- and magnesium industry, reduced flaring in the oil and gas extraction sector and reduced domestic

navigation. The reduction outweighs increased emissions from road traffic and from the production of fertiliser as well as from aluminium production and from the consumption of HFCs.

2.2 Emission trends by gas

As shown in Figure 4, CO_2 has always been the largest contributor to the total GHG emissions, followed by CH_4 and N_2O, PFCs, SF_6 and HFCs. In 2001 the relative contributions to the national totals from the different gases were; CO_2 74 per cent, CH_4 12 per cent, N_2O 10 per cent, PFCs and SF_6 less than 2 per cent each and HFCs less than 1 per cent. However, fluorocarbons constituted a larger and CO_2 a smaller fraction of the GHG emission total in the early 1990s than that in 2001.

2.2.1 Carbon dioxide (CO_2)

The Norwegian CO_2 emissions originate primarily from industrial sources related to oil and gas extraction and the production of metals, as well as from the transport sector. A relatively large share of the transport-related emissions originates from coastal navigation and the fishing fleet. Since generation of electricity is almost exclusively hydroelectric, emissions from stationary combustion are dominated by industrial sources and internal energy use. The distribution of CO_2 emissions over the various source categories is shown in Figure 6 together with the emission trend in the period 1990-2001.

From 1990 to 2001 the total CO_2 emissions increased by 19 per cent. The increases in natural gas use in gas turbines in the oil and gas extraction industry have been the most important contributor to the overall CO_2 increase.

In 2001 the total Norwegian emissions of CO_2 were 41.6 Mtonnes – an increase of 1 per cent from last year. However, it should be borne in mind that this increase is not exclusively indicative of a real growth in emissions in 2001, but is partly attributed to the unusually low figures estimated for 2000. As explained in Section 2.1 a mild winter season and changes in fuel taxes resulted in a temporary reduction in fuel stock-in-trade in 2000. This led in turn to lower emission estimates for 2000 since these are based on fuel sold rather than fuel consumed. Emissions from civil aviation and coastal navigation were also reduced in 2000, but the decrease was counteracted by higher emissions from oil and gas extraction.

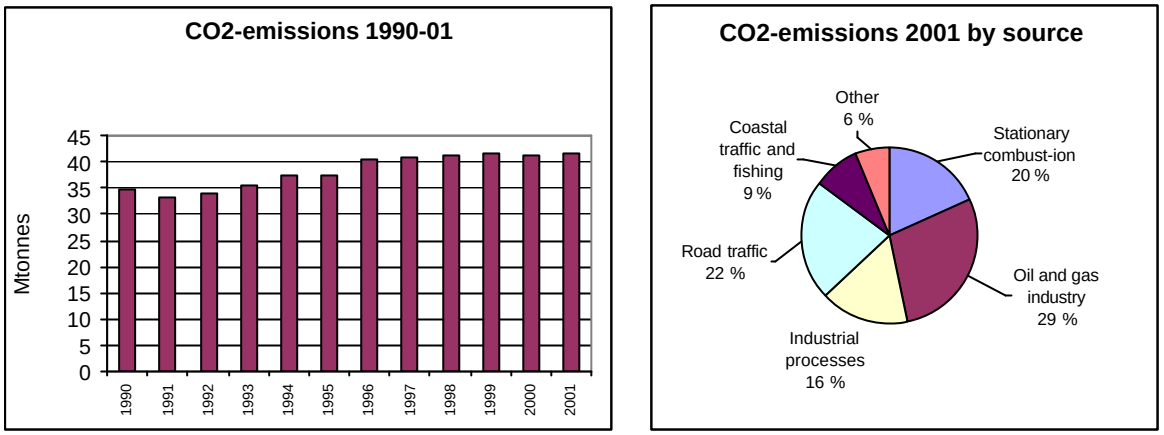


Figure 6. Norwegian CO_2 emissions 1990-2001 and their distribution by source in 2001. Source: SN/SFT

Emissions from the **oil- and gas industry** increased by about 56 per cent in the 1990s as a result of large increases in production volume of oil and gas and the export of natural gas in pipelines. However, emissions per unit produced oil/gas have been decreasing, because of technical and administrative improvements partly induced by a CO_2-taxation regime in 1991. Nevertheless, this trend has been counteracted in the last few years, mainly due to technical factors related to a shift to older and more marginal oil-and gas fields.

In the source category of **road transportation**, an increase of 19 per cent is detected in the CO_2 emission figures from 1990 to 2001. This rise is primarily attributed to the large increase (73 per cent) in the emissions from diesel vehicles over the years. Although emissions from gasoline vehicles decreased by 7 per cent during this time, this fall was counteracted by the significant shift from gasoline to diesel vehicles. The emission increase of about 7 per cent between 2000 and 2001 is partly attributed to the unusually low emission estimates for 2000 due to changes in fuel taxes as explained in Section 2.1.

Emissions of CO_2 from **navigation** have increased by 20 per cent from 1990 to 2001, mainly due to increased activity in the petroleum sector. The substantial increase in the production of Norwegian oil and gas in the North Sea during the 1990s resulted in increased traffic of supply boats to and from the oil platforms.

Chemical production (fertilisers, carbides and petrochemicals) has had an increase in CO_2 emissions by almost 19 per cent from 1990 to 2001. This growth is mainly due to the launch of a new plant producing methanol in 1997.

In the **heating sector** (commercial, institutional and residential) there has been a reduction in CO_2 emissions by 23 per cent from 1990 to 2001. This is the only sector with a significant CO_2 emission reduction, which is mainly caused by increase in the use of electricity rather than oil.

In 2001 the emissions were 18 per cent higher than those in 2000. As explained earlier, this development is attributed to a combination of a mild winter and unusually low emission estimates for 2000 rather than a real emission rise in 2001.

From the sources contributing less to the national emission total than the above categories, it is important to mention the substantial increase of 56 per cent detected in the emissions from **civil aviation** during the period 1990-2001. This development is due to rise in the number of civil flights. In 2001 the emission level was the same as the level in 2000. The steady upward trend recorded in the 1990s peaked at 1.2 million tonnes in 1999. Due to overcapacity in domestic air transport in the late nineties, one company left the market in 2000. This led to reduced activity levels and a subsequent emission reduction of about 9 per cent between 1999 and 2000/2001.

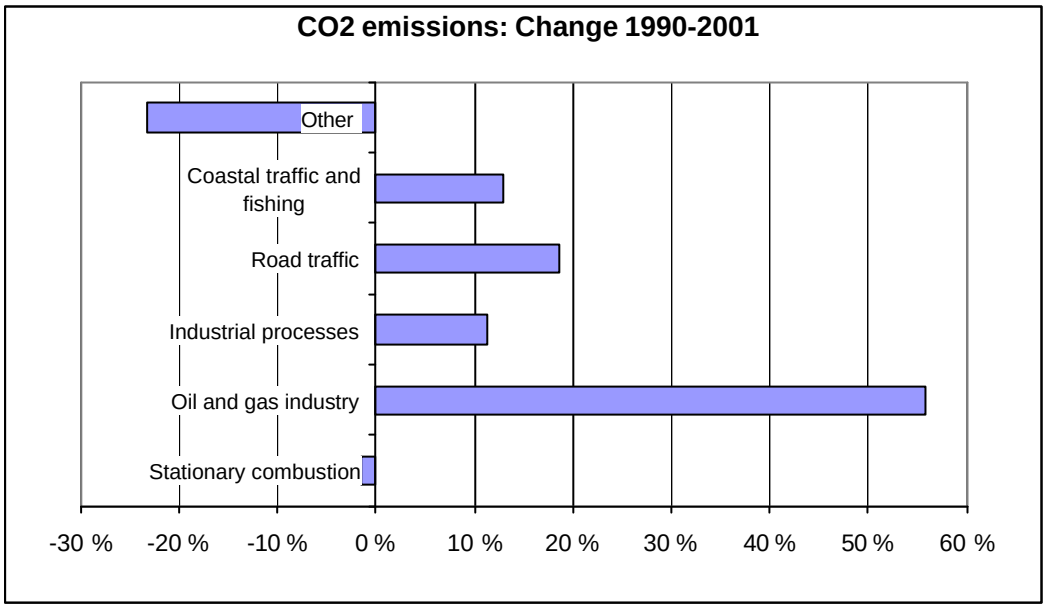


Figure 7. CO_2 emissions change in major Norwegian sources between 1990 and 2001. Source: SN/SFT.

2.2.2 Methane (CH_4)

As can be seen in Figure 6, about 89 per cent of the emissions of methane in 2001 originated from waste treatment and agriculture. These sources are relatively stable from year to year, and are little affected by short-term economic cycles. Combustion and evaporation/leakage in the oil- and gas industry accounted for 11 per cent of the total emissions in 2001, the largest fraction of which is releases of methane (venting) during the loading and unloading operations offshore. Minor sources include emissions from petrol cars, domestic heating and coal mining.

The emission trend is characterised by a slow increase in the first half of the 1990s and an even slower decrease since 1997. This feature is dictated primarily by emission changes in the oil- and gas industry due to changes in production volumes. Emissions from waste treatment were relatively stable throughout the 1990s, as higher waste volumes were offset by increased recycling of waste and increased burning of methane from landfills.

Emissions from agriculture are dominated by methane releases from enteric fermentation (84 per cent in 2001), with manure management being the second largest contributor (15 per cent in 2001), and cereals burning accounting for the remaining minor emitted fraction. In the period 1990-2001 the overall emissions from agriculture decreased by

approximately 1 per cent, particularly due to reduced population of cattle with a subsequent decrease in the emissions from enteric fermentation.

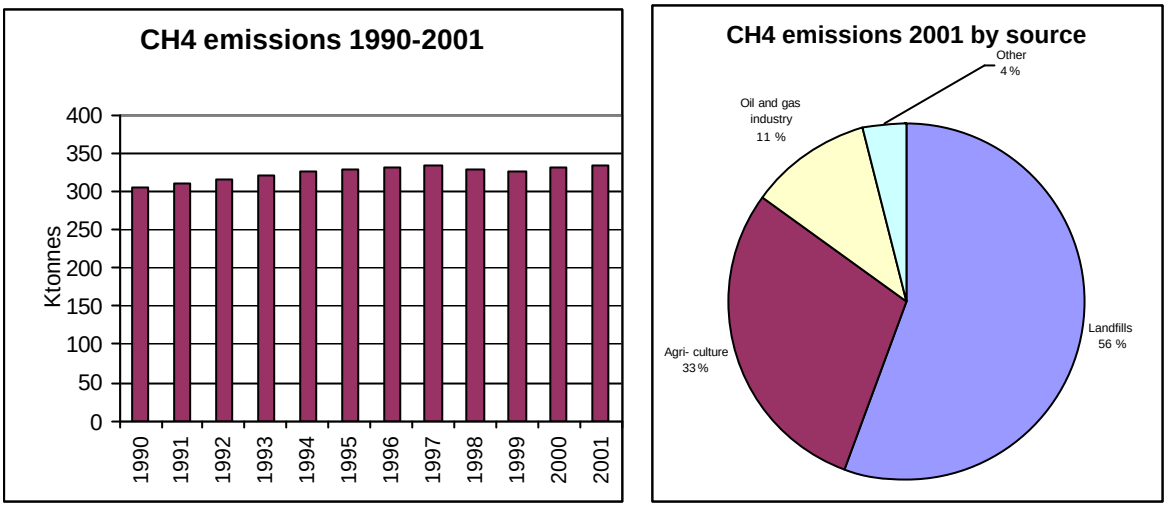


Figure 8. Norwegian CH_4 emissions 1990-2001 and their distribution by source in 2001. Source: SN/SFT

In 2001 the methane emissions were at the same level as in 2000 of about 332 ktonnes. During the period 1990-2001 the total CH_4 emissions increased by about 9 per cent. Figure 9 shows that this increase is due to increased emissions from oil- and gas industry and from landfills.

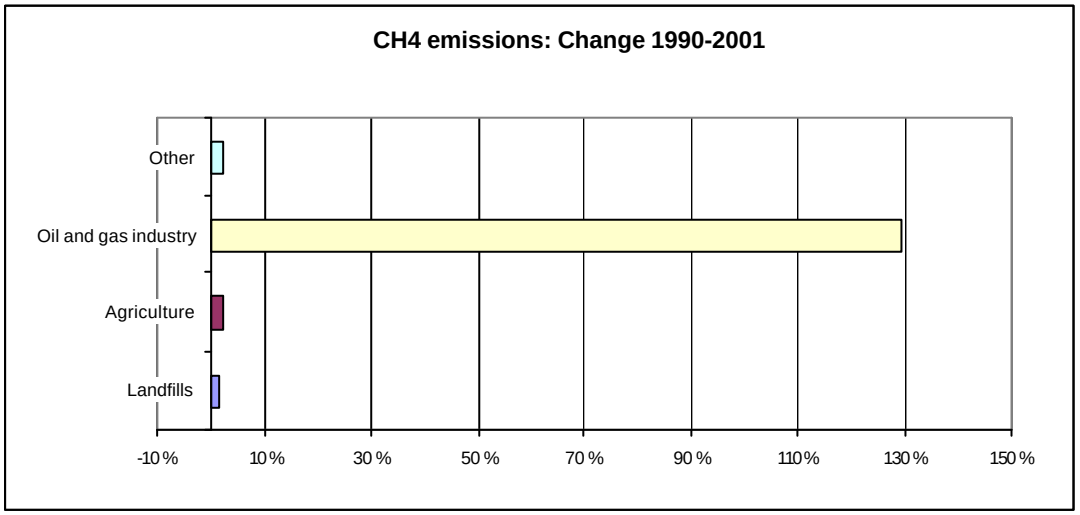


Figure 9. CH_4 emissions change in major Norwegian sources between 1990 and 2001. Source: SN/SFT

2.2.3 Nitrous oxide (N_2O)

Almost half of the Norwegian emissions of N_2O are of agricultural origin, in particular agricultural soils (49 per cent) – see Figure 10. In addition manure management in agriculture contributes by 2 per cent. These emissions have been rather stable through the 1990s and further on until 2001. The other major source is two plants producing nitric acid, which is one of the steps in the production of fertilisers. N_2O emissions from nitric acid production constitute about 1/3 of the national N_2O emissions.

Changes in the production processes of nitric acid led to decreased emissions in the beginning of the 1990s, while there was a moderate increase in emission in the following years due to increased production volumes. As shown in Figure 11, from 1990 to 2001 the N_2O emissions from agriculture and nitric acid production decreased by 4 per cent and 18 per cent respectively.

The total N_2O emissions experienced only a minor increase of 0.6 per cent between 2000 and 2001. During the period 1990-2001 emissions increased by only 1.3 per cent. This rise is mainly attributed to the increasing use of catalytic converters in mobile sources over the years. Emissions from road traffic increased by more than 6 times during the period 1990-2001 and in 2001 they accounted for 11 per cent of the national N_2O total. This increase is depicted in Figure 11. In 2001 road traffic contributed with 59 per cent to the emissions under the source category "Other".

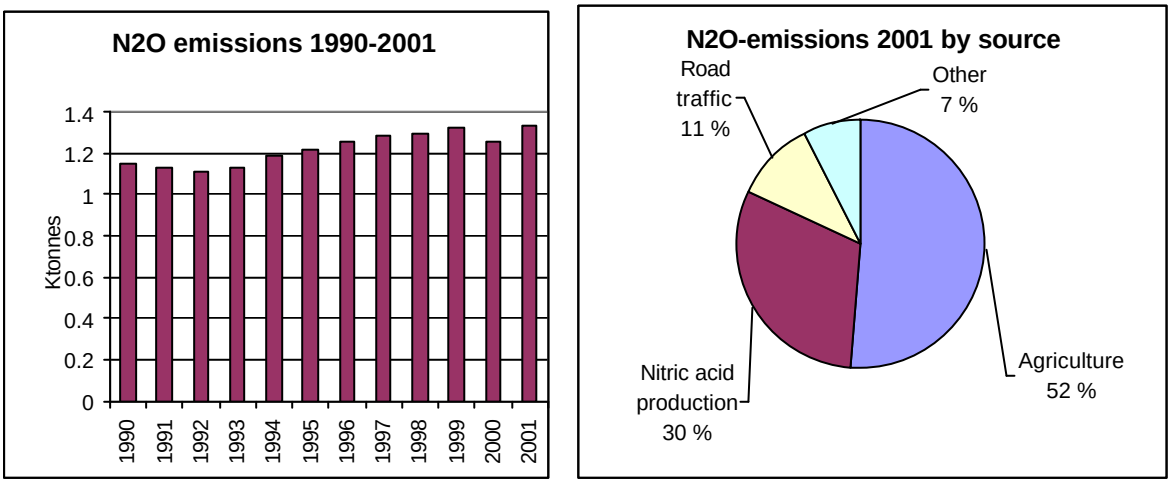


Figure 10. Norwegian N_2O emissions 1990-2001 and their distribution by source in 2001. Source: SN/SFT

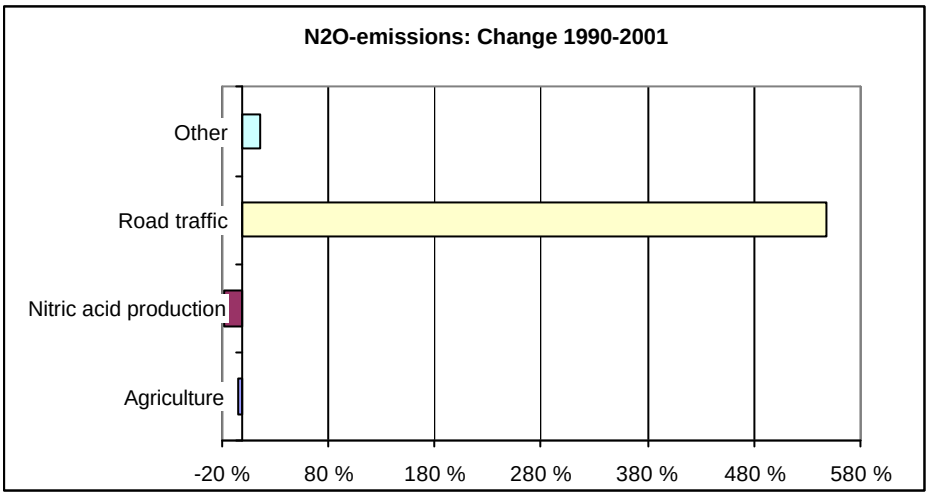


Figure 11. N_2O emissions change in major Norwegian sources between 1990 and 2001. Source: SN/SFT

2.2.4 Perfluorcarbons (PFCs)

The emissions of the perfluorcarbons tetrafluoromethane (CF_4) and hexa fluoroethane (C_2F_6) from Norwegian aluminium plants in 2001 were reported by the companies to be 149 and 6 tonnes respectively, corresponding to a total of 1 million tonnes of CO_2-equivalents.

The total emissions of PFCs decreased by 66 per cent in the period 1990-2001 following a steady downward trend as illustrated in Figure 12. Both CF_4 and C_2F_6 decreased in exactly the same manner. PFCs reduction is caused by improved technology and process control, which has led to a 72 per cent decrease in the amount of PFCs emitted per tonne aluminium produced during the period 1990-2001, see Section 4.2 for further details.

PFCs may be used as substitutes for ozone-depleting substances. In Norway, only one compound is used for this purpose, namely C_3F_8 (PFC-218). The actual emissions of C_3F_8 have been calculated at only 55 kg in 2000, corresponding to almost 390 tonnes of CO_2-equivalents.

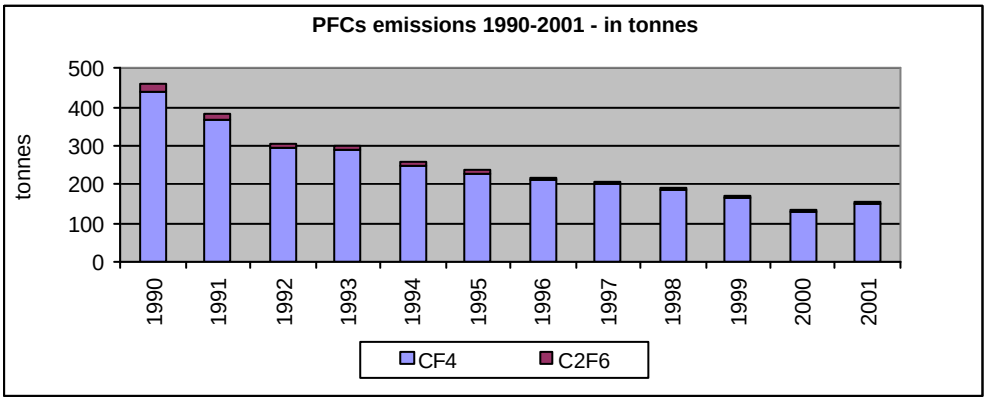


Figure 12. Emissions of PFC gases (CF_4 and C_2F_6) in Norway 1990-2001. Source: SN/SFT

2.2.5 Sulphur hexafluoride (SF_6)

The largest source of SF_6 emissions in Norway is magnesium production, where SF_6 is used to cover the surface of liquid magnesium to prevent it from oxidising. The covering gas is emitted to air after use and no SF_6 is expected to react with the metal. The consumption of SF_6 has been reduced through the 1990s due to improvements in technology and process management. However, the process management changes from year to year and consequently also the consumption of SF_6. In 2001 the SF_6 emissions were 65 per cent lower than those of 1990.

In the period 1990-1997, emissions were reduced by 75 per cent. From 1997 to 2000 emissions have increased by 40 per cent due to increased production and higher shares of production of primary magnesium versus recycled metal. However, emissions in 2001 were 14 per cent lower than those in 2000 partly due to reduced production of cast magnesium and partly to process management.

Primary magnesium is produced by one company in Norway. However, the company decided to retain only the secondary production in the future. Primary production stopped in 2002. It is anticipated that this will cut down the consumption of SF_6 by further 60-80 per cent.

The use of SF_6 as a cover gas in the aluminium foundries lasted only during the period 1992-1996. Since1997 SF_6 has not been used in the foundries.

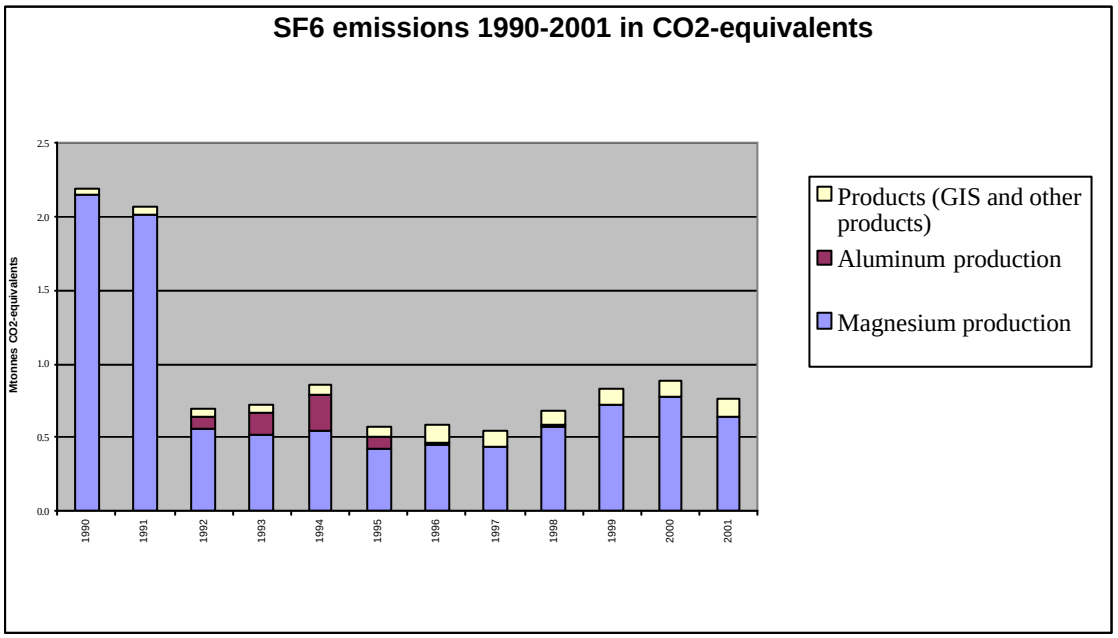


Figure 13. Emissions of SF_6 in Norway 1990-2001. Source: SN/SFT

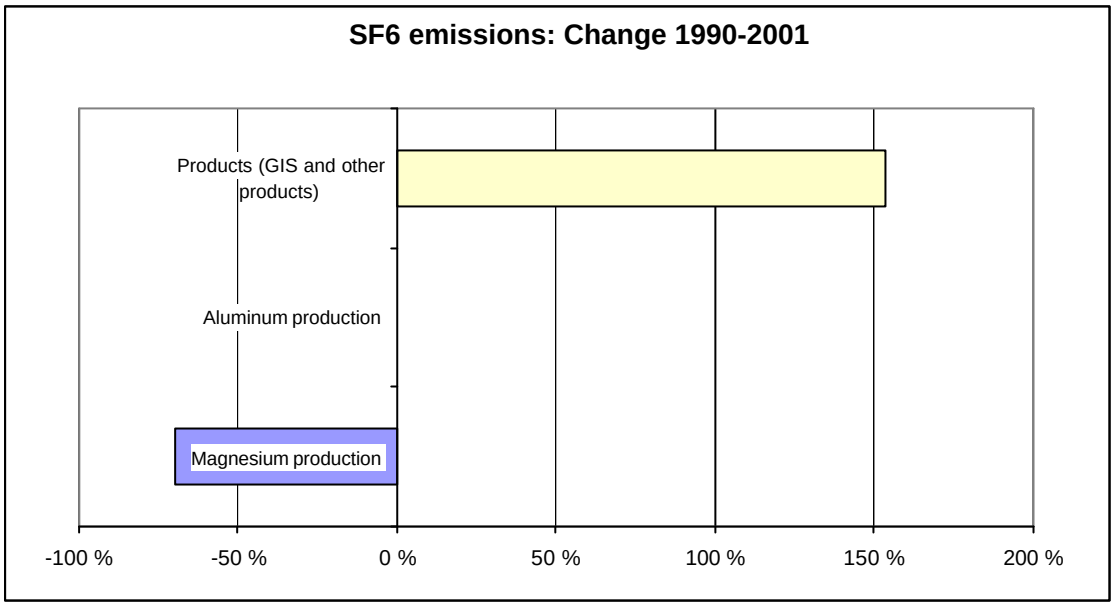


Figure 14. SF_6 emissions change in major Norwegian sources between 1990 and 2001. Source: SN/SFT

2.2.6 Hydroflorocarbons (HFCs)

The total actual emissions from HFCs used as substitutes for ozone depleting substances amounted to 0.292 Mtonnes of CO_2-equivalents in 2001. Compared to the emissions in 2000, this represents an increase of about 26 per cent. The emissions in 1990 were insignificant. The application category refrigeration and air conditioning contributed by far with the largest part of the HFCs emissions in 2001. The other categories foam and foam blowing, fire extinguishing products, and solvents and aerosol propellants contributed small amounts to the overall emissions. The emissions were calculated using the Tier 2 methodology. Figure 15 shows the emissions of HFCs in the period 1990-2001. A table showing the actual emissions of different HFCs over the same period can be found in Section 4.4. – Consumption of halocarbons (HFCs) (Table 9).

We have also calculated the potential emissions employing the Tier 1b methodology, which includes the import and export of chemicals in bulk and in products. The ratio between potential and actual emissions was about 23 in 1990, while it was reduced to ca. 5 in 1998 and further to about 4 in 2001. This shows that the consumption of HFCs still is growing, but at a much slower rate than in the 1990s. It is expected that the actual emissions will approach the potential emissions in about 20-30 years (SFT 2001b).

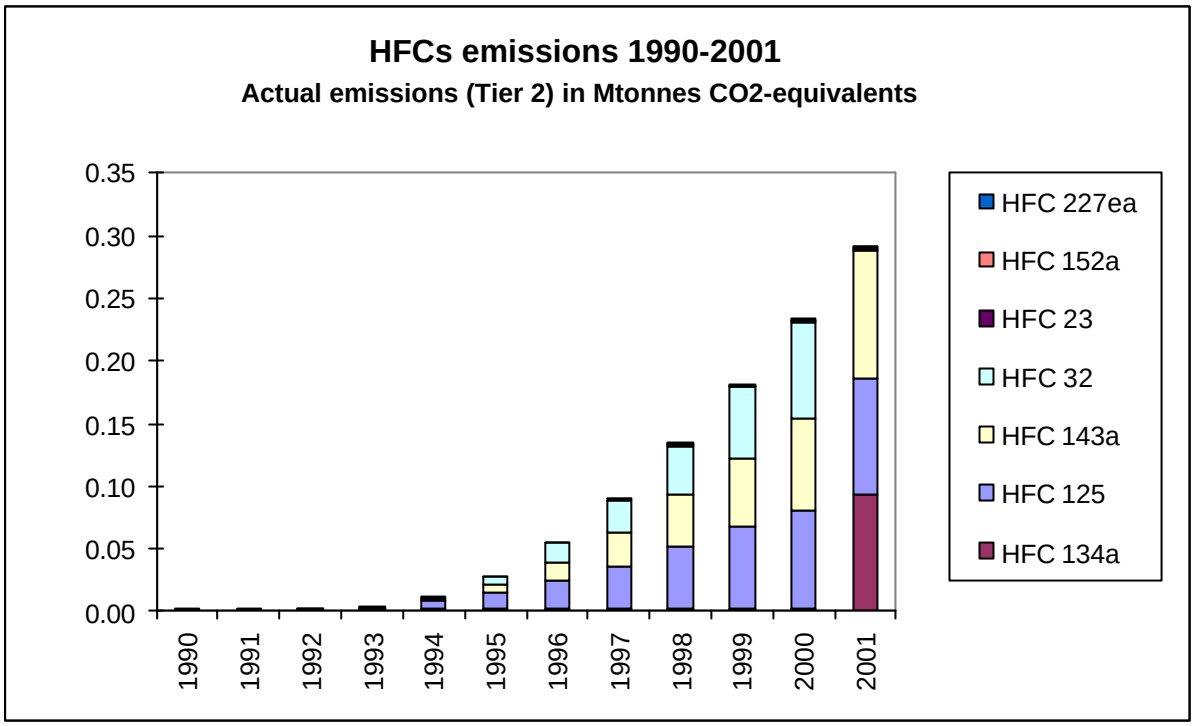


Figure 15. Emissions of HFCs in Norway 1990-2001. Source: SN/SFT

2.3 Emission trends by source

The largest contributor to the total greenhouse gas emissions in Norway is the Energy sector, followed by Industrial Processes, Agriculture, Waste and Solvent Use. During the 1990s the contribution of the Energy sector to the emission total increased by about 8 per cent, and this development occurred primarily at the expense of the contribution from Industrial Processes.

The distribution of the Norwegian greenhouse gas emissions over the UNFCCC sectors in 2001 is shown in Figure 16. Emissions from the Energy sector account clearly for 2/3 of the national total and Industrial Processes 4 times less than that.

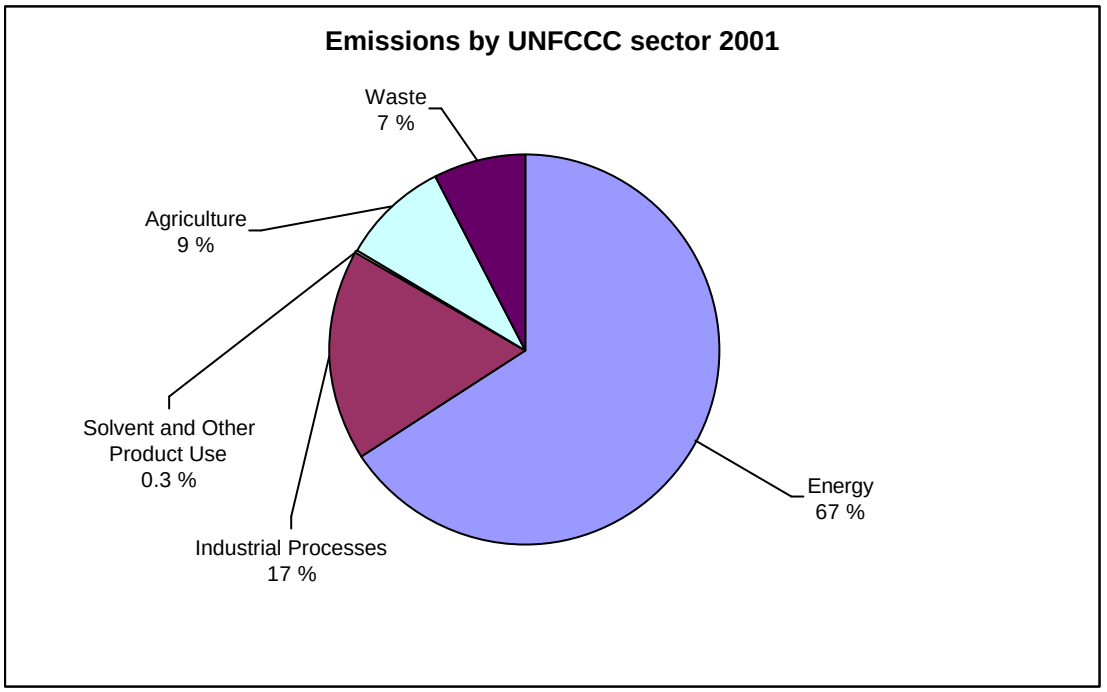


Figure 16. Emissions of greenhouse gases by sector in Norway in 2001. Source: SN/SFT

2.3.1 Energy

The Norwegian energy sector has traditionally been characterised by large amounts of readily available hydroelectric power. This has resulted in a preference of electricity in favour of fossil fuels in heating and many manufacturing processes.

The emission changes detected in the various source categories in the energy sector between 1990 and 2001 are illustrated in Figure 16 and discussed in the following. In addition, Figure 17 displays the distribution of 2001 emissions on the source categories in the Energy sector.

During most of the 1990s energy related emissions were increasing, mainly due to higher activity in the oil and gas extraction sector and in the transport sector. In 2001 the total emission level in this sector was 24 per cent higher than those of 1990. After a temporary emission reduction in 2000, emissions from the Energy sector reached the 1999 level in 2001 of about 36 Mt CO_2 equivalents. As already explained in Section 2.1 the relatively low emission level in 2000 is caused by a mild winter and tax changes which resulted in reduced use of fuels for heating purposes and reduced fuel sales respectively. The latter component has led to lower estimates of emissions from navigation, road vehicles and civil aviation.

Offshore oil- and gas extraction has played an important role in the national economy in recent decades. On the offshore oil- and gas installations, electricity and pumping power is principally produced by gas turbines and, to a lesser extent, diesel engines. Emissions from these sources are accounted for under the UNFCCC sector "*Manufacturing of Solid Fuels and Other Energy Industries*". In 2001 the emissions from oil and gas extraction off shore contributed to about 18 per cent of the total GHG emissions in Norway. In 1990 the corresponding contribution was 13 per cent and the growth detected can be explained by increased production of oil and gas. During the period 1990-2001 there was a 50 per cent

increase in the total greenhouse gas emissions from energy production offshore. Onshore energy industries comprise oil refineries and gas terminals.

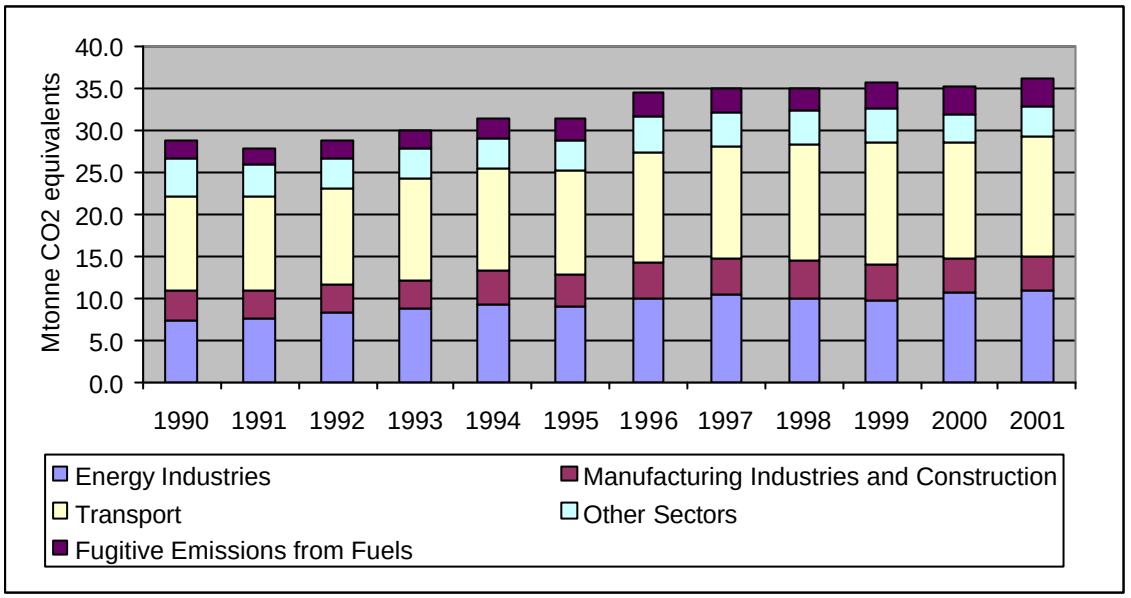


Figure 17. Total greenhouse gas emissions in the Norwegian energy source categories during the period 1990-2001. Source: SN/SFT

Public generation of electricity and heat is completely dominated by hydroelectric generation, the only important exception being waste incineration plants and a small coal combustion plant (6 MW) on the island of Spitsbergen.

Industrial emissions related to fuel combustion[2] originate to a large extent from the production of raw materials and semi-manufactured goods, e.g. alloys, petrochemicals, paper and minerals. Emissions from manufacturing and construction increased by 17 per cent in the period 1990-2001, with the most pronounced rise being in the petrochemical industry (starting up of a new methanol production plant) and the pulp and paper industry.

Emissions from **transport** showed an overall increase of about 25 per cent from 1990 to 2001, while there was an increase of 3 per cent from 2000 to 2001. The share of transport in the total GHG emissions was 25 per cent in 2001 and 22 per cent in 1990. Road traffic accounts for more than 2/3 of the total mobile emissions and these emissions have increased by 25 per cent since 1990. The temporary decrease of 3 per cent detected in the emissions from road vehicles from 1999 to 2000 is due to changes in fuel taxes from 1 January 2000 which led to change stock-in-trade for fuels. Emissions from navigation increased by 20 per cent from 1990 to 2001, mainly because of increased activity related to the oil- and gas extraction sector. Emissions from civil aviation have increased by 56 per cent since 1990 while there was an increase of less than 1 per cent from 2000 to 2001. Domestic civil aviation contributed to the total national GHG emissions by almost 2 per cent in 2001. Due to the fact that most railways are electrified in Norway, emissions of GHG from this source are insignificant.

[2] Mainly emissions from use of oil or gas for heating purposes. Does not include consumption of coal as feedstock and reduction medium, which is included in the industrial process category.

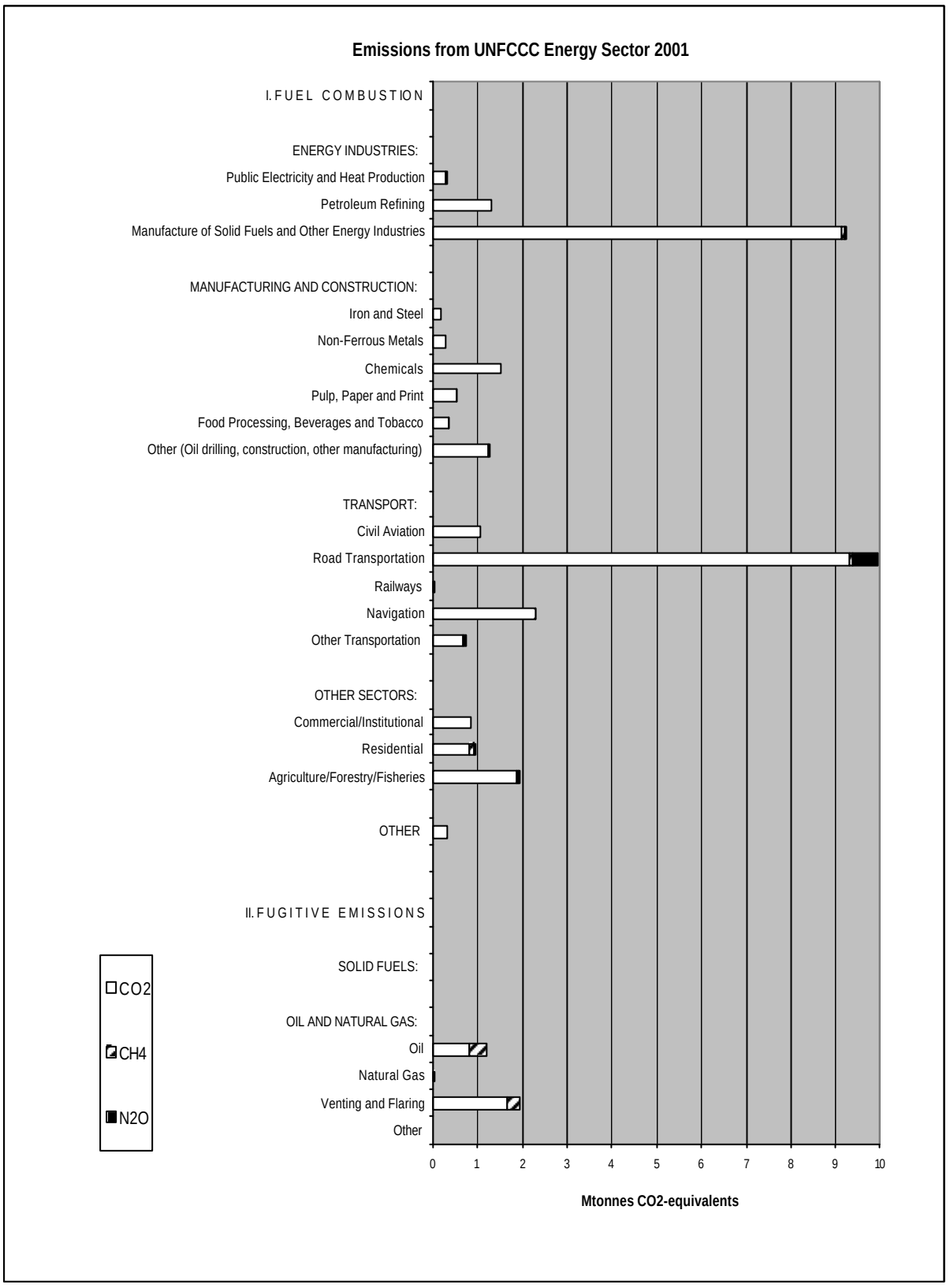


Figure 18. Emissions of greenhouse gases from the energy sector in Norway in 2001. Source: SN/SFT

Due to electrification of heating infrastructure, emissions from **residential sources** (included under "Other sectors" in the CRF tables) have decreased by about 40 per cent since 1990. However, new technologies and occasional electricity shortages have at times reversed this trend during the 1990s. A recent example is the relatively low emissions from this source category in 2000 due to the mild winter which led subsequently to relatively low consumption of fuels for heating purposes.

The source category termed **Fugitive emissions from fuels** in the CRF tables refers to emissions from oil and gas activities. These emissions originate from flaring of natural gas, leakages and venting of methane. Indirect CO_2 emissions from NMVOC emitted during the loading and unloading of oil tankers are also accounted for in this category. In order to minimise emissions from these activities, Norway has implemented various technical measures and a CO_2 tax. Nevertheless, due to large increases in production, emissions have increased by almost 40 per cent from 1990 to 2001. The emission level in 2001 is lower than the one in 2000 by 4 per cent mainly due to reduced flaring off shore.

2.3.2 Industrial processes

Production of raw materials is the main source of process related industrial emissions for both CO_2 and other greenhouse gases such as N_2O (fertiliser production), SF_6 (magnesium foundries) and PFCs (aluminium production). The industrial process sector accounts for about 20 per cent of the national greenhouse gas emissions. Figure 19 shows that emissions have been relatively stable at about 10 Mt CO_2 equivalents after a substantial reduction in the period 1990-1992 due to technological improvements and process management. The decreasing trend in the emissions of PFCs over the years has been counteracted by the rising emissions of CO_2 from this sector.

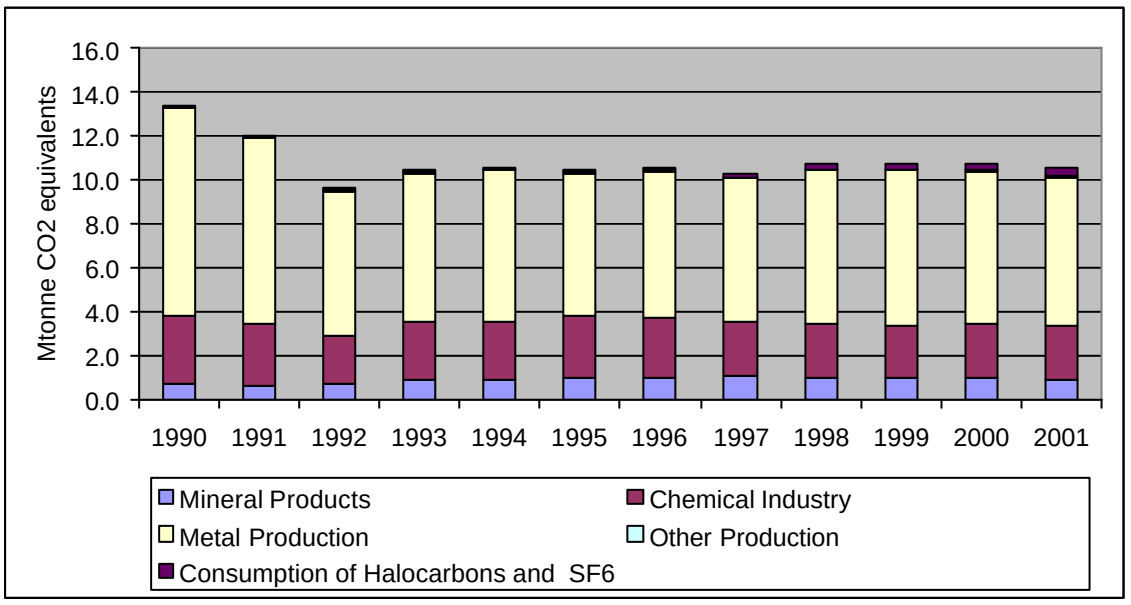


Figure 19: Total greenhouse gas emissions in the Norwegian industrial source categories during the period 1990-2001. Source: SN/SFT

During the first half of the 19th century there was a large-scale industrialisation in Norway. Many industrial communities appeared around the large hydroelectric resources, particularly in the western parts of the country. Typical products were raw materials and semi-manufactured goods such as aluminium and ferroalloys. The main energy source has always been hydroelectricity. However, fossil fuels have been used as reducing agents or raw materials. Greenhouse gases are emitted as process related gases.

Norway is a major producer of **ferroalloys** with 15 plants in operation. CO_2 is emitted from these plants due to the use of coal and coal coke as reducing agents. These emissions have increased by 11 per cent from 1990 to 2001 due to a growth in production. 5.3 per cent of national total GHG emissions were CO_2 from ferroalloys production in 2001.

Norway is one of the worlds leading producer of primary **aluminium** with 7 plants. Both the prebaked anode and the Søderberg (old and new) production technologies are in use. The main energy source is electricity, but CO_2 is emitted from the use of petrol coke, coke of coal and from coal electrodes. In addition, the production of aluminium gives rise to emissions of PFCs. From 1990 to 1992 the emissions of PFCs were reduced by as much as 33 per cent. Since then there has been a stable reduction until 2001 when the PFC emissions were 67 per cent lower than in 1990. The total GHG emissions from aluminium production were reduced by 38 per cent in the period 1990-2001. The reduction in PFCs emissions is caused by improved technology and process control, which has led to reduced PFC emissions per tonne aluminium produced from 3.49 to 0.99 tonnes CO_2 equivalents in the years 1990 to 2001. In 1997 the aluminium producers and the Ministry of Environment signed an agreement to reduce emissions of greenhouse gases from production. According to the agreement the emissions measured as CO_2-equivalents per tonne primary aluminium produced are to be reduced by 50 per cent in 2000 and 55 per cent from 2005. In 2001 the emissions of the greenhouse gases CO_2 and PFC were reduced by less than 50 per cent.

The major **iron** producing plant was closed down in 1988, but a minor plant still exists. Other metals produced in Norway today are nickel, zinc and magnesium, one plant of each.

Cement is produced in two plants in Norway. Cement production processes release CO_2 emissions from coal and waste used in direct fired furnaces, and from carbon in limestone. The latter is reported as process related emissions according to the 1996 Revised IPCC Guidelines. Due to growth in production the CO_2 emissions from cement production increased by 28 per cent from 1990 to 2001 and accounted in 2001 for 1.5 per cent of total GHG emissions.

The **chemical industry** in Norway includes primarily production of fertilisers and silicon carbide. These processes release N_2O (from nitric acid production) and CO_2 (from production of ammonia and carbides). The collective emissions of N_2O and CO_2 decreased by 22 per cent in the period 1990-2001 and in 2001 they accounted for 4.3 per cent of the total GHG emissions in Norway. The detected reduction is due to improved technology in the nitric acid production, which has, however, been somewhat counteracted by higher levels of production.

The major source of SF_6 emissions is **magnesium** production. These emissions have been reduced through the 1990s due to improvements in technology and process-management. The emissions in 2001 were 64 per cent lower than in 1990. However, there has been a significant increase in SF_6 emissions from 1998 due to growth in production of magnesium as well as increased production and higher shares of primary production versus recycled metal. The

consumption of SF_6 per tonne primary magnesium produced is higher than for recycled magnesium. However, the company producing primary magnesium stopped this activity in 2002 and retained only the production of secondary magnesium. Consequently, the annual emission figures are expected to decrease by about one third in subsequent years.

Refrigeration and air conditioning equipment is the most important application category related to emissions of **halocarbons** (HFCs). Increased application of air-conditioning systems in new cars amplifies the rapid growth in these emissions. Electrical switchgears and the use of SF_6 as trace gas are the most important source of non-process emissions of SF_6. Norway does not manufacture halocarbons or SF_6.

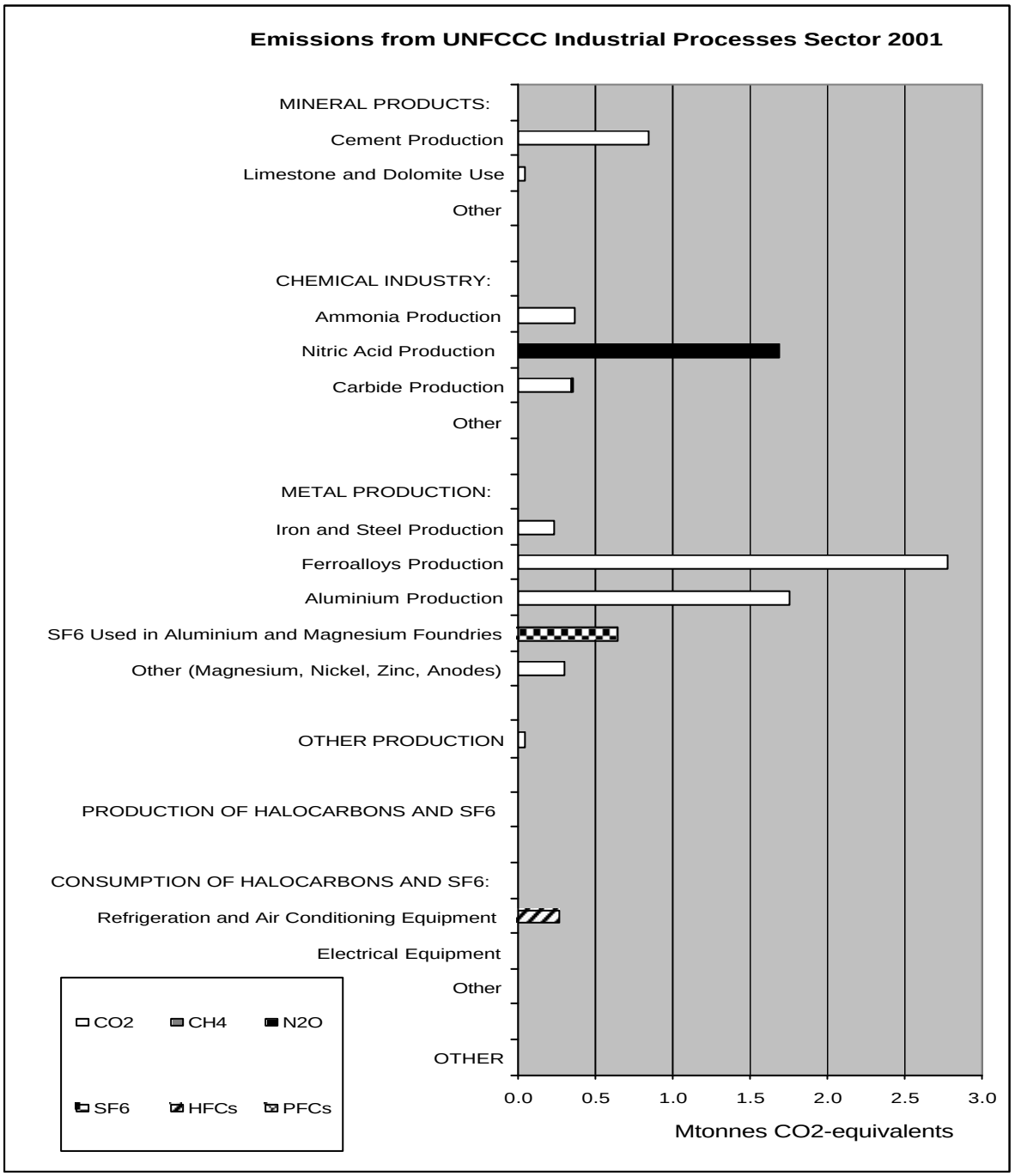


Figure 20. Emissions of greenhouse gases from the industrial processes sector in Norway in 2001. Source: SN/SFT

2.3.3 Solvent and other product use

The use of solvents and products containing solvent leads to emissions of NMVOC, which in turn oxidises in the atmosphere to form CO_2. This emission source represents a share of 0.2 per cent of the national totals of GHGs. The share has been more or less unchanged since 1990.

2.3.4 Agriculture

Emissions from agriculture were relatively stable during the 1990s, with emission levels of around 5 Mtonnes CO_2-equivalents.

Greenhouse gas emissions from agriculture comprise direct emissions of methane and nitrous oxide and oxidised emissions of CO_2. The GHG emissions from this sector accounted for 9 per cent of the overall Norwegian GHG emissions in 2001. Between 1990 and 2001 there has been a 2 per cent decrease attributed to reduced emitted amounts of N_2O.

The largest sources for agricultural GHG emissions are N_2O from soil processes and CH_4 from enteric fermentation from cattle and sheep et cetera. Each of these source categories contributes to almost 40 per cent of the total GHG emissions from the agricultural sector. The remaining emissions in this sector originate from indirect emissions of N_2O (N losses by volatilisation, leaching and runoff and sewage production), animal production outdoors (N_2O) and CH_4 and N_2O from manure management.

Over the period 1990-2001 the nitrous oxide emissions from agriculture decreased by about 4 per cent because of reduction in direct soil emissions due to that the amount of N in harvested products has been reduced which decreases the N_2O emissions from crop residues. Methane emissions have been unchanged in the same period. These figures might reflect the stability of the production in the agricultural sector and the absence of improvements in technology resulting in lower emissions of GHGs.

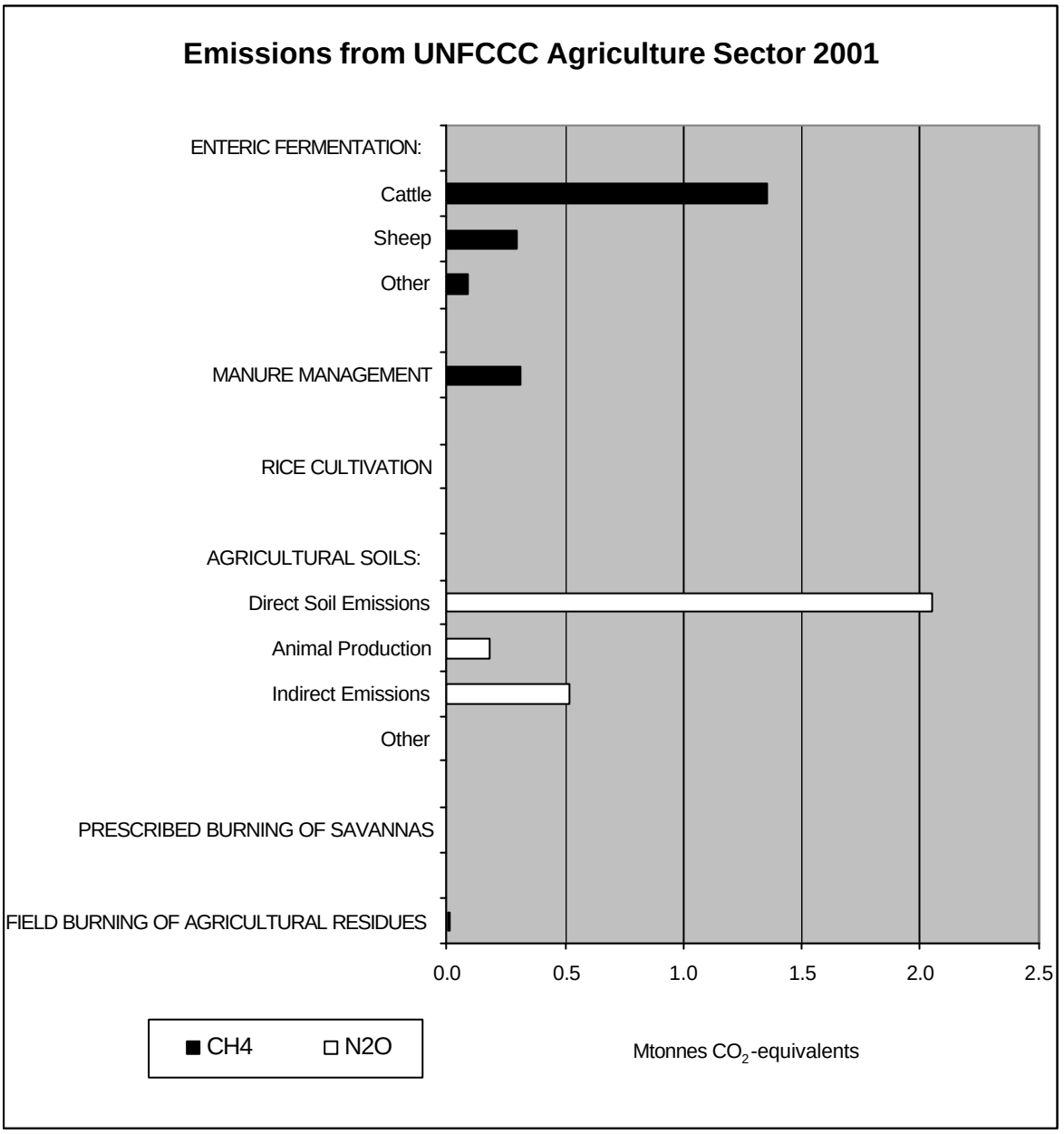


Figure 21. Emissions of greenhouse gases from the agriculture sector in Norway in 2001. Source: SN/SFT.

2.3.5 Waste

Emissions from waste were relatively stable during the 1990s, with emission levels of around 4 Mtonnes CO_2-equivalents.

Emissions of GHG from waste, mainly methane from landfills, accounted for 7.5 per cent of the total GHG emissions in Norway in 2001.

Figure 22 shows that emissions of methane have decreased slightly since 1996 due to 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 is today equal to 320 NOK per tonne waste disposed at landfill sites. In addition, landfills receiving biodegradable waste (waste containing degradable organic carbon (DOC)) are required to collect and treat landfill gas. Today 54 landfills have installed a landfill gas extraction system, and approximately 21 ktonnes of methane were recovered in 2001. In addition, the amounts of waste recycled have increased significantly since 1990.

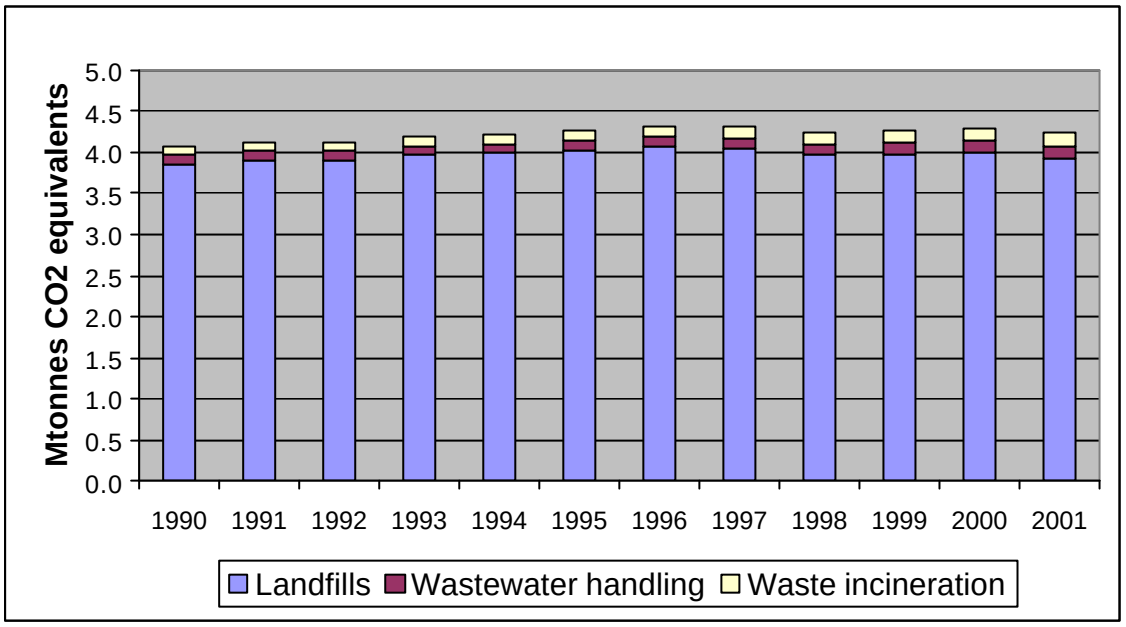


Figure 22. Total greenhouse gas emissions from the waste sector in Norway during the period 1990-2001. Source: SN/SFT

2.4 Land Use Change and Forestry

During the 1990s the net uptake of CO_2 from land-use change and forestry activities has almost doubled. The net removal of CO_2 in 2001 would offset 33 per cent of the total greenhouse gas emissions that year. This removal includes biomass above and below ground. However, the uptake of CO_2 in forest and agricultural soil is not included in the calculations. Furthermore, harvested wood products are calculated according to the IPCC default methodology and are, thus, expected to be emitted to the atmosphere immediately after harvest.

In Norwegian forests, until the beginning of 1900, the harvest was of about the same size as the regrowth. Since then the standing volume has increased, it almost doubled from 1925 to 2001, while the harvest has been about the same (10 million m^3 per year). Figure 23 shows this development for the period 1950 onwards. The large increase in the standing volume is primarily due to active forest management. The result is a considerable net increment and hence accumulation of carbon in forests.

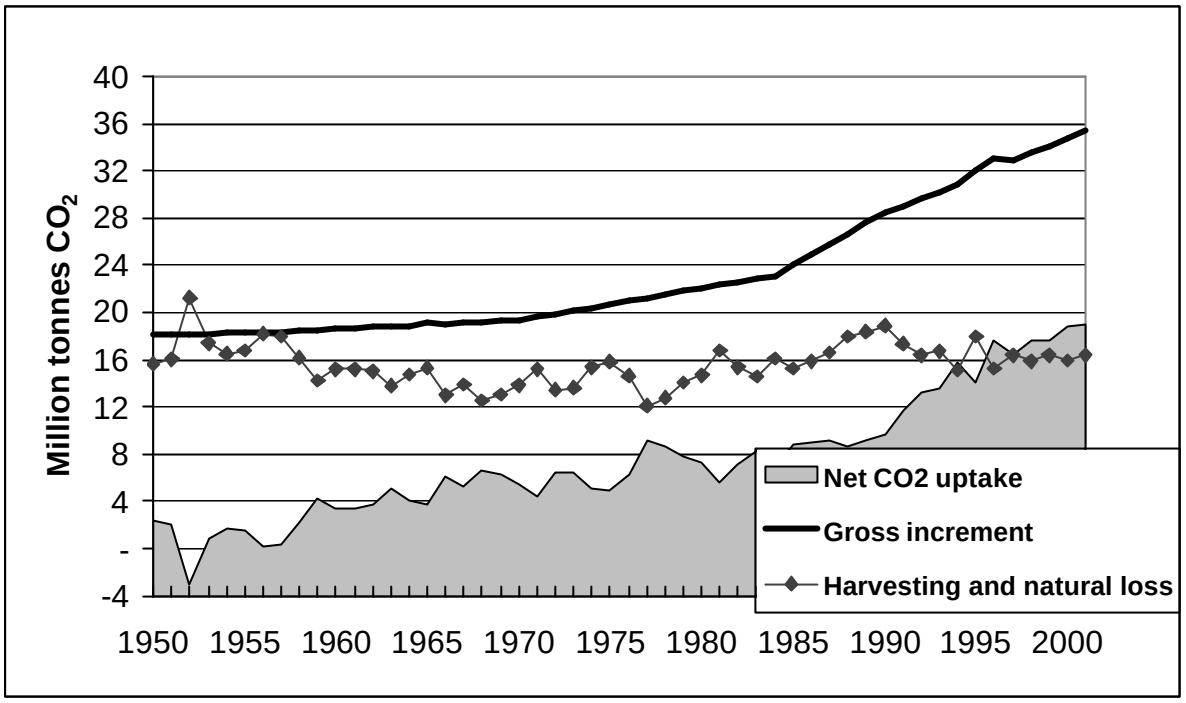


Figure 23. CO_2 removal in Norwegian forests during the period 1950-2001. Source: SN/SFT

The net CO_2 removal including biomass above and below ground increased from about 9.8 million tonnes CO_2 in 1990 to 19 million tonnes in 2001. The explanation for this is a continued increase in standing volume and gross increment while harvesting and natural losses did not increase. In the period 1990-2001, the standing volume under bark increased from about 578 million m^3 to 710 million m^3. The gross increment of biomass above and below ground increased from about 23.7 million tonnes CO_2 in 1990 to about 35.4 million tonnes CO_2 in 2001. Harvesting and natural losses did not follow the same increasing trend, but varied between 15.9 million tonnes CO_2 in 1998 and 19.7 million tonnes CO_2 in 1990. The total gross depletion was about 16.4 million tonnes CO_2 in 2001.

2.5 Emission trends for indirect greenhouse gases and SO_2

Nitrogen oxides (NOx), non-methane volatile organic compounds (NMVOC) and carbon monoxide (CO) have an indirect effect on climate through their influence on greenhouse gases, especially ozone. Sulphur dioxide (SO_2), on the other hand, affects climate through increasing the level of aerosols which have in turn a cooling effect on the atmosphere.The trend of these pollutants in Norway during the period 1990-2001 is presented in Figure 24.

Emissions of NO_X have decreased by about 1 per cent from 1990 to 2001. Reduced emissions from road traffic due to the introduction of stricter emission regulations have been counteracted by increased emissions from oil and gas production and navigation.

Emissions of NMVOCs increased by 28 per cent from 1990 to 2001 due to a growth in loading of crude oil, despite the reduced emissions from road traffic. The moderate downward trend in the emission between 1996 and 1998 is due to installation of a vapour recovery unit at one of the oil terminals onshore.

From 1990 to 2001 the emissions of CO have decreased by about 37 per cent, mainly because of new emission standards for motor vehicles.

Emissions of SO_2 were reduced by 52 per cent from 1990 to 2001. This trend has mainly been caused by the reduction in the sulphur content of all oil products and by lower process emissions from the production of ferroalloys and aluminium and from the refineries. Emissions from Industrial Processes, the most important contributor to the national SO_2 total emissions, decreased by 51 per cent during the same period.

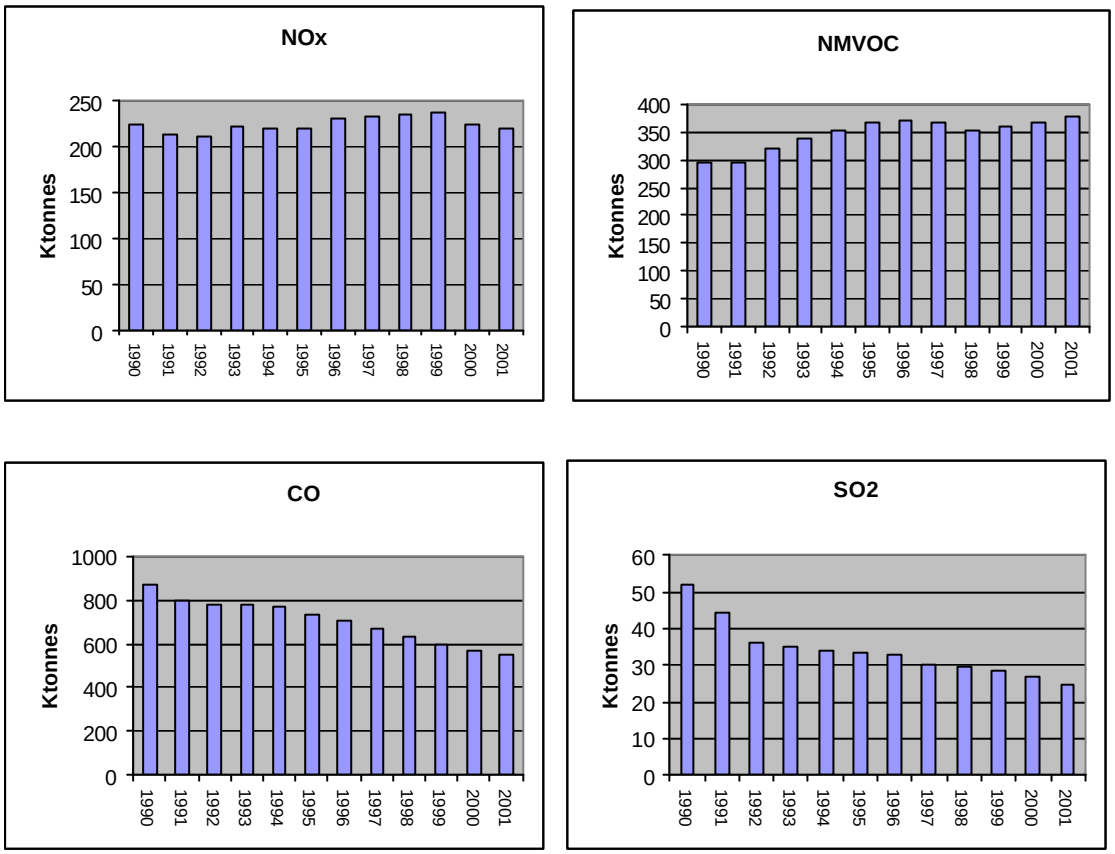


Figure 24. Emissions of NO_x, NMVOC, CO and SO_2 in Norway during the period 1990-2001. Source: SN/SFT

Chapter 3. Energy

3.1 Overview

The Energy sector accounts for around 2/3 of Norwegian GHG emissions. Road traffic and offshore gas turbines (electricity generation and pumping of natural gas in pipelines) are the sector's largest single contributors, while coastal navigation and energy used for the production of raw materials are other major contributors.

The source categories in the energy sector which are found to be *key sources* on the basis of their contribution to the total level and/or trend uncertainty are the following:

- Fuel combustion activities - A1-A4
- Manufacture of Solid Fuels and Other Energy Industries (oil and gas extraction) - 1A1c
- Civil aviation - 1A3a
- N_2O from road traffic – 1A3b
- Navigation - 1A3d
- Commercial/Institutional - 1A4a
- Venting and Flaring - 1B2c (CO_2 from venting, CO_2 from flaring, CH_4 from venting)
- Loading of crude oil offshore and onshore – 1B2a.

As indicated by the CRF code, the first key source category listed above is different from the rest in that it comprises a collection of activities explained in Section 3.2. This feature is a result of the way the Norwegian key source analysis was conducted (SN 2000).

A discussion of the above key sources is presented below, followed by a brief description of the non-key sources in this sector. Subsequently, cross-cutting issues are elaborated. These comprise the issues of:

- Comparison between the sectoral and reference approach
- Feedstocks and non-energy use of fuels
- CO_2 capture and storage in the Norwegian oil and gas production field of Sleipner
- Indirect CO_2 emissions from CH_4 and NMVOC.

Emissions from international bunker fuels and from Norwegian military activities are addressed in separate sections.

3.2 Fuel combustion activities – 1A1-1A4 (CO_2 from Oil combustion)

3.2.1 Description

The parameter which renders fuel combustion activities a key source is the CO_2 emissions from oil combustion in energy and manufacturing industries, in construction, in transport and in other sectors. This parameter is a key source both in level and in trend due to uncertainties in emission factors.

Emissions of CO_2 from fuel combustion activities in Norway have increased by about 20 per cent in the period 1990-2001. In 2001 they constituted about 80 per cent of the national CO_2 total.

3.2.2 Methodological issues

The general method to estimate emissions from energy combustion is to multiply energy use 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 to energy use. However, also emissions from these sources are estimated according to the overall energy balance. The methodology used in the estimation of CO_2 emissions from oil combustion is described in SN/SFT (2000).

Activity data

The energy consumption data used in the emission calculations are taken from the annual energy balances/energy accounts. These survey the flow of the different energy carriers within Norwegian economic activities. They include energy carriers used as raw materials and reducing agents. The latter are subtracted in the data used to estimate the combustion emissions. Some emissions vary with the combustion technology; a distribution between different sources is thus required. Apart from oil products, the total use of each energy carrier is determined by summing up reported/estimated use in the different sectors.

In the case of oil, the total use of the different oil products is based on Statistics Norway's annual sales statistics for petroleum products. This statistics is considered very reliable since all major oil companies selling oil products report to this statistics[3]. In contrast to the other energy carriers, there is thus a given total, which the use in the different sectors must sum up to. 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. In addition to oil products included in the sales statistics, a separate survey/census gives figures on use of waste oil. This survey/census is complete as incineration of waste oil is regulated.

Emission factors

Emission factors for CO_2 are independent of technology and are based on the average carbon content of fuels used in Norway (SFT 1990 and Norwegian Oil Industry Association –OLF 1994). The emission factors for CO_2 from combustion of various energy commodities are listed in Table 4 below as presented in the report SN/SFT 2000.

3.2.3 Uncertainties

The uncertainty in the emission figures under fuel combustion is determined to a large extent by the uncertainty in the emission factors. The uncertainty in the CO_2 emission estimates from the total oil combustion is estimated to be ±3 per cent of the mean (SN, 2000).

3.2.4 Source specific QA/QC and verification

The key source is subjected to the QA/QC procedures described in Section 1.6.

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

3.2.5 Recalculations

The revisions made recently in the inventory data are described below under the individual source categories, listed as key or non-key sources.

Table 4. Emission factors for CO_2 from combustion of various energy commodities. Source: SN/SFT

	Tonnes CO_2/tonne	Tonnes CO_2/1000 Sm^3	**Tonnes CO_2/TJ**
Coal[1]	2.42		86.1
Coal coke	3.19		111.9
Petrol coke	3.59		102.6
Wood etc.	0.0 (1.8[2])		0.0 (96[2])
Waste	0.25		23.8
Natural gas	2.75	2.34	57.3
Natural gas (flaring)	2.86	2.43	-
Refinery gas	2.80		57.6
Excess gas	2.50		50.0
Landfill gas[3]	0.275		
LPG	3.00		65.1
Gasoline (cars)	3.13		71.3
Gasoline (aviation)	3.13		71.3
Kerosene (heating)	3.15		73.1
Kerosene (aviation) (jet fuel)	3.15		73.1
Diesel (road transport)	3.17		73.5
Marine diesel/gas oil	3.17		73.5
Light fuel oil	3.17		73.5
Heavy fuel oil	3.20		78.8
Waste oil	3.20		78.8

[1] Individual emission factors for two factories are used for coal.
[2] Non-fossil emissions not included in the inventory.
[3] Only fossil carbon is taken into account (plastic, rubber, PVC, polyethylene etc.).

3.2.6 Planned improvements

A comprehensive document describing in detail all procedures involved in Norway's emission inventorying activities is currently under preparation by Statistics Norway and the Norwegian Pollution Control Authority. This work is also in response to one of the conclusions drawn during the in-depth review in October 2002, which addressed the need for better documentation routines in the Norwegian inventory system.

3.3 Manufacture of Solid Fuels and Other Energy Industries – 1A1c (Gaseous fuels combustion in oil and gas extraction)

3.3.1 Description

Emissions from the manufacture of solid fuels do not occur in Norway. Emissions from this source category refer almost exclusively to CO_2 and originate predominately from the combustion of natural gas in offshore oil and gas extraction. At these installations, electricity and pumping power are principally produced by gas turbines and to a lesser extent, diesel engines. In 2001 the CO_2 emissions from such gas combustion were 96 per cent of the source

total. The remaining fraction is due to the use of diesel fuel oil in gas turbines and machinery. The emission of CH_4 and N_2O in these operations is negligible.

In recent decades offshore oil- and gas extraction has played an important role in the national economy. In 2001, oil and gas extraction accounted for 19 per cent of the national total GHG emissions and 55 per cent of the stationary CO_2 emissions. Emissions of CO_2 in 2001 were 50 per cent above the 1990 level.

Oil and gas extraction is a key source in level and in trend due to uncertainties in both activity data and emission factors.

3.3.2 Methodological issues

The calculation methodology applied is described in (SN/SFT 2000). According to the IPCC Good Practice Guidance (IPCC 2001) it is used the Tier 2 methodology.

Activity data are based on the consumption figures reported by the Norwegian Petroleum Directorate for all platforms on the Norwegian part of the continental shelf, including the Norwegian economic part of platforms shared with the UK. Data reports include 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. The same situation applies for combustion of natural gas in turbines at gas terminals on shore.

The emission factor for CO_2 from combustion of natural gas in gas turbines is from a study by the Norwegian Oil Industry Association (OLF 1994) reflecting the average carbon content of the natural gas.

At the offshore gas-condensate field Sleipner West the natural gas contains about 9 per cent CO_2. To reduce the CO_2 content in the natural gas to an acceptable level before transported to consumers onshore approximately 1 million tonnes of CO_2 are captured and then stored in a sandstone saline aquifer not fare from the gas field. In the cross cutting Section 3.13.3 methodology for this part of the inventory is described.

3.3.3 Uncertainties

The uncertainty in the activity data is ± 4 per cent and in the CO_2 emissions factor ± 7 per cent. The uncertainty in the emission factor is relatively high as the gas composition can vary according to field.

3.3.4 Source specific QA/QC and verification

The QA/QC procedures applied are described in Section 1.6.

3.3.5 Recalculations

The energy data for gas terminals have been revised in the final energy accounts for 2000. This is the reason for the recalculation of CO_2 this year. There have of course also been recalculations for CH_4 and N_2O for the same reason, but these are of minor importance for the component total.

3.3.6 Planned improvements

Thorough documentation of all procedures involved in the preparation of the inventory data for this source category is in preparation and will be finalised in the second half of 2003.

3.4 Civil aviation – 1A3a

3.4.1 Description

Emissions of CO_2 from civil aviation accounted for about 3 per cent of the total Norwegian CO_2 emissions in 2001. Aviation is a minor source of emissions of methane and nitrous oxide in Norway (less than 0.5 per cent of the total in both cases).

National emissions of CO_2 from civil aviation have increased by more than 56 per cent from 1990 to 2001.

Civil aviation is a key source with respect to level due to uncertainties in activity data.

3.4.2 Methodological issues

The calculation methodology applied is described in report SN 2002. 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 under 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 3.12).

The types of fuel used in aircraft are both jet fuel (kerosene) and gasoline. The latter is used in small aircraft only. Consumption of aviation gasoline is based on sales figures. Domestic consumption of jet kerosene has been reported to SN 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.

The Norwegian Petroleum Industry Association provides emission factors for CO_2 from the combustion of jet fuel and gasoline (SN/SFT 2000). The emission factors for N_2O and CH_4 are uncertain. Default emission factors from the IPCC (IPCC 1997a,b) are used for jet fuel, while factors for CH_4 for gasoline are derived from VOC data. The NO_X, CO and VOC emission factors are aircraft specific as given in EEA (2001).

3.4.3 Uncertainties

The uncertainty in the emissions from aircraft is about 20 per cent of the mean due to the difficulty in separating domestic emissions from bunkers (SN, 2000). In recent study on emissions from aircraft (SN, 2002), fuel consumption was also estimated bottom-up and compared to the reported figures (source specific QA/QC). 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.

3.4.4 Source specific QA/QC and verification

All inventory elements in this source category are subjected to QA/QC routines described in Section 1.6.

3.4.5 Recalculations

No revisions have been performed in this source category.

3.4.6 Planned improvements

Thorough documentation of all procedures involved in the preparation of the inventory data for this source category is under way and will be finalised in the second half of 2003.

3.5 N_2O from Road Traffic – 1A3b

3.5.1 Description

Emissions of N_2O from road traffic accounted for 11 per cent of the N_2O total and 1 per cent of the national GHG emissions in 2001. Since 1989 they have been increasing rapidly due to the introduction of catalytic converters. In 2001 N_2O emissions were more than six times greater than the 1990 levels.

This source category is a key source with respect to total level and trend due to uncertainties in the emission factors.

3.5.2 Methodological issues

Emissions from road traffic are estimated by a model operating at Statistics Norway (SFT 1993; SFT/SN 1999b). A detailed description of its present structure is presented in (SN/SFT 2000). The calculation is based on detailed vehicle types and technologies, annual mileage per type and driving modes. Emissions from cold start and evaporation are estimated separately. The model results (expressed as average emission factors) are used as input to the general emission model.

Activity data such as vehicle numbers and mileage are used to allocate fuel consumption to usage classes. They are, as far as possible, taken from official registers, public statistics and surveys. However, some data are based on assumptions.

The emission factors are derived from driving cycle measurements made in Norway and other countries. The most important sources, besides Norwegian measurements reported to SFT (SFT, 1993), are data from (Eggleston et al. 1991, EEA 1997) and (Hassel et al. 1994). Emissions from warm engines and additional emissions from evaporation and cold starts are calculated separately. Evaporative emissions are estimated by the method described in the Corinair Guidebook (EEA 1996). Cold start emissions are calculated using factors from the COPERT Programme and from Sérié & Joumard (1996), taking into account detailed driving

patterns and regional temperature data. Changes in emission factors due to ageing of vehicles have been taken into account by introducing ageing factors per 10,000 km.

3.5.3 Uncertainties

All sources of N_2O have an assessed uncertainty of more than 100 per cent (SN 2000).

3.5.4 QA/QC and verification

Source category elements undergo the general QA/QC routines described in Section 1.6. Top down and bottom up data on fuel consumption are annually compared for gasoline and diesel vehicles. For gasoline the difference is small (maximum a few percent), for diesel it is far higher (about 30-40 per cent). The reason is probably that diesel is used for other applications than road transport, higher uncertainty in consumption factors and that the driving mode data are uncertain.

3.5.5 Recalculations

There have been revisions in the energy accounts regarding the consumption of auto diesel in agriculture. These revisions have influenced the on-road/off-road distribution of the total diesel consumption. Up to 1997 this revision led to an increase in the road traffic emissions. For 1998-2000 the road traffic emissions have been reduced compared with last year's submission. This methodological change required recalculations of all components for the whole time series. The revision has been most important for CO_2.

3.5.6 Planned improvements

This source category is very important for the trend. It has, therefore, been prioritised in the inventory improvements the last years (SN 2000). The future improvement of the estimate of N_2O from road traffic is dependent on the availability of measurement data that are applicable for Norwegian conditions. Recent studies have indicated that the increase in N_2O emissions factors is reduced for the newer types of technology. Norway will consider changing the emission factor if this documentation is confirmed by more studies.

3.6 Navigation – 1A3d

3.6.1 Description

Emissions of CO_2 from Norwegian navigation increased by almost 19 per cent in the period 1990-2001 due to general growth in economy activity, primarily in the oil and gas extraction sector. In 2001 they accounted for 4 per cent of the total GHG emissions in Norway. The contribution of CH_4 and N_2O to the total emission in this sector is insignificant.

Navigation is a key source both in level and trend due to uncertainties in activity data.

3.6.2 Methodological issues

The levels and the spatial distribution of emissions from national sea traffic are estimated by an updated and improved methodology presented in the report SN 2001. This methodology is based on the work performed by Statistics Norway (SN, 1996; SN, 1998 and 2001a). 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 3.12) and in accordance with the IPCC Good Practice Guidance.

Annual emissions are estimated from sales of fuel to domestic shipping and fishing and an average emission factor. For 1993 and 1998 emissions have also been estimated based on a bottom up approach (SN 2001a)[4]. In particular, 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. The fuel use is used to verify the use estimated from sales figures. Emissions were estimated from ship and size specific emission factors and the fuel use. From this, average emission factors were estimated for application in the annual update based on fuel sales.

Information on fuel use in different vessel types is drawn from available statistics and/or obtained through calculations. Figures on use of marine gas oil, heavy distillates and heavy fuel oil in domestic navigation are taken from the annual sales statistics for petroleum products. For fuels used in fishing vessels, figures from sales statistics are used directly.

Information on fuel used in freighters is gathered from surveys performed by SN. In cases where information on oil related vessels are lacking, data are collected directly. Data on fuel consumed by public road ferries are available from the Directorate of Public Roads, whereas the consumption in 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 the report SN 1996.

The annual sales statistics for petroleum products gives figures on use of marine gas oil, heavy distillates and heavy fuel oil in domestic navigation. 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.

For CO_2 the standard emission factors based on carbon content are used (for marine gas oil/diesel and special distillate: 3.17 kg/kg fuel; for heavy fuel oil: 3.20 kg/kg fuel).

Emission factors for CH_4 and N_2O are 0.23 g/kg fuel and 0.08 g/kg fuel, respectively, and are taken from IPCC (1996).

3.6.3 Uncertainties

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 (SN 2000).

[4] This approach is too resource demanding to perform annually.

3.6.4 Source specific QA/QC and verification

All inventory elements in this source category are subjected to QA/QC routines described in Section 1.6.

In 2001 bottom-up (from surveys) and top down data (from sales) on fuel consumption were compared (SN 2001a). 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 precise in the sale statistics. A similar deviation has been found for the years 1993 and 1998 which, as mentioned above, were studied more closely. In the calculations, sales figures are used as they are assumed to be more complete and are annually available.

3.6.5 Recalculations

There has been an increase in emissions for all components in 2000 due to the revision of the preliminary energy data.

3.6.6 Planned improvements

Thorough documentation of all procedures involved in the preparation of the inventory data for this source category is under way and will be finalised in the second half of 2003.

3.7 Commercial/Institutional – 1A4a

3.7.1 Description

Emissions from the commercial and institutional sector have increased by 4 per cent during the period 1990-2001. In 2001 they accounted for 1.5 per cent of the total GHG emissions in Norway.

This sector is a key source with respect to total level uncertainty due to uncertain activity data and change in trend.

3.7.2 Methodological issues

The emission calculation is based on a Tier 2 methodology that is described in (SN/SFT 2000).

The sales statistics for petroleum products, derived from reports on sales figures from the oil companies, constitute the basis for annual figures on the use of different oil products in Norway. These are the basis for the calculation of Norwegian emission figures by economic sectors.

While for some sectors (i.e. manufacturing plants) SN collect annual reports on their energy use, for other sectors such as Commercial/institutional the available statistics on fuel consumption is very limited. Activity data for this source category are based on occasional surveys. However, the consumption in these sectors is always balanced so that the total fuel consumption (based on sales figures) is accounted for.

For liquid fuels, coal and coke the CO_2 emission factors used reflect the average carbon content of Norwegian fuels (SFT 1990 and OLF 1994).

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 the 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 estimated for.

3.7.3 Uncertainties

The emission factors for CH_4 have an uncertainty of 50-100 per cent of the mean, while the uncertainty in the emissions factors of N_2O exceed 100 per cent (SN 2000). The CO_2 emission factors are well known, within ± 3 per cent.

3.7.4 Source specific QA/QC and verification

All inventory elements in this source category are subjected to QA/QC routines described in Section 1.6.

3.7.5 Recalculations

There has been an increase in emissions for all components in 2000 due to the revision of the preliminary energy data.

3.7.6 Planned improvements

Thorough documentation of all procedures involved in the preparation of the inventory data for this source category is under way and will be finalised in the second half of 2003.

3.8 Fugitive emissions from oil loading - 1B2a-b

3.8.1 Description

The major emissions from the source category 1B2a-b are direct emissions of CH_4 and indirect emissions of CO_2 from oxidised NMVOC during loading, unloading and storage of crude oil on shuttle tankers off shore. In addition this source category includes emissions of CH_4 and NMVOC, and hence indirect CO_2 emissions, from loading of crude oil on-shore, distribution of oil products, gas terminals and from refining and storage of oil at refineries, see Section 3.13.4.

This source category contributes to about 2 per cent of the total GHG emission in Norway in 2001. Due to increased amounts of crude oil loaded and a general growth in the petroleum sector the emissions have increased by 120 per cent since 1990.

CH_4 emissions and indirect emissions of CO_2 from oil loading etcetera are key sources both in level and in trend due to uncertain emission factors.

3.8.2 Methodological issues

Methodology

The emissions of CH_4 and NMVOC from loading, unloading and storage of crude oil on shuttle tankers are calculated on the basis of the amount of crude oil loaded, unloaded and stored and on field specific emission factors. Since year 2000 some tankers have had installed vapour recovery units (VRU). Emissions from loading, unloading and storage of crude oil with and without VRU are calculated separately for each field. Only the Norwegian part of oil production at fields with oil loading is included.

A similar method is used for calculating emissions from loading of crude oil at the two Norwegian oil terminals onshore and the emissions are reported by the terminals to SFT. The emission factor is considerably lower at one terminal than at the other because the oil is transported by ship to the terminal 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. In 2001, NMVOC emissions at this terminal were estimated to be as much as 51 per cent lower than they would have been without VRU. However, VRU technology is not designed to reduce methane and ethane emissions.

Activity data

The amount of crude oil loaded at shuttle tankers used in the calculation of CH_4 and NMVOC are collect by SN from the Norwegian Petroleum Directorate (OD). This data from each field is reported by the field operators to OD. The allocation of the amount of crude oil loaded/unloaded and stored at shuttle tankers with or without VRU is from the annually report the field operators is committed to deliver to SFT and OD.

Emission factors

Emission factors used in the calculation of the CH_4 and NMVOC emissions are field specific and is reported to SFT and OD in the same annually report as mentioned before. SFT forwards the emission factors to SN.

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.

3.8.3 Uncertainties

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

3.8.4 Source-specific QA/QC and verification

SN collects the activity data used in the calculation from the Norwegian Petroleum Directorate (OD). The figures are quality controlled by comparing them with the figures reported in the field operators annually report to SFT and OD.

The calculated emissions are compared with the emission data the field operators report to SFT and OD. When discrepancies are found between the two sets of data this is investigated and corrections are made if appropriate. If errors are found SFT contacts the plant to discuss the reported data and changes are made if necessary.

3.8.5 Recalculations

The emission data for 1997-2000 is recalculated since the previous submission of data to UNFCCC due to revised emission factors for some oil fields.

3.8.6 Planned improvements

There are no specific plans to improve reported data before NIR 2004.

3.9 Fugitive emissions from venting and flaring - 1B2c (CO_2 from venting, CO_2 from flaring, CH_4 from venting)

3.9.1 Description

Fugitive emissions in the Norwegian energy sector originate primarily from the extraction and handling of crude oil and gas. This includes CO_2 emissions from flaring of natural gas off shore, CO_2 from flaring at gas terminals and refineries, CO_2 from well-testing and venting of CH_4 during drilling and extraction of oil and gas some minor emissions of CH_4 and N_2O from flaring. The major source in sector 1B2 is flaring on oil- and natural gas fields and venting of CH_4. CO_2 from flaring off shore contributed in 2001 to more than 2 per cent of the total GHG emissions in Norway. Despite increased activity in the extraction sector the CO_2 emissions from flaring is at the same level in 2001 as in 1990. From 2000 to 2001 the emission decreased by more than 20 per cent. Technical measures have been implemented to minimise emissions from venting and flaring. The venting rate is low due to strict security regulations.

Venting and flaring in oil and gas extraction off shore is a key source with respect to the total trend due to uncertainties in emission factors.

3.9.2 Methodological issues

Methodology

CO_2 emissions from flaring off shore are calculated by SN on the basis of field specific gas consumption data and country specific emission factor for natural gas.

Emissions of CH_4 and NMVOC from cold venting and diffuse emissions are reported to SFT from each field operator. The emissions are dependent on the age of the platform, the production volume et cetera.

Activity data

The amount of gas flared that SN use in the calculation of the CO_2 emissions from flaring is collected from the statistical office in the Norwegian Petroleum Directorate (OD). OD receives monthly reports with the amount of gas flared. The same data are also included in an annually report to SFT and OD. The two set of data are compared in a quality control of the consumption data.

Emission factors

In the calculation of CO_2 emissions from flaring off shore we use a country specific emission factor. Plant specific emission factors are available but not yet included in the inventory. This is mainly due to difficulties in preparing a consistent time-series.

3.9.3 Uncertainties

Due to uncertainties in the emission factor flaring is a key source in total trend. It is not likely to expect that the uncertainty in trend will be lower when we include field specific emission factors in the calculation.

The uncertainty in the CH_4 emissions and in the indirect emissions of CO_2 is higher than it is for flaring.

3.9.4 Source-specific QA/QC and verification

SN and SFT 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 that there is a tax on gas flared off shore. NPD has a thorough control of the amount of gas reported as flared.

3.9.5 Recalculations

There has been no recalculation of the CO_2 emissions from venting and flaring off shore since the previous submission to the UNFCCC.

3.9.6 Planned improvements

As mentioned several times in the report, Norway is preparing an extended documentation report for all sources in the Norwegian GHG inventory. A detail description of the methodology for the calculation of emissions from the source category 1B2 Venting and flaring is of great importance in the report.

3.10 Coal mining – 1B1a

3.10.1 Description

Norway produces coal on the Arctic island of Spitsbergen. The total production of coal in 2001 was 1.8 million tonnes that is six times higher than in 1990in 2001. The emissions of CH_4 from coal mining were 958 tonnes in 2001.

Emissions from the Russian mine are not included in the Norwegian GHG Inventory.

Coal mining is a key source due to change in trend and due to that the national emission factor we use is in an order of magnitude less than IPCC's default factors.

3.10.2 Methodological issues

Methodology

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).

Activity data

The amount of coal extracted is reported by the plant to SN.

Emission factor

In 2000 the emissions of methane from coal mining were measured in two steps. First, coal was sampled and the methane content in coal was analysed by (IMC Technical Services Limited 2000). 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. This factor also includes the possible emission from handling and crushing at the coal power plant. 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.

Secondly the methane content in ventilation air from the underground coalmines at Spitsbergen was measured. From the Norwegian mines the methane content in the ventilation air was measured to 0.1-0.4 m^3 methane per tonne coal (Bergfald & Co 2000). The low content of methane is explained with the mine's location 300-400 meter *above* sea level. The rock at Spitsbergen is porous and therefore methane has been aired through many years.

According to IPCC`s Good Practice Guidance the Norwegian mine at Spitsbergen should be defined as an underground mine but due to other characteristics it has emissions that are more like those from surface mines. Considering the above mentioned measurements we therefore conclude to use the 0.54 kg methane per tonne coal as emission factor when calculating methane emission from coal mining in Norway.

3.10.3 Uncertainties

The uncertainty in the activity data is regarded as being low. On the other hand there is great uncertainty in the emission factor; maybe as much as -50 to +100 per cent (SN 2000).

3.10.4 Source-specific QA/QC and verification

Internal checks of the emission time-series is carried out by SN and SFT and corrections are made when errors are detected.

3.10.5 Recalculations

No recalculations of the emission data are performed since previous submission to UNFCCC.

3.10.6 Planned improvements

Emissions from the Russian mine will be investigated and included in the Norwegian GHG Inventory in NIR 2004.

3.11 Non-key sources

The non-key sources in the energy sector are:

- Energy industries (1A1), excluding CO_2 from oil combustion activities (A1-A4) and CO_2 from gas combustion under Manufacture of Solid Fuels and Other Energy Industries (1Ac)
- Manufacturing Industries and Construction (1A2)
- Transport (1A3), excluding Civil aviation (1A3a), N_2O from Road Traffic (1A3b) and Navigation (1A3d)
- Other sectors (1A4), excluding Commercial/Institutional (1A4a)

A brief discussion on some methodological issues is given below. The recalculations performed in the various non-key sources are described in Section 3.11.6.

3.11.1 Energy industries - 1A1

The non-key sources under this category are electricity and heat generation and oil refineries. Norway mainly produces electricity from hydropower, so emissions from electricity production are small compared to most other countries. Due to the large production of oil and gas, the combustion emissions from energy production are high.

Public Electricity and Heat Production

The energy producers 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 takes place at Norway's only dual purpose power plant at Svalbard/Spitsbergen, but is relatively small. Waste combustion at district heating plants is reported both to Statistics Norway and the Norwegian Pollution Control Authority and the data are considered to be of high quality. Some emission figures are reported from the plants based on measurements, while others are estimated from reported figures on amounts burned.

Petroleum Refining

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.

The emission factors used in the calculations are described in the report SN/SFT 2000.

3.11.2 Manufacturing Industries and Construction – 1A2

Statistics Norway carries out annual surveys on energy use in manufacturing industries, which supply most of the data material for combustion emissions in these sectors. Information is collected from the major manufacturing plants, while use in smaller plants is estimated. The data on energy use in manufacturing industries are considered to be of high quality. A separate survey gives information on the use of waste oil.

In the case of the construction sector, figures on the use of the different energy carriers are partly taken from the sales statistics for petroleum products and are partly projected from earlier surveys. Energy data are considered to be rather uncertain.

The emission factors used in the calculations are described in the report SN/SFT 2000.

3.11.3 Transport – 1A3

Road transport

The annual sales statistics for petroleum products gives the total use of petrol and auto diesel. After subtraction of use in other sources, i.e. motorized equipment, railways, small boats and snow scooters, the remainder is split between different road vehicles in a separate road traffic model, taking into account lots of available information on car sizes, annual mileage and specific consumption. In some sectors, e.g. agriculture, all use of auto diesel is placed on motorized equipment, while keys to split the use between equipment and cars are used in some manufacturing industries (based on occasional surveys). Some petrol and auto diesel is used in small boats and snow scooters in households. Most of the petrol and auto diesel, however, is used in vehicles. In the late nineties, natural gas was introduced locally, and on a very small scale, in some road vehicles.

Railways

Railway traffic in Norway uses mainly electricity; the minor amounts of diesel used in locomotives are collected annually from The Norwegian State Railways.

Pipelines

Figures on natural gas used in turbines for pipeline transport are reported annually from the Norwegian Petroleum Directorate. These emissions are reported under source category 1A3e.

Motorised equipment

Auto diesel and petrol are used in motorized equipment. In some sectors, e.g. agriculture, all use of auto diesel is placed on motorized equipment, while keys to split the use between equipment and cars are used in some manufacturing industries. For small boats and equipment in households, figures from previous calculations at the National Institute of Technology are used. The total consumption in motorized equipment is considered to be quite uncertain.

The emission factors used in the calculations are described in the report SN/SFT 2000.

3.11.4 Other sectors - 1A4

Households

Statistics Norway's annual survey on consumer expenditure gives figures on use of wood in households. Use of coal coke is based on information from an importer. 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 decided. This method 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. Even more so, as it from the late nineties has been necessary to adjust also 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.

The emission factors used in the calculations are described in the report SN/SFT 2000.

Agriculture

Figures on use of energy in agriculture are included in surveys performed regularly. Sales figures are used to project these figures in the years between. A minor use of coal is collected annually from the only consumer.

Military

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

The emission factors used in the calculations are described in the report SN/SFT 2000.

3.11.5 Recalculations – non key sources Energy

All recent revisions performed for the non-key sources are briefly described in the following.

1A1 a Public Electricity and Heat Production

Emissions of N_2O from waste incineration by district heating production have not been calculated before. Using the national assumption that 2.5 per cent of the reported NO_X emissions are N_2O, emissions have been transferred to N_2O. This recalculation has been carried out for the whole period 1990-2001.

1A2 a Iron and Steel

There are small revisions in the figures compared with last year's submission. The revision is caused by changes in the energy accounts from the preliminary to the final 2000 figures.

1A2c Chemicals

Some small revisions in the energy accounts for use of CO gas have been made for one plant for the whole time series.

1A2d Pulp, Paper and Print

Better knowledge of the waste fractions incinerated at one plant has led to changed CO_2 emission factor. The emission figures for this plant have been recalculated for the years 1998-2000 for this reason. Before 1998 the plant burned only wood waste. CO_2 emissions from this are included elsewhere.

1A2f Other

Revisions in the preliminary energy figures (2000) led to recalculations of emission figures for all components for this source.

1A4b i Residential plants

Emission figures for all components have been recalculated based on revisions of energy data for the whole time series. The estimates of fuel wood consumption have decreased. The student population was erroneously included when fuel wood consumption data on a household basis were grossed up to national figures. This does not lead to any changes for CO_2 since biotic carbon is included elsewhere. But the revision is most important for CH_4.

Furthermore, there are some improvements in the energy accounts giving revised figures for consumption of fuel oil and charcoal. This led to recalculated emission data for CO_2, CH_4 and N_2O for the whole time series.

1A4c Agriculture/Forestry/Fishing

The emission figures are recalculated for all components compared with last year's submission caused by improved energy data for auto diesel in the agriculture sector.

There have been revisions in emission figures for all components due to revised energy data. Emissions from national fishing are now based on fuel sale.

3.12 International bunker fuels

In accordance with the IPCC Guidelines, emissions from international aviation and marine bunker fuels are excluded from national totals. They are presented separately for information in Table 5.

Table 5. Emissions of CO_2, CH_4, N_2O, NO_X , CO, NMVOC and SO_2 from ships and aircraft in international traffic bunkered in Norway, 1990-2001. Unit: 1000 tonnes. CO_2 in Mtonnes. Source: SN/SFT

Marine	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
CO_2	1.5	1.3	1.6	1.7	1.8	2.3	2.5	3.0	2.9	2.7	2.7	2.6
CH_4	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2
N_2O	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
NOx	30.3	25.6	32.1	34.3	37.8	46.2	50.7	61.4	61.8	58.3	57.8	56.0
CO	1.4	1.2	1.5	1.6	1.8	2.2	2.4	2.9	2.6	2.5	2.5	2.4
NMVOC	1.1	0.9	1.2	1.3	1.4	1.7	1.9	2.3	2.2	2.1	2.0	2.0
SO_2	9.9	9.7	12.3	13.5	14.0	13.7	15.4	18.8	14.9	12.9	11.5	13.1

Aviation	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
CO2	0.6	0.6	0.6	0.6	0.6	0.6	0.7	0.8	0.8	0.9	0.9	0.8
CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N_2O	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NOx	2.1	1.9	2.0	2.4	2.3	2.2	2.6	2.9	3.0	3.4	3.3	3.0
CO	0.8	0.7	0.7	0.9	0.8	0.8	0.9	1.0	0.8	1.0	0.9	0.8
NMVOC	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
SO_2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

In 2001, CO_2 emissions from ships and aircraft in international traffic bunkered in Norway amounted to a total of 3.4 million tonnes, which corresponds to about 8 per cent of the total Norwegian CO_2 emissions. The CO_2 emissions from marine and aviation bunkers were reduced by 6 per cent between 2000 and 2001.

The emissions of CO_2 from ships in international traffic have increased by as much as 73 per cent from 1990 to 2001, while emissions of CO_2 from aircraft increased by 33 per cent in this period. The reason for such an increase is primarily growth in traffic. Aircraft engines are more fuel-efficient now than they were some years ago. This means that the increase in international air-traffic has been higher than that of the emissions.

3.12.1 Methodological issues

Figures for international bunker fuel are drawn from the Petroleum statistics. The consumption of aviation bunker fuel in Norway, reported to the UNFCCC, is estimated as the difference between total purchases of jet kerosene in Norway for civil aviation (Petroleum Statistics) and reported domestic consumption. The quantities of fuel bought abroad by Norwegian airlines are reported directly to SN by the airlines.

The emission factors used in the calculation is described in (SN/SFT 2000).

3.12.2 Precursors

Emissions of NO_x from ships were 56 ktonnes, or about 25 per cent of the total Norwegian NO_x emissions in 2001. During the period from 1990 to 2001, NO_x emissions from international shipping bunkered in Norway increased by 85 per cent. NO_x emissions resulting from international aviation amounted to 3 ktonnes in 2001. They increased by 43 per cent

from 1990 to 2001. As for the other gases in the table, emissions from international aviation and marine bunker fuels are small compared to the total Norwegian emissions of these gases.

3.13 Cross-cutting issues

3.13.1 Sectoral versus reference approach

As shown in the CRF Table 1Ac (Annex 6), comparison of CO_2 emissions from fuel combustion between the Reference and the National Approach (RA and NA respectively) has revealed large deviations in both the energy consumption data (32 per cent) and the CO_2 emissions (7.25 per cent). In the case of CO_2 emissions, the deviation between the two approaches for the years 1990 and 1998-2001 is displayed in Table 6.

In 2001 Norway carried out a special study in 2001 in an attempt to reduce these differences and to better explain them (SN 2001d). The study revealed that the differences appeared due to problems in connection with the application of the RA. The elements that contributed most were:

- Large crude oil and natural gas production and export
- Unknown crude oil carbon content
- Large amounts of fossil energy used as feedstock and reducing agents.

In Rypdal (2001) several changes in RA were proposed, such as:

- Consequent use of production, export and import data as reported by SN to IEA
- Contact with large refineries in order to obtain better estimates of average crude oil carbon content – this point was followed up in the case of one refinery
- Use of the same feedstock data as used in the SA rather than using IPCC (1996) default assumptions.

The large systematic deviations from the national sectoral approach in Table 6 for the last three years are probably due to inaccuracies in the oil and gas production or export statistics. Due to the large production and export, small errors can lead to large amounts of CO_2 compared to national total emissions. This is also reflected in the large statistical error in the energy balance. The estimate also deviates from the one made by IEA. The main reason for this is that IEA distributes the statistical error between the RA and SA. The IEA estimate is furthermore based on default assumptions about carbon stored, which can differ from the actual situation in Norway.

It should be noted that the large deviations are not indicative of uncertainties in the CO_2 estimates made by Norway, as the statistics of *end use* of energy is generally accurate.

Table 6. Comparison between the reference approach and the sectoral approach. 1990, 1998-2001. Gg. Change in per cent. Deviation in per cent. Source: SN/SFT

	1990	1998	1999	2000	2001	90-98	90-99	90-00	90-01
National Sectorial Approach (Gg)	26.4	31.7	31.9	31.0	32.0	20 %	21 %	17 %	21 %
National Reference Approach (Gg)	25.3	32.0	34.4	33.8	34.3	21 %	30 %	28 %	30 %
Deviation (%)	**-4.27 %**	**0.91 %**	**7.79 %**	**8.81 %**	**7.25 %**	**-1 %**	**-9 %**	**-10 %**	**-9 %**

3.13.2 Feedstocks and non-energy use of fuels

Emissions from the use of feedstocks are according to the Good Practice Guidance and 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.

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

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 green house 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. 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 field and the injection program have been in operation since 1996. Statoil monitor the injected CO_2 with respect to leakages. Investigations carried out so far show that the injected CO_2 have been kept in place without leaking out.

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 green house gas inventory. In 2001 this emission amounted to 3050 tonnes CO_2. The figure for the other years is given in Table 7.

Table 7. Emissions of CO_2 from the Sleipner CO_2-injection plant due to inaccessibility of the injection facilities. Source: SFT

	1996	1997	1998	1999	2000	2001
CO_2 (tonnes)	..	29	4,195	9,150	8,318	3,050

Methodological issues

In order to document what happens with the CO_2 Statoil together with energy companies and research institutes from several countries have started a R&D project called "The saline aquifer carbon dioxide storage (Sacs) project". The core of Sacs 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. One was conducted before injection started, and another took place in the autumn of 1999. 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.

Uncertainties

The reported data covers emissions to the atmosphere when the injection system is out of operation. These data are considered most accurate. So far there have not been detected any leakage from the storage. The uncertainty in the emissions has not been estimate. However, we expect to have more reliable information when the monitoring program is put in place according to Statoil's emissions licence – see QA/QC and verification below.

QA/QC and verification

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. The storage of CO_2 is included in the emission licence for the Sleipner West field. According to the license Statoil should draw up a proposal for a monitoring program of the CO_2-storage within July 1 2003. Furthermore Statoil shall report the amount of CO_2 injected and the results of the monitoring every year to The Norwegian Pollution Control Authority. The monitoring program will give an system for QA. 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. They are counted for in the emissions inventory.

3.13.4 Indirect CO_2 emissions from CH_4 and NMVOC

According to the reporting guidelines to the Climate Convention it is required to include all emissions of carbon from fossil compounds in the national GHG 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 hence 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 GHG inventory. However, indirect CO_2 emissions from non-combustion sources originating from the fossil part of CH4 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 GHG emission inventory:

- Coal Mining and Handling – 1B1a
- Gas terminals – 1B2b
- Oil terminals – 1B2a
- Refineries – 1B2a
- Oil gas extraction activity – especially from loading of crude oil – 1B2a and 2B2c
- Distribution of oil products – 1B2a
- Solvent and other product use - 5
- Solid waste disposal – 6A.

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

Chapter 4. Industrial Processes

4.1 Overview

The methodology used to calculate emissions of GHG from industrial processes is described in detail in Section 3.2 of the report SN/SFT 2000. Furthermore, an overview of emissions from industrial processes is presented in Section 2 in this report.

PFCs from Aluminium production, CO_2 from ferroalloy production and consumption of halocarbons are key sources in level and/or trend due to high emission level, changing trend and uncertainty.

4.2 PFCs from Aluminium production – 2C3

4.2.1 Description

PFCs from aluminium production accounted for 1.8 per cent of the national total GHG emissions in 2001. This is a decrease from 5.8 per cent in 1990. The reduction has been achieved by improving the efficiency of the production process and by installing point feeders to reduce the numbers and duration of anode effects per cell day (AEF). This has caused a reduction of the PFC emissions per tonne aluminium produced in Norway from 3.49 kg CO_2-equivalent in 1990 to 0.99 kg CO_2-equivalent in 2001. The relative emissions of PFCs in CO_2 equivalents per tonne Aluminium produced have increased by 14 per cent from 2000 to 2001. This is due to operational problems such as power failure, unstable amperage and anode problems, which has resulted in increased anode effects. Some plants changed from Søderberg to Prebaked technology during 2001, and they report that the start-up of the new furnaces has resulted in small increases in the specific emissions.

More than 60 per cent of the aluminium was produced with Prebaked technology in 2001. Approximately 30 per cent was produced by old Søderberg and 10 per cent by new Søderberg technology.

PFCs from aluminium production are a key source both in level and trend due to uncertainty in the emission factors and the reduced share of total emissions from 1990 to 2001.

4.2.2 Methodological issues

Methodology

The calculation methodology for CF_4 and C_2F_6 from aluminium production is described in (SN/SFT 2000). According to IPCC's Good Practice Guidance the methodology used in the calculation is a Tier 3b methodology. Each plant annually reports production data and emissions by technology to SFT.

Activity data

Activity data included in the calculation of PFC is number of AED; average annual amperage in kA, number of cells in production, number of production days and number of "newly started" cells.

Emission factors

We use country specific emission factors based on measurements done at two plants in 1992, at two plants in 1997 and at all plants in 1999/2000. Measurements show that the content of C_2F_6 in anode gas is 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 were not measured. The 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 is then 4 per cent. These results are confirmed by the measurements made in 1997 and in 1999/2000. Experience gained from measurements shows that the anode effect's duration in minutes (AED) has greater variation than expected and this has to be reflected in the calculation. Duration of anode effects is today a constant in the calculation of the emission.

Current published data from measurements from aluminium industries in Norway (Kvande et al., 2001) indicates that C_2F_6 emissions constitute 6 per cent of the total PFCs emissions during anode effects. The results have not yet been included in the emission estimates and will probably not be included before the result is confirmed by more measurements.

4.2.3 Uncertainties

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 (SN, 2000). This is in spite of the efforts that have been done to improve the quality of the emission data.

4.2.4 Source-specific QA/QC and verification

SFT do internal checks of the emission figures that the plants report to SFT every year. If errors are found SFT contacts the plant to discuss the reported data and changes are made if necessary.

4.2.5 Recalculations

There has been no recalculation of PFC emissions since last year submission of NIR 2002 to UNFCCC.

4.2.6 Planned improvements

No specific improvements are planned to better the PFC emission data from the aluminium industry.

4.3 CO_2 from Ferroalloy production – 2C2

4.3.1 Description

CO_2 emissions from ferroalloy production accounted for 5.1 per cent of the national total GHG emissions in 1990 and have increased to 5.4 per cent in 2001. The total CO_2 emissions from production of ferroalloy have increased by 11 per cent from 1990 to 2001. There has been a growth in production of ferroalloys in the period and shift in range of products.

CO_2 emissions from production of ferroalloys are key source in level and trend due to uncertainty in emission factors and the large share of total emissions.

4.3.2 Methodological issues

Methodology

The method used in the calculation of CO_2 emissions from production of ferroalloy is in accordance with the method recommended by the IPCC (IPCC 1997b). This methodology is based on consumption of reducing agents and electrodes and national emission factors. Emission data is reported from each plant in an annual report to SFT.

Activity data

Calculation of emissions is based on the consumption of reducing agents and electrodes in the production of ferroalloys.

Emission factors

The emission factors used are country specific based on the actual composition of the raw materials. They are listed in Table 8.

Table 8. Emission factors for CO_2 from production of ferroalloys. Unit: Tonnes CO_2/tonne reducing agent or electrode. Source: SINTEF (1998b, 1998c, 1998d and 1998e) and emission inventory from SN and SFT

	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

4.3.3 Uncertainties

CO_2 from the production of ferroalloy is key source in level due to uncertainty in emission factors. The uncertainties in activity data and emissions factor have been calculated at ± 5 % and ± 7 % respectively.

4.3.4 Source-specific QA/QC and verification

SN makes an annual quality control (QC) of the emission data on the bases of the consumption of reducing agents they collect in an annual survey and average emission factors.

4.3.5 Recalculations

There has been no recalculation of the CO_2 emissions from ferroalloy production since the submission of NIR 2002.

4.3.6 Planned improvements

No specific plans to improve the CO_2 emission data for the production of ferroalloy are prepared before NIR 2004.

4.4 Consumption of halocarbons (HFCs and PFCs) – 2F

4.4.1 Description

HFCs and PFCs are used as substitutes for ozone depleting substances (CFCs and HCFCs) that are being phased out under the Montreal Protocol. They are used in varied applications, including refrigeration and air-conditioning equipment, as well as in foam blowing, fire extinguishing, as solvents and as aerosol propellants. There is no production of HFCs and PFCs in Norway. The emissions are calculated on the basis of information on imported bulk and products containing HFCs/PFCs.

In 2001, the total emissions from HFCs and PFCs used as substitutes for ozone depleting substances were 292 ktonnes of CO_2-equivalents. Almost all of this originated from HFCs; the PFC emissions are negligible in comparison. The application categories refrigeration and air conditioning contribute by far with the largest part of the HFC and PFC emissions in Norway, thus the other categories contributed only small amounts to the overall emissions. Like in many other Annex I countries, the consumption of these gases has had a strong upward trend since 1990, because of the phasing out of ozone-depleting substances.

Table 9 shows the trend in actual emissions of all HFCs and PFCs used in Norway as substitutes for ozone-depleting substances during the years 1990 through 2001 calculated by the Tier 2 methodology. We have also calculated the potential emissions of HFCs and PFCs during the same period, using the Tier 1b methodology (see CRF Table 2 II, sheet 2).

Table 9. Actual emissions of HFCs and PFCs in Norway (Tier 2) 1990-2001 in tonnes. Unit: Gg CO_2-equivalents. Source: SN/SFT

Compound	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
HFC-134a	0.00	0.04	0.19	1.78	5.45	10.23	17.24	26.21	38.20	50.21	61.08	71.83
HFC-125	0.00	0.00	0.00	0.00	0.47	2.38	5.47	9.71	14.73	19.86	25.93	32.93
HFC-143a	0.00	0.00	0.00	0.00	0.19	1.52	3.86	6.84	10.43	14.75	20.28	26.85
HFC-32	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.15	0.33	0.65	1.04	1.51
HFC-23	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.07	0.07	0.07	0.07
HFC-152a	0.13	0.41	0.65	0.79	0.81	0.99	1.47	2.41	4.79	5.99	7.73	10.15
HFC-227ea	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.11	0.15	0.16	0.17	0.28
PFC-218	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.06	0.06	0.06	0.06	0.06
Total (CO_2-eq)	**0.02**	**0.11**	**0.34**	**2.43**	**9.23**	**26,0**	**53.2**	**88.9**	**133.1**	**179.9**	**232.5**	**292.1**

4.4.2 Methodological issues

The emissions of HFCs and PFCs are calculated using the Tier 2 methodology and a bottom-up approach. The emissions are calculated on a detailed level, based on consumption figures and emission characteristics related to specific processes and equipment. 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 on import of products containing HFCs and PFCs were collected through a survey in 1999 (SFT 1999), and the activity data for the following years were estimated by extrapolating these figures. A new survey will be carried out in the near future. 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. It was found that the ratio between potential and actual emissions was about four in 2001.

4.4.3 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 1a (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. The emissions are rather underestimated than overestimated, as some imported bulk/products may not be included. 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.

4.4.4 Source-specific QA/QC and verification

There is no specific QA/QC procedure for this sector. See Section 1.6 for the description of the general QA/QC procedure.

4.4.5 Recalculations

There have not been any recalculations in the HFC and PFC data since the previous submission.

4.4.6 Planned improvements

On 1 January 2003 a new tax was imposed on the production and import of HFCs and PFCs in Norway. The tax is differentiated based on the GWPs of the compounds. This will most likely result in improved figures on imported HFCs and PFCs in products and in bulk. It is thus anticipated that the emissions estimates will be more accurate in the future.

4.5 Non-key sources

4.5.1 Cement Production – 2A1

The production of cement gives rise to both non-combustion and combustion emissions of CO_2. The non-combustion emissions originate mainly from the calcinations of the raw material calcium carbonate. The resulting calcium oxide is heated to form clinker and then crushed to form cement. Emissions factors calculated particularly for the two Norwegian factories are used (0.520 and 0.541 respectively, compared to IPCC default emission factor of 0.5071). These are based on the actual composition of the raw material. The plant responsible report production data annually and SN calculates the emissions on this basis.

4.5.2 Lime Production – 2A2

CO_2 is emitted during the production of lime. Actual production volumes of lime are used as activity data in the emission calculation. These data are reported to SN by the producers. Plant-specific emissions factors for lime and dolomite respectively are used in the calculation of emissions.

4.5.3 Limestone and Dolomite Use – 2A3

In Norway sulphuric acid waste from a specific plant is neutralised with limestone. This produces CO_2 emissions. An emission factor of 0.45 tonnes CO_2 per tonne sulphuric acid is used, calculated from the reaction equation.

4.5.4 Ammonia Production – 2B1

Ammonia is produced as one of the steps during fertiliser production. Hydrogen is needed to produce ammonia, and hydrocarbon gases (LPG) is the basis for the production of hydrogen. The generated CO_2 emissions are calculated by SN from figures on consumed LPG provided by the enterprise. The chemical composition of the gases varies, and we have chosen to use the emission factor recommended by the IPCC (3 tonnes CO_2/tonne LPG). The calculated emission figures agree quite well with emissions figures reported by the enterprises.

A part of the CO_2 which is generated during the production process is captured and sold to other companies in Norway or exported. The amount of CO_2 sold/exported has been taken into account in this submission to the UNFCCC. In 2000, approximately 200,000 tonnes CO_2 were captured and sold. 50,000 tonnes of this were used in Norway, mainly as carbonic acid

in carbonated beverages (now reported under Food and Drink 2D2). The rest, 150,000 tonnes were exported, and are thus subtracted from the emission figure.

4.5.5 Nitric Acid Production – 2B2

Nitric acid production is another step in the manufacturing of fertiliser. There are two plants where nitric acid is produced in Norway. The process generates emissions of nitrous oxide. At one plant the N_2O emissions are measured continuously, while they are calculated from monthly measurements at the other. The production technology has been improved since 1990, which has resulted in a reduction in emissions of about 5 % from 1990 to 2001.

4.5.6 Carbide Production – 2B4

Silicon carbide and calcium carbide are produced in Norway. Petrol coke is used as reducing agent in the production of silicon carbide, and the activity data is consumed petrol coke. A country-specific emissions factor is used (2.51 tonnes CO_2/tonne petrol coke), which deviates somewhat from the IPCC default factor (2.3). The reason for this difference is use of different percentages related to sequestered carbon in produced silicon carbide.

In addition to CO_2, methane may be emitted from petrol coke during parts of the process. The IPCC emission factor is used to calculate these emissions.

The production of calcium carbide also generates CO_2 emissions when limestone is heated and when petrol coke is used as a reducing agent. Emissions estimates are based on the amount of calcium carbide produced each year, and a country-specific emission factor. The emission factor deviates somewhat from the IPCC default factor (1.71 tonnes CO_2/tonne CaC_2 compared to the IPCC factor of 1.8). This is because the IPCC assumes that all the calcium carbonate is calcinated, while the Norwegian factor takes into account that some of the sequestered carbon will be released over time. Production data are reported annually to SN for both silicon- and calcium carbide, which performs the emissions calculations.

4.5.7 Iron and Steel Production – 2C1

The CO_2 emissions from non-combustion processes in iron and steel production are estimated from the use of coal and coke. The annual consumption figures are reported to SN, which performs the emission calculations.

4.5.8 Aluminium Production – CO_2 – 2C3

Emissions of CO_2 from aluminium production are calculated on the basis of consumption of reducing agents. This includes carbon electrodes, electrode mass and petroleum coke. The emissions factors are primarily calculated from the carbon content of the reducing agents. Earlier Statistic Norway (SN) estimated the CO_2-emissions from consumption data provided by the enterprises, but from 2001 the companies calculate and report their emissions to the Norwegian Pollution Control Authority (SFT). New calculations of emissions have been performed for all the years from 1990 based on this change in methodology. For 1990 and 1991 there were no reported data, hence a recalculation was made using production data and reported emissions data for 1992.

4.5.9 SF_6 used in Aluminium and Magnesium Foundries – 2C4

SF_6 is used as a cover gas in the aluminium and magnesium industries. The gas is assumed to be inert; hence the emissions are set equal to the consumption of SF_6. Since 1996 SF_6 is no longer used during aluminium production. It is still used in magnesium production, but the consumption has decreased strongly since the beginning of the 1990s. The primary magnesium production stopped in 2002 and only secondary production is retained. It is anticipated that this will cut down the consumption of SF_6 by 60-80 per cent.

4.5.10 Food and Drink – 2D2

As mentioned under 4.5.4 Ammonia Production, some CO_2 from this production is used as carbonic acid in carbonated beverages. In 2000, about 50,000 tonnes CO_2 were sold for national use, and as mentioned most of this for lemonade production. The whole tonnage is reported under this category, 2D2, although the largest part of the emissions takes place after the bottles are opened and not in the breweries. The figures were previously reported under 2B2 Nitric Acid Production (the part of this is now reported under Ammonia Production 2B1).

4.5.11 Recalculations – non key sources Industrial Processes

2A2 Lime Production

In the new submission emissions from lime production are reported under 2A2.

2B1 Ammonia Production

The plant that produces ammonia (and nitric acid) captures parts of the CO_2 emitted during the production process. The CO_2 is a by-product of the ammonia production and is sold to other companies in Norway or exported. The amount of CO_2 sold has been taken into account in this submission to the UNFCCC. In 2000, approximately 200,000 tonnes CO_2 were captured and sold. 50,000 tonnes of this were used in Norway, mainly as carbonic acid in carbonated beverages. The rest, 150,000 tonnes were exported. The export has increased during the nineties. In 1990, the export was approximately 50,000 tonnes. This recalculation has lowered the Norwegian CO_2 emissions in 2000 with 150,000 tonnes compared to what was reported in NIR 2002. Likewise, the 1990-figures of CO_2 are 50,000 tonnes lower than in NIR 2002.

2C3 Aluminium Production

Previously Statistics Norway calculated the emissions of CO_2 from aluminium production based on the consumption of reducing agents. Now SN and SFT are using the data for the emission amounts that the industries themselves report to the SFT. The methodological change has been made for all years from 1990. For 1990 and 1991, no reported data existed, so a recalculation has been made using production data and reported emission data for 1992.

2D2 Food and Drink

As mentioned under 2B1 Ammonia Production, Norway now takes into account that some CO_2 from this production is exported or used in other national industries. The most important national use of this is as carbonic acid in carbonated beverages. In 2000, about 50,000 tonnes CO_2 were sold for national use, and as mentioned most of this for lemonade production. The

whole tonnage is reported under 2D2 even if most of the emissions take place after the bottles are opened and not in the breweries.

In 1990 the emissions were 20,000 tonnes, and they had increased to 50,000 tonnes in 2000. The figures were previously reported under 2B2 Nitric Acid Production (the part of this is now reported under Ammonia Production 2B1).

Chapter 5. Solvent and other product use

5.1 Solvent and other product use

5.1.1 Description

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 and the CO_2 is included in the total GHG emissions reported to UNFCCC. Indirect CO_2 emissions from solvents represent approximately 0.2 per cent of the total GHG emissions in 2001.

Solvents and other product use are non-key sources.

5.1.2 Methodological issues

Methodology

The methodology is described in SN/SFT 2000 and in detail in SFT 1995 (only in Norwegian). The methodology is based on a solvent balance approach. The solvent balance follows the flow of solvents from production, import and export, via transformation, to incineration or consumption. This methodology gives independent emission estimates for each year of the inventory and covers in principle all fugitive sources. For further explanation of the methodology see Section 3.2.18 in SN/SFT 2000.

The equation applied for the solvent balance is:

Emissions = (Production + Import - Export - Destruction – Raw material use)
· Solvent content · Fraction emitted + Emissions from certain industrial processes

Activity data

Activity data used in the solvent balance is collected by SN in cooperation with authorities like NORSAS, SFT and the Norwegian Product Register. See the report SN/SFT 2000 for more details.

Emission factors

The calculation of indirect CO_2 emissions from NMVOC is based upon the content of carbon in NMVOC. In the Norwegian GHG inventory we assume that the average content is about 82 per cent. The indirect emission factor for CO_2 is then 3 kg CO_2/kg NMVOC (0.82 multiplied with 44/12), see Section 3.13.4.

5.1.3 Uncertainties

An uncertainty analyses was performed for long-range air pollutants by SN (SN 2001c). The analyses conclude that the source category Solvents are one of the highest ranked NMVOC sources with regard to uncertainty.

5.1.4 Source-specific QA/QC and verification

Internal checks of the time-series of calculated emissions data and input activity data is conducted by SN and corrections are made when errors are found.

5.1.5 Recalculations

There has been no recalculation of the indirect CO_2 emissions from solvents since submission of NIR 2002.

5.1.6 Planned improvements

No specific plans to improve the indirect CO_2 emission data for solvents are prepared for this year.

Chapter 6. Agriculture

6.1 Overview

About 9 per cent of the total Norwegian emissions of greenhouse gases originate from agriculture in 2001. According to the key source analysis emissions of methane from enteric fermentation and emissions of nitrous oxide from agricultural soils are key sources in level due to high uncertainty in activity data and/or emission factors. These two emission sources are the main contributors to uncertainty in level. A presentation of the two key sources is included below, followed by a brief overview of the non-key sources in this sector.

6.2 CH_4 from Enteric Fermentation – 4A

6.2.1 Description

Enteric fermentation contributed 82.8 ktonnes of CH_4 emissions in 2001. This constitutes 85 per cent of the CH_4 emissions from agriculture, and 29 per cent of the total national emissions of CH_4. 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. Norway also has tame reindeer emitting some CH_4.

6.2.2 Methodological issues

The methodology for calculating CH_4 from enteric fermentation is in accordance with IPCC's Good Practice Guidance Tier 1 method. Numbers of animals of each kind and average emission factors are used to calculate emissions.

Activity data

Emissions are estimated from the animal population taken from SN's livestock population statistics (numbers are given in Table 3 in Annex 2). Data are based on population counts, with annual estimations from sample surveys for the ruminants (cattle and sheep) and applications for economic support for the remaining animals.

Emission factors

We use Tier 1 default emission factors from IPCC (1996) for each kind of animal (IPPC 1997a,b) Emissions from reindeer, deer and ostrich are also included in the Norwegian calculations. The emission factor used for reindeer is 11 kg/animal/year, which has been estimated by scaling the emission factors for goats and sheep according to carcass weight. For deer the emission factor is 52.64 kg/animal/year and has been estimated by scaling the emission factor for cattle. The emission factor for ostrich is 4.97 kg/animal/year and has been estimated by scaling the emission factor for horses. Emission factors for all animal species are given in Annex 3.

6.2.3 Uncertainties

There has been a tendency for an increase in body mass for dairy cattle in recent years. This constitutes an uncertainty factor that is not reflected in the simple Tier 1 methodology.

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, and a great uncertainty connected to the number of all types of poultry.

Emission factors

Although the emissions depend on several factors and therefore vary between different individuals of one kind of animal, we apply average emission factors for each kind. The standard deviation of the emission factors is considered to be ±25 per cent. Use of IPCC Tier 1 emission factors leads to enhanced uncertainty compared to a Tier 2 approach. The reason why Tier 1 is used is lack of data to perform Tier 2 calculations.

6.2.4 Source-specific QA/QC and verification

In 2001 a project was initiated to determine the exact number of animal populations. This was completed in 2002. Revised data on animal populations form the basis for the emission calculations.

6.2.5 Recalculations

New revised figures for the population of different animals have been used for the whole time period 1990-2001. A new source, emission of CH_4 from fur animals (fox and mink) has also been included. The emission factor has been calculated by scaling the emission factor for swine, due to carcass weight.

6.2.6 Planned improvements

There are currently no planned improvements in the methodology to calculate methane emissions from enteric fermentation.

6.3 N_2O from Agricultural Soils – 4D

6.3.1 Description

Different agricultural soil management practices lead to emissions of nitrous oxide (N_2O). In Norway, the emissions mainly originate from the use of synthetic fertilisers, from crop residues and from the cultivation of soils with a high organic content (histosols) due to enhanced mineralisation of old, nitrogen-rich organic matter. Emissions of N_2O also arise from the use of animal manure on agricultural soils, from droppings of grazing animals and from biological nitrogen fixation (the main N-fixing crop in Norway is clover). Furthermore, nitrous oxide is emitted indirectly through volatilisation, leaching and runoff of nitrogen. Of these, nitrogen leaching and run-off is the major source.

The emissions of nitrous oxide in Norway from agricultural soils accounted for about 50 per cent of the total N_2O emissions in 2001. The emissions from these sources amounted to 8.9

ktonnes in 2001, or 2.7 Mtonnes calculated in CO_2-equivalents. They accounted for about 5 per cent of the total Norwegian greenhouse gas emissions that year.

6.3.2 Methodological issues

This chapter presents the methodology used to calculate emissions of nitrous oxide from agricultural soils. Three sources of N_2O 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 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, and sewage production).

The methodology for these different sources is briefly described in the following. A more thorough description of the methodology including tables of emission factors etc. is contained in Annex 2.

Direct N_2O emissions from agricultural soils – 4D1

The direct emissions of N_2O from the use of *synthetic fertiliser* are calculated from data on annual consumption of fertiliser and the nitrogen content, multiplied with the IPCC default emission factor. The emissions are corrected for ammonia (NH_3) that volatilises during application. The emission factors vary with the type of fertiliser (see Annex 2 for further explanation).

All *animal excreta* that are not deposited during grazing are used as manure in Norway. Emissions of N_2O from manure used as fertiliser are calculated from the total number of animals, the amount of nitrogen in the manure and the IPCC default emission factor (IPCC 1997b). We employ Norwegian values for N in excreta from different animals and national information on the usage of different manure systems. The N_2O emissions are corrected for ammonia that volatilises during application.

Another source of nitrous oxide emissions is connected to *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, b). The amount of nitrogen fixed is multiplied with the IPCC default emission factor.

Concerning re-utilisation of nitrogen from *crop residues*, there is only limited information. Nitrous oxide 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,b). 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 has been multiplied with the IPCC default emission factor.

Large N_2O emissions occur as a result of *cultivation of soils with a high organic content* (histosols) due to enhanced mineralisation of old, N-rich organic matter (IPCC 1997a,b). The emission is 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.

Direct N_2O emissions from animal production – 4D2

The emissions of N_2O deposited during grazing are estimated from the animal population and the amount of nitrogen in the manure. The data are based on population counts, with annual estimations based on sample surveys for the ruminants (cattle and sheep) and applications for economic support for the remaining. The amount of N deposited during grazing has been multiplied with the IPCC default emission factor. The emissions have been corrected for the amount of ammonia volatilised.

Indirect N_2O emissions from agricultural activity – 4D3

Atmospheric deposition of nitrogen compounds through *volatilisation* fertilises soils and surface waters, and enhances biogenic N_2O formation. The deposition of ammonia is assumed to correspond to the amount of NH_3, which volatilises during use of synthetic fertiliser and manure. The N_2O emission is given by multiplying the amount of nitrogen from deposition with the IPCC default emission factor.

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,b) proposes a default value of 30 per cent, but in the Norwegian inventory a national factor of 18 per cent (JORDFORSK 1998) is used, that 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 get the emission of N_2O.

Today, the N_2O emissions arising from the *application of industrial and urban wastes* on agricultural fields are not included in the Norwegian inventory. However, this emission source will be included in the future. At present, no data is available for the amount of industrial waste applied as nutrient. Some waste from the fish industry has been used as nutrient[5], but this source is assumed to be very limited in Norway. We have included data for the N_2O emission arising from *sewage sludge* applied on fields. These emissions have been calculated by multiplying the amount of nitrate in the sewage sludge applied with the IPCC default emission factor.

6.3.3 Uncertainties

Activity data

There are several types of activity data entering the calculation scheme: *Sale of nitrogen fertiliser:* The data are based on sales figures. Two methodologies are used for data collection and the outputs agree very well. The uncertainty is within ±5 per cent. *Amount of manure:* The N_2O emissions are estimated from figures on animal population. The data are considered to be known within ±5-10 per cent. The nitrogen excretion factors are uncertain, but they have been improved the past years (the range is considered to be within ±15 per cent). The Norwegian factors deviate largely from the IPCC default factors (by 40 to several hundred per cent. *Fate of manure:* There is significant uncertainty connected to the allocation of manure between what is used as fertiliser and droppings on pastures. The emissions of nitrous oxide are corrected for ammonia that volatilises during application. The NH_3 emissions are

[5] Personal communication, Line Diana Blytt, Norwegian Agricultural Inspection Service.

estimated from the animal population. The data are considered to be known within ±5-10 per cent (SN 2001f). *Nitrogen left after harvest:* Norwegian factors have been used. These are lower than the IPCC default factors by 40 per cent. The harvest of nitrogen is determined within ±10 per cent, but the expansion factor to account for nitrogen left is very uncertain. Assessed uncertainty range is about ±50 per cent. *Deposition of other agricultural emissions:* The data are based on national NH_3 emission figures. These are within ±30 per cent. *Leakage of nitrogen:* The upper limit for the leakage is the applied nitrogen. The uncertainty is roughly about ±70 per cent. *Cultivation of organic soils:* Data are based on a one-year survey, and are uncertain by more than a factor of three.

Emission factors

The uncertainties in the N_2O emission factors in relation to agricultural soils are high. In the report SN 2000 it was assumed a factor of two according to IPCC (1996). In IPCC (2001) these uncertainty intervals have been narrowed somewhat. For the emission of nitrous oxide from different storage systems, the IPCC default emission factors are used. They have an uncertainty range of -50 per cent/+100 per cent (IPCC 2001) except for the storage category "daily spread" where it is not applicable. The ammonia emissions from agriculture are estimated based on national conditions. The uncertainties are still high due to high variability and gaps in data. The uncertainty for animal manure is ±30 per cent (SN 2001f). 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).

6.3.4 Source-specific QA/QC and verification

In 2002, a project funded by the Nordic council & Council of ministers was carried out. The study compared the results for emissions of greenhouse gases from the agricultural sector in the national emission inventories of the different Nordic countries with the results using the IPCC default methodology and the IPCC default factors. The results for the Nordic countries are collected in a report by Petersen and Olesen (2002). The main conclusions of the report are that there are currently large differences between the Nordic countries in the application of the IPCC methodology. In some cases the estimates of activities differ considerably, in other cases different emission factors were applied. Furthermore, it was found that there is a great need to improve the IPCC methodology and to make it more locally adapted, but based on common guidelines. Several elements of improvement were suggested; e.g. that the climatic variation within the Nordic countries should be accounted for in the estimates of CH_4 emissions from manure, and that the emission factors for nitrous oxide from both direct and indirect sources should be differentiated more than what is currently the case. For some of the emission sources there is a lot of experimental data available, and there is sufficient knowledge to improve the methodology. But there is a clear need to better link experimental data with the use of systems modeling.

6.3.5 Recalculations

Recalculations have been performed for some components of this sector. This has resulted in the reporting of larger emissions of N_2O compared to what was reported last year from the agricultural sector. A new source, emission of N_2O from *sewage sludge* applied on fields, has been included. The emission factor for *cultivation of histosols* has been changed according to IPCC Good Practice Guidance, which gives increased N_2O-emissions. The recalculations have been made for the whole period 1990-2001.

6.3.6 Planned improvements

Before the next submission of the NIR, the total amount of manure calculated in Statistics Norway's manure balance will be updated with new data for the population of different animals and new data for grazing times and a new set of coefficients for the amount of N in manure from different animal types. This will lead to minor revisions of the emission figures for 1990-2000 for N_2O from animal wastes applied to soil, and emission of N_2O from grazing animals. The N_2O-emission from crop residues will also be revised. N_2O emissions from the application of industrial and urban wastes on agricultural fields are not included in this inventory, but they will be included in the future.

6.4 Non-key sources

6.4.1 CH_4 emissions from manure management – 4Ba

CH_4-emissions due to manure management amounted to 15.1 ktonnes in 2001. Organic material in manure is transformed to CH_4 in an anaerobic environment by microbiological processes. Emissions from cattle are most important in Norway. The emissions from manure depend on several factors; type of animal, feeding, manure management system and weather conditions (temperature and humidity). The methodology to calculate methane emissions from manure management follow a Tier 2 approach (IPCC 1997b). Details are given in Annex 2.

6.4.2 N_2O emissions from manure management – 4Bb

The emissions of N_2O take place during storage or handling of manure (i.e. before the manure is added to soils), and they are estimated on the basis of figures on animal population. The emission sources are split into manure in storage, droppings on pastures, manure during and after spreading, and emissions from reindeer. In Norway, all animal excreta that are not deposited during grazing are used as manure. N_2O from manure are estimated in accordance with the IPCC default method (IPCC 1997b), but with Norwegian values for nitrogen in excreta from different animals. Tables on the values we have used for nitrogen in excreta from different animals and on different manure systems are given in Annex 2.

The emissions of N_2O are affected by the amount of ammonia (NH_3) emissions from the manure. These emissions depend on several factors, e.g. type of animal, nitrogen content in fodder, manure management, climate, the time of spreading of manure, cultivation practices and characteristics of the soil. 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. In the Norwegian emission inventory ammonia volatilisation values from Statistics Norway's ammonia model are used, which are expected to give more correct values for Norway.

6.4.3 Field burning of agricultural residues - 4F

In 2002, the emissions of CH_4, N_2O, NO_X and dioxin from agricultural residual burning were included in the Norwegian inventory. Field burning of agricultural residues (cereal crops) gives emissions of a large range of standard combustion products. For 2001, this activity gave rise to 440 tonnes of CH_4, 8.6 tonnes of N_2O, 312 tonnes of NO_x and 9106 tonnes of CO. The emissions by burning of crop residue are being calculated due to the guidelines in the IPCC reference manual (IPCC 1997b). Methodology for the calculation of emissions and emission

factors are given in Annex 3. The annual amount of crop residue burned on the fields is calculated based on data from Statistics Norway and the Norwegian Crop Research Institute.

The uncertainty in the crop residues and other agricultural waste is high. An exact estimate has not been made, but the number can be underestimated due to lack of statistics in this area.

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. The uncertainty in the data applied can be larger than this for all pollutants.

6.4.4 NH_3 emissions from treatment of straw – 4G

Emissions of NH_3 from treatment of straw amounted to 780 tonnes in 2001. The emissions depend only on the amount of NH_3 used. It is estimated that 67 per cent of the ammonia applied is not integrated with the straw, and is therefore emitted after the treatment. The amount of NH_3 used per year is obtained from Norsk Hydro and the Norwegian Agricultural Supply Cooperative. The emission factor is estimated by the Department of Animal Science at the Agricultural University of Norway. Uncertainty in the estimate of emissions from ammonia treatment of straw is rather low (±5 per cent) (SN 2001f).

6.4.5 CO_2 emissions from liming of agricultural soils

According to IPCC Good Practice Guidance, these emissions should be reported under Land use Change and Forestry. We have, however, included them here due to national circumstances. In the next NIR they will be reported under the LUCF category.

Process emissions of CO_2 from agriculture derive from liming. The total emissions from this source amounted to 113.4 ktonnes CO_2 in 2001. This is a non-key source in the Norwegian emission inventory. Lakes and agricultural soils are limed in Norway to reduce the damage from acidification. Application of calcium carbonate ($CaCO_3$) gives rise to CO_2-emissions. The Norwegian Agricultural Inspection Service gives data for the amount of limestone applied. The emission factor used is 0.44 tonne CO_2 per tonne calcium carbonate applied (SFT 1990). National total emissions have been reported yearly from 1990 and onwards.

6.4.6 CO_2 emissions and removals from soil – 5D

CO_2 emissions from liming of agricultural soils are entered in source category 4D Agricultural Soils whilst it according to the CRF should have been reported under 5.D CO_2 Emissions and Removals from Soil. This will be changed in NIR 2004, see Section 1.8. Total emissions from this source amounted to 113.4 ktonnes CO_2 in 2001. This is a non-key source in the Norwegian emission inventory. Application of calcium carbonate ($CaCO_3$) gives rise to CO_2-emissions.

The Norwegian Agricultural Inspection Service gives data for the amount of limestone applied. The emission factor used is 0.44 tonne CO_2 per tonne calcium carbonate applied (SFT 1990). National total emissions have been reported yearly from 1990 and onwards.

6.4.7 Field burning of agricultural residues - 4F

In 2002, the emissions of CH_4, N_2O, NO_X and dioxin from agricultural residual burning were included in the Norwegian inventory. Field burning of agricultural residues (cereal crops) gives emissions of a large range of standard combustion products. For 2001, this activity gave rise to 440 tonnes of CH_4, 8.6 tonnes of N_2O, 312 tonnes of NO_x and 9106 tonnes of CO. The emissions by burning of crop residue are being calculated due to the guidelines in the IPCC reference manual (IPCC 1997b). Methodology for the calculation of emissions and emission factors are given in Annex 3. The annual amount of crop residue burned on the fields is calculated based on data from Statistics Norway and the Norwegian Crop Research Institute.

The uncertainty in the crop residues and other agricultural waste is high. An exact estimate has not been made, but the number can be underestimated due to lack of statistics in this area.

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. The uncertainty in the data applied can be larger than this for all pollutants.

6.4.8 Other non-key sources: NH_3 emissions from treatment of straw – 4G

Emissions of NH_3 from treatment of straw amounted to 780 tonnes in 2001. The emissions depend only on the amount of NH_3 used. It is estimated that 67 per cent of the ammonia applied is not integrated with the straw, and is therefore emitted after the treatment. The amount of NH_3 used per year is obtained from Norsk Hydro and the Norwegian Agricultural Supply Cooperative. The emission factor is estimated by the Department of Animal Science at the Agricultural University of Norway. Uncertainty in the estimate of emissions from ammonia treatment of straw is rather low (±5 per cent) (SN 2001f).

6.4.9 Recalculations - non-key sources Agriculture

4A Enteric Fermentation

New revised figures for the population of different animals have been used for the whole time period 1990-2001. A new source, emission of CH_4 from fur animals (fox and mink) has also been included. Emission factor has been calculated by scaling the emission factor for swine, due to carcass weight.

4B Manure Management

New revised figures for the population of different animals have been used for the whole time period 1990-2001. A new source, emission of N_2O from storage of manure has also been included. The figures are calculated for all years using the methodology recommended in the IPCC Guidelines.

4D Agricultural Soils

The emission factor for N_2O from *cultivation of histosols* has been changed from 5 to 8 kg N_2O-N/ha according to IPCC Good Practice Guidance. Recalculations have been made for the whole period 1990-2001.

A new source, emission of N_2O from *sewage sludge* applied on fields has also been included for all years. IPCC emission factor has been used.

NH_3 emissions from *manure storage* were reported under 4D in the previous submission. This is now reported under 4B. In addition, new population data for different animals have been used in Statistics Norway's ammonia model, which has given minor revisions of the emission figures for 1990-2000. This affects the emission of N_2O for the sources where the amount of ammonia volatilization is reducing the amount of N going to N_2O emissions, actual by synthetic fertilizing, use of animal wastes on soil, emission of N_2O from grazing animals and N losses by volatilization.

4 F Cereals

The amount of straw burned has been recalculated for 1997, 1999 and 2000, due to new data for crop production.

Chapter 7. Land-use change and forestry

7.1 Overview

According to the IPCC, the reporting of emissions and removals from land-use change and forestry should include four activities: changes in forest and other woody biomass stocks, forest and grassland conversion, abandonment of managed lands and CO_2 emissions and removals from soils. In Norway, it is difficult to separate the contributions from the first three categories, and removals and emissions are reported for changes in forest and other woody biomass stocks. However, land use changes occur at a very small scale; 2 kha/year as deforestation and 30 kha/year as afforestation, and the omittance of these categories in the present inventory is not likely to have a significant impact on the inventory. Land use changes are assessed from remeasured sample plots in the national forest survey. There are legal restrictions to deforestation which ensures that uncontrolled deforestation does not take place, and that forests are regenerated on harvested lands through replanting or natural regrowth. harvested lands through replanting or natural regrowth.

The inventory includes net removal of CO_2 from total biomass above and below ground in Norwegian forests. However, uptake of CO_2 in forest and agriculture soil and non-CO_2 gas emissions and removals from forest soils and residues are presently not included in the inventory. This inclusion of these sources and sinks in the inventory is dependent upon publication of the IPCC Good Practice Guidance on LUCF. Further, the carbon stock change of harvested wood products is not included in the inventory as the IPCC default method is used, where harvested wood is counted as emissions the year the harvest takes places.

In Norway, removals and emissions from forests and other woody biomass stocks represent a large net sink. The reason for this is expansion of forest biomass as a result of planting and natural regrowth at the beginning of the 20th century, see also Section 2.4. However, the area of forest cover has not increased substantially. Because the changes in forest and woody biomass stocks are a large net sink in Norway, it is considered to be a key source.

7.2 Changes in forest and woody biomass stocks - 5A

7.2.1 Overview

According to the IPCC, the reporting of emissions and removals from land-use change and forestry should include four activities: changes in forest and other woody biomass stocks, forest and grassland conversion, abandonment of managed lands and CO_2 emissions and removals from soils. In Norway, it is difficult to separate the contributions from the first three categories, and removals and emissions are reported for changes in forest and other woody biomass stocks. However, land use changes occur at a very small scale; 2 kha/year as deforestation and 30 kha/year as afforestation, and the omittance of these categories in the present inventory is not likely to have a significant impact on the inventory. Land use changes are assessed from remeasured sample plots in the national forest survey. There are legal restrictions to deforestation which ensures that uncontrolled deforestation does not take place, and that forests are regenerated on

Forested land in Norway covers about 12 million ha, which is about 37 per cent of Norway's total area of 32.4 million ha, see Figure 25. This includes productive forest, other wooded land and forest above the coniferous forest limit. As an average for the years 1994-1998, the total volume under bark for this forest area was almost 680 million m^3, see Figure 26.

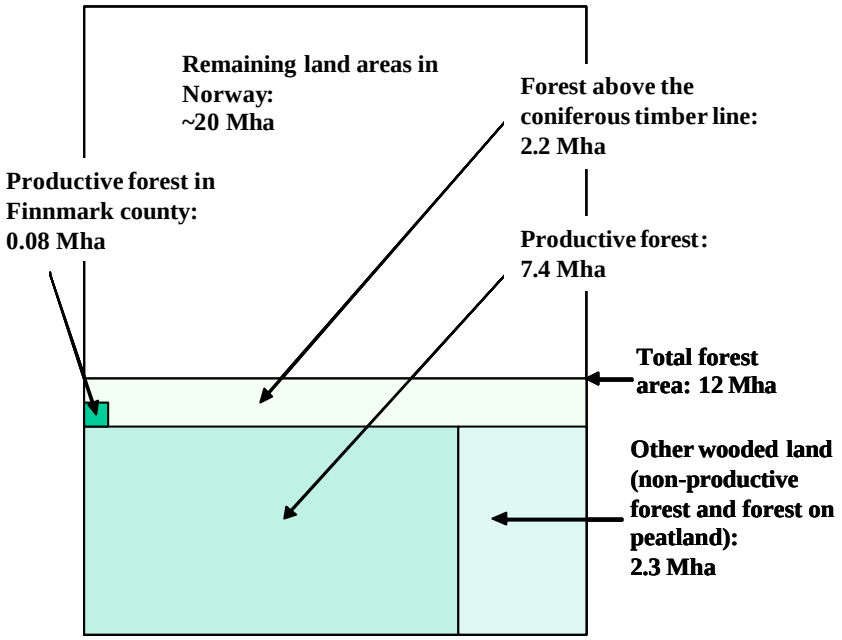


Figure 25. Total forest area in Norway and distribution of categories of forest and other wooded land (average for the period 1994-1998). Source: Norwegian Institute of Land Inventory and SFT

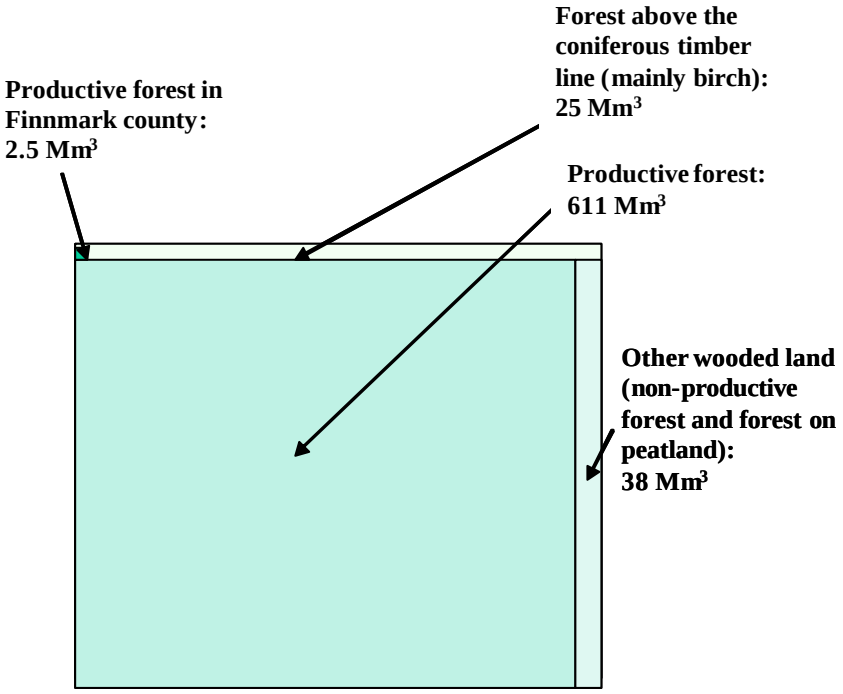


Figure 26. Total forest volume in Norway in million m^3 under bark, as an average for the period 1994-1998). Source: Norwegian Institute of Land Inventory and SFT

A clear distinction between managed and non-managed forest is difficult to establish in Norway, as logging can take place at very long intervals and the forest be left to natural regrowth in intermittent periods. Productive forest is defined as forest with a minimum productivity of 1 m^3 pr ha pr year. However, the CO_2 inventory presented in our submission to UNFCCC excludes carbon stock changes in forest above coniferous forest limit (mountain birch forest and moorland with poorly developed forest), but includes productive forest and other wooded land. Coniferous forest in Finnmark county is also included. Finnmark is the northernmost county in Norway, situated between 68 and 71 degrees north. Finnmark accounts for less than 0,5 per cent of the growing stock of productive forests, and an even smaller fraction of gross increment.

The standing volume under bark (growing stock) for productive forest and other wooded land was estimated to be 710 million m^3 at the end of 2001. The gross increment in Norwegian forests is estimated to be about 24 million m^3 in 2001, corresponding to 35.4 million tonnes of CO_2 when converted to total biomass above and below ground. A total of 16.4 million tonnes of CO_2 were harvested or depleted, which resulted in a net removal of 19 million tonnes of CO_2. This corresponds to 33 per cent of the national CO_2 equivalent emissions.

The total gross depletion of 16.4 million tonnes of CO_2 is the sum of contributions from total biomass removed in commercial harvest (5.6 million tonnes CO_2), traditional fuel wood consumed (1.1 million tonnes CO_2), other wood use (0.2 million tonnes CO_2), logging and sivilcultural waste (7 million tonnes CO_2) and natural losses (2.5 million tonnes CO_2). The sectoral background data and carbon balance are given in Annex 3.

7.2.2 Methodological issues

The inventory of removals and emissions from forestry considers removals due to forest biomass expansion and emissions due to fellings and natural losses. A country specific approach is applied for constructing the national forest balance, using national statistics. The forest balance is created in the following steps:

- A national forest inventory which estimates the growing stock and annual gross increment of forests in m^3/year
- Depletion from fellings, estimated from national statistics on fellings, volume of commercial pulpwood and timber and fuelwood consumption
- Depletion from natural losses
- Calculation of biomass and carbon removal from the volume balance obtained above

The Norwegian Institute of Land Inventory (NIJOS) is responsible for the national forest inventory and supplies all data on forest growing stock and increments. Statistics Norway calculates the national forest balance. A more detailed account of the calculation of the forest balance is given in Annex 3.

The national forest inventory and estimation of stock and gross increment

The Norwegian Institute of Land Inventory (NIJOS) performs the national forest inventory every year. The forest inventory started in 1919 and applies a systematic sampling using permanent sample plots. In the period 1986-1993 permanent sample plots were established in forests in a 3 x 3 km grid. Most of the forest area in Norway is included, except Finnmark county and mountain birch forest. Approximately 10,500 sample plots are located on

productive forest and other wooded land. On average, each sampled area comprises about 3 x 10^{-5} of the surveyable area. Measurements are taken of all trees with a dbh = 5 cm, with an inventory cycle of 5 years. Measurements are carried out on an area of 250 m^2, and stand parameters are based on a plot size of 0.1 ha. Sample plots are characterized as productive or non-productive. Location coordinates and all collected data on individual sample plots are stored in a database at NIJOS.

In order to account for the productive forest in Finnmark county, a separate balance for this county is prepared. This balance uses 1990 as reference year. Stock and gross increment data for Finnmark were obtained from Statistics Norway's Agricultural Census of 1990. The census used a less sophisticated method than the regular forest inventory, being mainly based on information from forest owners. The current forest balance use inventory data for the cycle 1994/1998 as input (NIJOS 2000). The growing stock according to the inventory is taken as growing stock at the end of 1996 (31.12.96 = 1.1.97). The gross increment according to the inventory is taken as valid for 1996. Both growing stock and increment data are given as trunk volume under bark. Increment estimation is based on increment boring.

Calculation of the present standing volume is done as a projection of the standing volume computed from inventory data for the cycle 1994/1998 (NIJOS 2000), using field-collected growth data. As there is a five year cycle of the inventory, using the computed standing stock for a five-year period gives the lowest uncertainty. The growing stock of productive forest in Norway was about 710 million m^3 at the end of 2001, and a net growth of 12.4 million m^3 (see Annex 3 for details). Growth rates are calculated from the inventory data as *gross increment/growing stock*. The growth rates are differentiated by species. Note that the rate uses the growing stock at the end of the year instead of the beginning. The rationale for this method was to improve the correspondence between the forest balance and the inventory in the reference year of 1996. If we had considered the inventory as the growing stock in the beginning of the reference year, then the growth rate would have been more straightforward, but the stock and increment data from the inventory would have appeared in different years in the forest balance result tables. The slightly higher growth resulting from this approach also seemed to correspond better with the change between different inventory cycles.

Estimation of fellings and fuelwood consumption

Data on fellings are taken from two sources in Statistics Norway: Commercial roundwood removals (published annually) and the Agricultural Census from 1990. Data on total fuelwood consumption are taken from the energy balance. The data are used as shown in Table 11.

Table 11. Data used in the estimation of fellings and fuelwood production in Norway.

Forest balance calculation and result	Felling type	Input data
Commercial consumption exclusive fuel wood	Commercial pulpwood and timber (as reported to FAO)	Commercial roundwood removals (annual)
Fuelwood consumption	Commercial fuelwood	Energy consumption data (Statistics Norway)
	Non-commercial fuelwood	Agricultural Census 1990 (fixed)
Other private wood consumption	Non-commercial timber etc (use by forest owner)	

Fellings in Finnmark county is treated separately from the other counties. There is currently registered only fuelwood fellings in Finnmark.

Logging residues and natural losses

Logging residues and natural losses are calculated as fixed percentages of total fellings and gross increment, respectively. The factors were established in cooperation with experts at the National Institute of Land Inventory (Schøning 1992) and are given in Annex 3.

Calculation of the forest balance and carbon balance

The forest balance is calculated as standing volume under bark. This is expanded to total biomass using the IPCC default ratio of 1.9 for managed forests (IPCC 1997). The factor has been applied to both removal and increment data, as both are given as trunk volume. Expansion of fellings is assigned to logging residues. Total biomass is converted to dry mass using national species-specific values given in Annex 3, ranging from 0.38-0.50. Conversion to carbon content is done using the IPCC default value of 50 per cent. Calculation of the forest balance and carbon balance is done by Statistics Norway, who also archives the necessary data.

7.2.3 Uncertainties

There are uncertainties related to the national forest survey, the use of expansion factors and in the data sources for constructing the forest balance.

In the calculation of the forest balance, the use of a default biomass expansion factor represents an uncertainty. At present, no national or species-specific biomass expansion factors have been developed. Also, the use of annual stock data for calculating net growth represents an uncertainty particularly for single year results. Inventory data are not annual, and growth and felling estimates do not fully account for change in stock between inventory cycles. Averages over several years are more certain. This is the reason why data for a five-year period are used as the basis for calculating the standing stock. The uncertainty of annual change in forest is, however, far lower than in the biomass stock. The last important uncertainty is with respect to the data on fuelwood consumption. Data on fuelwood consumption are taken for the energy balance, as this gives more correct data, showing higher fuelwood consumption. However, the calculation of net forest increment after felling has not been corrected for this figure for fuelwood consumption. This has not been done yet due to time constraints. The higher fuelwood consumption gives a smaller standing stock and smaller gross increment. The error in gross increment is estimated to be about 1 per cent.

No national analysis of total uncertainty in the Norwegian forest balance has been undertaken. The forest balance uses a best estimate. A careful estimate of total uncertainty would be in the range of 40 per cent, based *inter alia* on Swedish analyses of their forest balance, which treats forest types similar to the Norwegian.

7.2.4 Source-specificQA/QC and verification

The Norwegian Institute of Land Inventory undertakes a control assessment each year to check data quality and ensure consistent methodology in the survey. Statistics Norway examines the various statistical data for consistency over time.

7.2.5 Recalculations

No recalculation has been undertaken for the removals in the forestry sector since last submission.

7.2.6 Planned improvements

The finalization of the Good Practice Guidance for LULUCF is expected to give important clarifications as to how the forest inventory should be improved, as more specific guidelines will be given.

With respect to the data material, one acknowledged improvement is to ensure consistent use of data on fuelwood consumption in the energy data and the forest balance. This has not been updated for the calculation of the forest balance, and will be addressed. Current planned improvements for the increment data is that it will be based on measured increment diameter of each tree on the permanent sample plots, assessed over the period between two inventories. The next survey to collect increment data will be in 2004, and diameter measurements can be used then. Trees which have been felled or died during the reference period will be included.

Chapter 8. WASTE

8.1 Overview

This sector consists of the sub-sectors Managed waste disposal on land (6.A1), Waste incineration (6.C) and Waste water handling (6.B) which include Domestic and Commercial Wastewater and N_2O from human sewage.

It is only emissions of methane from solid waste disposal that is key source in the waste sector.

The GHG emissions from the waste sector have increased by 3.8 per cent from 1990 to 2001 while the total emissions of GHG in Norway have increased by 8 per cent. Due to growth in activity the emissions from the sub-sectors (except sector 6.A1), have increased continuously since 1990. Methane emissions from landfills have been quite stable in the period. Higher volumes of municipal solid waste (MSW) produced have been offset by increased recycling of waste, increased burning of methane from landfills and higher volumes of waste incinerated. The reason for the reduction in specific methane emissions from waste is most likely that a landfill tax for organic waste was introduced in 1999.

In 2001 the waste sector contributed to 7.5 per cent of the total GHG emissions in Norway. This is a reduction from 7.8 per cent in 1990.

8.2 Managed waste disposal on land – 6.1A

8.2.1 Description

Emissions of methane from solid waste disposal are a key source in level and trend due to uncertainty in activity data, emission factor and change in trend. The sector's share of the national total GHG emissions has decreased from 7.4 per cent in 1990 to 7.0 per cent in 2001.

Norway does not report emissions from unmanaged solid waste disposal (SWDS) sites. The reason for this is that emissions from these sites are minimal and that currently no survey statistics are available.

Norway is aware of the fact that the CH_4 emissions per capita from landfills are the highest among all the reporting Parties. This is due to the combined approach of the model and specific conditions in Norway and may also be due to that emissions of methane from organic industrial solid waste is included in the inventory.

8.2.2 Methodological issues

Methodology

In the calculation of methane emissions from landfills Norway has developed a model which is described in detail in (SFT 1999b). The model is based on the IPCC theoretical first order kinetics methodologies (IPCC 1997b). We use a Tier 2 methodology that is based upon a

range of country-specific and IPCC default approaches. This methodology is consistent with the IPCC Good Practice Guidance.

The model takes into account the fact that methane is emitted from waste deposited over a period of years. Improved waste statistics have become available in the last few years, giving better data on waste volumes and waste composition (SN 1998a). The model therefore now gives a good estimate of methane emissions from municipal waste and private industrial landfills. The effect of weather conditions is taken into account in the model.

Activity data

The activity data for the waste sector come from a number of sources. Municipal waste is assessed by annual surveys carried out by SN. Data on commercial waste are taken from surveys conducted every three years, also carried out by SN. Additionally, information on SWDS and incineration is provided to SFT from the county governors, who are responsible for issuing permits and are required to record waste information, which is stored on a national database called INKOSYS. Plant-specific information and assumptions are contained in (SFT 1999b). In consultation with Norwegian experts, the collection and detail of the activity data have been found to be consistent with the IPCC Good Practice Guidance.

Data from each landfill site with recovery units for methane is sampled by the county governors and reported to SFT. This data is imported into the national model for calculating methane from landfills.

Emission factors

The emissions factors used in the Norwegian model is a mixture of country-specific factors, conjectured by a range of officials and Norwegian waste experts, and IPCC defaults values applied where country-specific information was not available. Table 12 shows some of the variables used in the calculations of methane from solid waste disposals.

Table 12. Variables used in the calculations of methane from landfills. Source: SFT (1999a)

Variables	Type of waste		
	Household	Commercial/ Institutional	Manufacturing
$t_{1/2}$ (half life)	9.5 years	11 years	11 years
Landfill gas potential (L_0)	370 Nm^3/tonne	355 Nm^3/tonne	425 Nm^3/tonne
Correction factor (1997[6]) (MCF)	1.00	0.80	0.80
Oxidation effect	10 per cent	10 per cent	10 per cent

8.2.3 Uncertainties

The uncertainty of the calculated methane emissions from landfills is overall ranked in both level and in trend as one of the most uncertain emission estimates in the Norwegian GHG

[6] Different correction factors for different years.

inventory. This is the situation even if this emission source recently has been prioritised for inventory improvement. The importance of the uncertainties in calculations of methane from landfills will decrease with decreased source contribution, but it will most likely still remain among the main uncertainties in the Norwegian GHG inventory.

The methodology we 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 the last years and the same is true regarding the data for recovered methane.

8.2.4 Source specific QA/QC and verification

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 is 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 landfills site, the site is contacted to seek for an explanation. Corrections are made if there is no plausible explanation of the change.

8.2.5 Recalculations

Emissions estimates of methane from SWDS in 1998-2000 have been recalculated since last year's submission of GHG emission data for Norway. The following recalculations are made:

- Recovery data in the period 1998-2000 have been changed for some landfill sites
- Data on industrial and the manufacturing waste have been revised for the period 1998-2000

The recalculations have resulted in a change in the emission level of methane from landfills of 1.19 per cent in 2000 and 0.11 per cent in 1998.

8.2.6 Planned improvements

A documentation of all procedures involved in the preparation of the inventory data for solid methane disposal on land will be finalised in 2003.

8.3 Non-key sources

8.3.1 Solid waste disposal on land – CO_2 – 6A

The reported estimate of CO_2 emissions from landfills includes both direct emissions and indirect emissions from oxidation of methane in the atmosphere. It is only the fossil carbon in the deposited waste that is included in CO_2 emission inventory and this is in accordance with the IPCC's Good Practice Guidance.

8.3.2 Waste water handling – N_2O and CH_4 – 6B

We have reported emissions of methane and nitrous oxides from domestic and commercial wastewater only. 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.

The CH_4 from domestic sludge are calculated together with the waste water emissions. Emissions of methane from domestic waste water are calculated according to the IPCC default methodology, and from this year activity data for Gg DC/yr is reported and the new Good Practice EF of 0.6 kg CH_4/kg DC is used. A country-specific factor for the fraction that is anaerobic treated is being used.

For N_2O, emissions are calculated from nitrification/denitrification that occurs in the pipelines and the N_2O that occur in the waste water plants, in the biological step. This is assumed to be a more precise method than the recommended IPCC method that is based on the annual per capita protein intake. The N_2O from sewage sludge applied on fields are reported under Section 4.

8.3.3 Waste incineration – CO_2 – 6C

Waste combusted for energy purpose is included in sector 1A1 and it is only the fossil carbon of the combusted waste that is included.

8.3.4 Recalculation – non-key sources Waste

6A Solid Waste Disposal on Land

Emissions estimates of methane from SWDS in 1998-2000 have been recalculated since last year's submission of GHG emission data for Norway. The following recalculations are made:

- Recovery data in the period 1998-2000 have been changed for some landfill sites
- Data on industrial and the manufacturing waste have been revised for the period 1998-2000

6B Wastewater Handling

The emission factor for CH_4 from municipal waste water handling has increased, because the factor for Bo, kg CH_4/kg BOD is updated to 0.6 from 0.25 according to IPCC Good Practice Guidance. Recalculations have been made for the whole period 1990-2001.

6C Waste Incineration

The emission factor for CO_2 from flaring of methane from solid waste disposal was previously erroneously set to 0. This factor is now set to 0.275 tonnes/tonnes, the same as for methane (also from solid waste disposal) used in boilers. The factor takes into account that only the fossil part of the CO_2 should be reported here.

Chapter 9. Recalculations

This chapter describes the rationale for the recalculations performed in this year's submission to the UNFCCC and points out the differences from the 2002 submission. The recalculations refer only to CO_2, CH_4 and N_2O. HFCs, PFCs and SF_6 figures have not been recalculated since the last submission.

9.1 Overall description of recalculations in 2003

The main reasons for recalculations in 2003 are:

- improvements in the energy data
- inclusion of new emission sources
- changes in emission factors

There have been improvements in the energy data for some sectors for the year 2000 compared to the previous submission. The energy accounts for 2000 that was the basis for last year's submission 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.

The energy accounts are published annually. Just as for the emission inventory there might be recalculations in the energy data too. Such improvements often lead to changed figures for the whole time series. This year changes have been made related to the following sources:

- fuel wood consumptions in households
- heating oil, gasoline and auto diesel consumption in agriculture
- heating oil consumption in households

N_2O emissions from the agricultural sector have been increased mainly due to inclusion of new sources categories. N_2O-emissions from manure management, has been included, as well as emission of N_2O from sewage sludge applied on fields. New revised data for animal populations also gives changes in the N_2O-emissions. The emission factor for cultivation of histosols has been changed, which gives increased N_2O-emissions.

Detailed explanations for each recalculation are given both in the corresponding sections of the sectors already discussed and in Section 9.2 below. Further details are also given in the recalculation tables in the CRF.

In Section 9.3 below a description of the implication for emission levels and trends is given.

9.2 Specific description of the recalculations in 2003

9.2.1 Energy

1A1a Public Electricity and Heat Production

Emissions of N_2O from waste incineration by district heating production were not calculated before. Using the national assumption that 2.5 per cent of the reported NO_X emissions are N_2O, emissions have been transferred to N_2O. This recalculation has been carried out for the whole period 1990-2001.

1A1c Manufacture of Solid Fuels and Other Energy Industries

The energy data for gas terminals have been revised in the final energy accounts for 2000. This is the reason for the recalculation of CO_2 this year. There have of course also been recalculations for CH_4 and N_2O for the same reason, but these are of minor importance for the component total

1A2a Iron and Steel

There are small revisions in the figures compared with last year's submission caused by changes in the energy accounts from the preliminary to the final 2000 figures.

1A2c Chemicals

There have been some small revisions in the energy accounts for use of CO gas for one plant for the whole time series.

1A2d Pulp, Paper and Print

Better knowledge of the waste fractions incinerated at one plant has led to changed CO_2 emission factor. The emission figures for this plant have been recalculated for the years 1998-2000 for this reason. Before 1998 the plant burned only wood waste. CO_2 emissions from this are included elsewhere.

1A2f Other

Revisions in the preliminary energy figures (2000) led to recalculations of emission figures for all components for this source.

1A3b Road Transportation

There have been revisions in the energy accounts regarding the consumption of auto diesel in agriculture. These revisions have influenced the on-road/off-road distribution of the total diesel consumption. Up to 1997 this revision led to an increase of the road traffic emissions. For 1998-2000 the road traffic emissions have been reduced compared with last year's submission. This methodological change required recalculations of all components for the whole time series. The revision has been most important for CO_2.

1A3d Navigation

There has been an increase in emissions for all components in 2000 due to the revision of the preliminary energy data.

1A4a Commercial / Institutional

There has been an increase in emissions for all components in 2000 due to the revision of the preliminary energy data.

1A4b i Residential plants

Emission figures for all components have been recalculated based on revisions of energy data for the whole time series. The estimates of fuel wood consumption have decreased. The student population was erroneously included when fuel wood consumption data on a household basis were grossed up to national figures. This does not lead to any changes for CO_2 since biotic carbon is included elsewhere. But the revision is most important for CH_4.

Furthermore, there are some improvements in the energy accounts giving revised figures for consumption of fuel oil and charcoal. This led to recalculated emission data for CO_2, CH_4 and N_2O for the whole time series.

1A4c Agriculture/Forestry/Fishing

The emission figures are recalculated for all components compared with last year's submission caused by improved energy data for auto diesel in the agriculture sector.

There have been revisions in emission figures for all components due to revised energy data. Emissions from national fishing are now based on fuel sale.

1B2a Fugitive emissions from oil loading – 1B2a

The emission data for 1997-2000 is recalculated since previous submission of data to UNFCCC due to revised emission factors for some oil fields.

9.2.2 Industrial processes

2A2 Lime Production

In the new submission emissions from lime production are reported under 2A2.

2B1 Ammonia Production

The plant that produces ammonia (and nitric acid) captures parts of the CO_2 emitted during the production process. The CO_2 is a by-product of the ammonia production and is sold to other companies in Norway or exported. The amount of CO_2 sold has been taken into account in this submission to the UNFCCC. In 2000, approximately 200 000 tonnes CO_2 were captured and sold. 50 000 tonnes of this were used in Norway, mainly as carbonic acid in carbonated beverages. The rest, 150 000 tonnes were exported. The export has increased during the nineties. In 1990, the export was approximately 50 000 tonnes. This recalculation has lowered the Norwegian CO_2 emissions in 2000 with 150 000 tonnes compared with what was reported in NIR 2002. Likewise, the 1990-figures of CO_2 are 50 000 tonnes lower than in NIR 2002.

2C3 Aluminium Production

Previously Statistics Norway calculated the emissions of CO_2 from aluminium production based on the consumption of reducing agents. Now SN/SFT are using the data for the emission amounts that the industries themselves report to the SFT. The methodological

change has been made for all years from 1990. For 1990 and 1991, no reported data existed, so a recalculation has been made using production data and reported emission data for 1992.

2D2 Food and Drink

As mentioned in the text under 2B1 Ammonia Production, Norway now takes into account that some CO_2 from this production is exported or used in other national industries. The most important national use of this is as carbonic acid in carbonated beverages. In 2000, about 50,000 tonnes CO_2 were sold for national use, and as mentioned most of this for lemonade production. The whole tonnage is reported under 2D2 even if most of the emissions often take place after people have opened the bottle and not in the breweries.

In 1990 the emissions were 20,000 tonnes, and they increased to 50,000 tonnes in 2000. The figures were previously reported under 2B2 nitric acid production (the part of this now reported under ammonia production 2B1).

9.2.3 Agriculture

4A Enteric Fermentation

New revised figures for the population of different animals have been used for the whole time period 1990-2001. A new source, emission of CH_4 from fur animals (fox and mink) has also been included. Emission factor has been calculated by scaling the emission factor for swine, due to carcass weight.

4B Manure Management

New revised figures for the population of different animals have been used for the whole time period 1990-2001. A new source, emission of N_2O from storage of manure has also been included. The figures are calculated for all years using the methodology recommended in the IPCC Guidelines.

4D Agricultural Soils

The emission factor for N_2O from cultivation of histosols has been changed from 5 to 8 kg N_2O-N/ha according to IPCC Good Practice Guidance. Recalculations have been made for the whole period 1990-2001.

A new source, emission of N_2O from sewage sludge applied on fields has also been included for all years. IPCC emission factor has been used.

NH_3 emissions from storage were reported under 4D in the previous submission. This is now reported under 4B. In addition, new population data for different animals have been used in Statistics Norway's ammonia model, which has given minor revisions of the emission figures for 1990-2000. This affects the emission of N_2O for the sources where the amount of ammonia volatilization is reducing the amount of N going to N_2O emissions, actual by synthetic fertilizing, use of animal wastes on soil, emission of N_2O from grazing animals and N losses by volatilization.

Before the next submission, the total amount of manure calculated in Statistics Norway's manure balance will be updated with new data for the population of different animals and new data for grazing times and a new set of coefficients for the amount of N in manure from

different animal types. This will lead to minor revisions of the emission figures for 1990-2000 for N_2O from animal wastes applied to soil, and emission of N_2O from grazing animals. The N_2O-emission from crop residue will also be revised.

4F Cereals

The amount of straw burned has been recalculated for 1997, 1999 and 2000, due to new data for crop production.

9.2.4 Waste

6A Solid Waste Disposal on Land

Emissions estimates of methane from SWDS in 1998-2000 have been recalculated since last year's submission of GHG emission data for Norway. The following recalculations are made:

- Recovery data in the period 1998-2000 have been changed for some landfill sites
- Data on industrial and the manufacturing waste have been revised for the period 1998-2000

6B Wastewater Handling

The emission factor for CH_4 from municipal waste water handling has increased, because the factor for Bo, kg CH_4/kg BOD is updated to 0.6 from 0.25 according to IPCC Good Practice Guidance. Recalculations have been made for the whole period 1990-2001.

6C Waste Incineration

The emission factor for CO_2 from flaring of methane from solid waste disposal was previously erroneously set to 0. This factor is now set to 0,275 ton/ton, the same as for methane (also from solid waste disposal) used in boilers. The factor takes into account that only the fossil part of the CO_2 should be reported here.

9.3 Implications of the recalculations

9.3.1 Implications for emission levels

Table 13 shows the total effect of the recalculations for the emission levels. The CO_2 levels are somewhat lowered in this submission compared to the previous mainly because export of CO_2 is withdrawn and because of new emission data for aluminium industry. The increase in emission of N_2O is mainly due to changes in the calculations of emissions from the agricultural sector. There have not been any recalculations for HFCs, PFCs and SF_6.

The total greenhouse gas emissions measured in CO_2 equivalents have increased by 0.5 per cent in 2000 and reduced by 0.3 per cent in 1990 compared to previous submission.

Table 13. The effect of recalculations performed in the 2003 submission. Difference in per cent between 2003 submission and 2002 submission. All numbers are without Land-Use and Forestry. Source: SN/SFT

	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	CO_2 equivalent
1990	-0.90	-0.23	7.19	-	-	-	-0.32
1998	-0.65	-0.13	8.15	-	-	-	0.08
1999	-0.53	0.19	7.31	-	-	-	-0.06
2000	-0.47	2.32	7.61	-	-	-	0.52

Source: SN/SFT

9.3.2 Implications for emission trends

Table 14 shows the total effect of the recalculations for the emission trends. According to the 2002 submission the CO_2 emissions increased with 17.4 per cent from 1990 to 2000. In the 2003 submission this increase was calculated to 17.9 per cent. Similarly the increase for methane was calculated to 8.4 per cent, while it was 5.6 per cent in last year's submission. The trend for N_2O increased from 0.5 to 0.9 per cent in the 2003 submission.

The increase in total greenhouse gas emissions measured as CO_2 equivalent has changed from 6.3 per cent in last year's submission to 7.4 per cent in this submission.

Table 14. The effect of recalculations performed in the 2003 submission on the estimated total greenhouse gas emission change between 1990 and 2000. Per cent increase from 1990 to 2000. All numbers without Land-Use and Forestry. Source: SN/SFT

	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	CO_2 equivalent
Trend 1990-2000 (this submission)	17.9	8.4	0.9	-	-	-	7.4
Trend 1990-2000 (previous submission)	17.4	5.6	0.5	-	-	-	6.3

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Annex 1: Key sources

This chapter outlines the Tier 2 methodology used to find which sources are key sources in the Norwegian Greenhouse gas emission inventory. The methodology, activity data and emission factors used for the key sources is then summarised. Methodologies for the non-key sources are described in SN/SFT (2000).

Methodology to identify key sources

Key sources in the Norwegian Emission Inventory are identified as described in (SN 2000). This report gives conclusions on both uncertainties in the total emissions and trends and on the sensitivity of the conclusions of possible errors of each input parameter. According to IPCC's Good Practice Guidance (IPCC 2001) the methodology used is a Tier 2 method.

Key sources 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 source is according to IPCC (2001) which is based on (SN 2001).

A short description of the method used to identify key sources and results is given. For further details one should refer to the report SN 2000.

The key source 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. Correlations are taken into account in the analysis. 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. Furthermore, emission factors and activity data can be assessed separately. In addition the Tier 1 method can identify sources that are not actually key according to Tier 2 (SN 2001).

The steps taken to find key sources with respect to level and trend were the determination of uncertainties in input parameters (AD and EF) and the use of sensitivity analysis to identify which parameters in the inventory influence most the total GHG emissions in level and in trend. 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. Emission sources defined as key sources are shown in Table 1 and 0.

The values of level uncertainty importance of activity data are generally lower than the emission factors. This is because the uncertainty in activity data usually is lower than that in the emission factors. The amount of solid waste disposed of and the amount of oil used for domestic shipping are the main activity data influencing the uncertainty importance in level. The emission factors for N_2O from agricultural soils are dominating the uncertainty importance. CH_4 from landfills and PFC from aluminium production are the next contributors to level uncertainty importance.

The trend uncertainty importance identifies HFC from product use, N_2O from road traffic and PFC from aluminium production as the main sources contributing to the trend uncertainty.

The analyses have been performed for 1990 GHG emission data and projected emissions for 2010. The main conclusion is that there are few differences in the result for 1990 compared with 2010.

Table 1. Uncertainty importance of input parameters with respect to total level uncertainty. 1990 and 2010.

Activity data. Ranking of the main important parameters (uncertainty importance ≥ 0.002).

	1990			***2010***	
IPCC category	**Source**	**Unc_imp**	**IPCC category**	**Source**	**Unc_imp**
6A	Solid waste disposal	0.007	6A	Solid waste disposal	0.005
1A3d	Oil - shipping	0.004	1A3d	Oil - shipping	0.004
1A1c	Gas - oil and gas extraction	0.002	1A1c	Gas - oil and gas extraction	0.003
1A3a	Oil - aviation	0.002	1A3a	Oil - aviation	0.002
1A4a	Oil - services	0.002	1A4a	Oil - services	0.002
			1A4b	Oil - households	0.002

Emission factors. Ranking of the main important parameters (uncertainty importance ≥ 0.002).

	1990			**2010**	
IPCC category	**Source**	**Unc_imp**	**IPCC category**	**Source**	**Unc_imp**
4D	N_2O from agricultural soils (other)	0.11	4D	N_2O from agricultural soils (other)	0.09
4D	N_2O from agricultural soils (fertiliser)	0.04	4D	N_2O from agricultural soils (fertiliser)	0.03
4D	N_2O from agricultural soils (manure)	0.03	4D	N_2O from agricultural soils (manure)	0.02
6A	CH_4 from landfilled waste	0.01	6A	CH_4 from landfilled waste	0.007
2C3	PFC from aluminium	0.01	1A1-1A4	CO_2 from oil combustion	0.006
1A1-1A4	CO_2 from oil combustion	0.005	1A1c	CO_2 from gas - oil and gas extraction	0.006
1A1c	CO_2 from gas - oil and gas extraction	0.004	3F	HFC used in products	0.005
4A	CH_4 from cattle	0.003	1A3b	N_2O from road traffic	0.005
2C2	CO_2 from ferroalloy production	0.002	2C3	PFC from aluminium	0.004
1B2a-b	CO_2 + CH_4 from oil loading	0.002	1B2a-b	CO_2 + CH_4 from oil loading	0.003
			4A	CH_4 from cattle	0.003

Source: SN 2000

Table 2. Uncertainty importance of input parameters with respect to total trend uncertainty. 1990 and 2010.

Activity data. Ranking of the main important parameters (uncertainty importance elasticity ≥ 0.01 or < -0.01).

IPCC category	**Source**	**Unc_imp**
1A1c	Gas - oil and gas extraction	+0.01
6A	Solid waste disposal	- 0.01
1A3d	Oil - shipping	+0.01

Emission factors. Ranking of the main important parameters (uncertainty importance elasticity ≥ 0.01 or <- 0.01).

IPCC category	Source	Unc_imp
2F	HFC consumption	+0.02
1A3b	N_2O from road traffic	+0.02
2C3	PFC from aluminium production	-0.02
1A1c	CO_2 from natural gas combustion	+0.01
1A	CO_2 from oil combustion	+0.01
1B2a	CH_4 from oil loading	+0.01
1B2a	CO_2 from oil loading	+0.01
6a	CH_4 from landfilled waste	-0.01
1B2c	CH_4 from venting	-0.00
1B2c	CO_2 from venting	-0.00
1B2c	CO_2 from flaring	+0.00

Source: SN 2000

Annex 2: Manure management and Agricultural soils (4B, 4D)

N_2O

In Norway, all animal excreta that are not deposited during grazing are used as manure. N_2O from manure are estimated in accordance with the IPCC default method (IPCC 1997b), but with Norwegian values for N in excreta from different animals according to Table 1 and fraction of animal categories manure handled by different manure systems, Table 2.

Table 1. *N in excreta from different animals*

	kg/animal/year[2]
Dairy cattle	89.8
Non-dairy cattle > 1year	38.5
Non-dairy cattle < 1year	30.3
Horses	52.3
Sheep	9.6
Dairy goats	14.0
Pigs for breeding	24.3
Pigs for slaughtering[1]	4.0
Hens	0.8
Chicks bred for laying hens[1]	0.16
Chicks for slaughtering[1]	0.058
Ducks, turkey[1]	0.37
Mink, females	4.7
Foxes, females	11.9

[1] Per stalled animal.

[2] Includes pasture.

Source: Sundstøl and Mroz (1988).

The emissions of nitrous oxide from manure are estimated using the following equation, in accordance with the IPCC Tier 2 method (IPCC 1997a,b):

$$(2) E = \sum_s \left\{ \left[\sum_i \left(N_i \cdot Nex_i \cdot MS_{i,s} \right) \right] \cdot EF_s \right\}$$

E: Emissions of N_2O-N (kg N_2O-N/yr)
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

NH_3

Statistics Norway's NH_3-model is used for calculating the emissions of ammonia from manure management. The emission sources are split into manure in storage, droppings on pastures, manure during and after spreading, and emissions from reindeer. Emissions from the different sources are given below in Table 2.

Table 2. *Emission data from Statistics Norway's ammonia model. 1999*

Emission sources	Emission (tonnes NH_3)
Manure in storage	5152.4
Manure during and after spreading	10701.2
Droppings on pastures	601.9
Emissions from reindeer	32.2
Synthetic fertiliser	5773.0
Treatment of straw	1326.6

Activity data

N_2O

Emissions are estimated from the animal population, see Table 3 below. The data are based on population counts, with annual estimations based on sample surveys for the ruminants (cattle and sheep) and applications for economic support for the remaining.

Table 3. *Numbers of animals. 1999*

	No. of animals
Total	
Horses	43 467
Non-dairy cattle	668 497
Dairy cattle	347 363
Sheep	1 724 619
Goats	73 999
Pigs	629 965
Poultry	11 132 680
Fur-bearing animals	154 462
Reindeers	188 025
Deer	1 739
Ostrich	2 113

Source: Agricultural Statistics from Statistics Norway.

NH_3

The parameters included are shown in Table 4.

Table 4. *Parameters included in the estimation of NH_3 emissions from manure and manure management*

Input	Sources
Number of animals	Statistics Norway, Norwegian Grain Administration
Percentage of manure dropped into fields during grazing	ECETOC (1994)
Cultivation	Norwegian Grain Administration
Emissions from storage of manure	Morken (1994)
Area where manure is spread, split by cultivation practice and time of spreading	Statistics Norway (Sample Survey of Agriculture)
Emissions to air during spreading of manure	Claesson and Steinbeck (1991), Morken (1994)

Table 5. *Nitrogen excreted in manure and urine. kg/animal/year*

	Total nitrogen excreted	NH_3-N
Horses	50.5	18.9
Cattle	19.6-85.7	7.1-37.6
Sheep	8.61	5.6
Goats	12.3	5.5
Pigs	3.96-20.24	2.8-13.9
Poultry	0.03-0.61	0.01-0.3
Fur-bearing animals	1.2-2.38	0.5-1.0

Source: Bleken (1996) and Morken (1994).

Emission factors

N_2O

The IPCC default values for N_2O emission factors from manure management are used. These are consistent with the Good Practice Guidance (IPCC 2001).

Table 6. *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 drylot	0.02
Pasture range and paddock	0.02
Other system	0.005

Source: IPCC 1997b

Use of synthetic fertilizers gives emissions of N_2O and NH_3. Manure applied to soils gives emissions of N_2O. Indirect emissions include N_2O emissions from leaching and runoff and ammonia volatilisation.

Method

Synthetic fertiliser

N_2O

Direct emissions of N_2O are calculated from the use of synthetic fertiliser. The annual consumption is multiplied with the IPCC default emission factor. The emissions are corrected for ammonia that volatilises during application.

NH_3

Calculations of NH_3 emissions from use of fertiliser are based on the amounts of nitrogen supplied and factors for the percentage of nitrogen emitted during spreading. The emission factors vary from one type of fertiliser to another. ECETOC (1994) estimated emission factors, see Table 7. The emission for the 1999 is given in Table 2.

Table 7. Emission factors for different fertilisers. Per cent of applied N

Fertiliser	Emission factor
Urea	15
Ammonium sulphate	5
Ammonium nitrate	5
Other	1

Source: ECETOC (1994) and Norsk Hydro.

N_2O from manure applied to soils

In Norway, all animal excreta that are not deposited during grazing are used as manure. Further, it is assumed that animals do not emit N_2O themselves, but emissions of N_2O from manure management before manure application on fields will be taken into account. The total amount of nitrogen in manure is estimated from the number of animals and factors for each kind of animal. Emissions of N_2O from manure used as fertiliser are 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 ammonia that volatilises during application.

N_2O from biological nitrogen fixation

Another source of nitrous oxide emissions is connected to 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,b). The amount of nitrogen fixed is multiplied with the IPCC default emission factor.

N_2O from crop residues

There is only limited information concerning re-utilisation of nitrogen from crop residues. Nitrous oxide 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,b). 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 has been multiplied with the IPCC default emission factor.

N_2O from industrial and urban wastes

Today, the N_2O emissions arising from the application of industrial and urban wastes on agricultural fields are not included in the Norwegian inventory. This emission source will be included in the future, though. No data is available for the amount of industrial waste applied as nutrient. Some waste from the fish industry has been used as nutrient[7], 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.

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 mineralisation of old, N-rich organic matter (IPCC 1997a,b). The emission is 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.

[7] Personal communication, Line Diana Blytt, Norwegian Agricultural Inspection Service.

N_2O from grazing animals
The amount of N deposited during grazing has been multiplied with the IPCC default emission factor. The emissions have been corrected for the amount of ammonia volatilised.

N losses by volatilisation
Atmospheric deposition of nitrogen compounds fertilises soils and surface waters, and enhances biogenic N_2O formation. Deposition of ammonia is assumed to correspond to the amount of NH_3, which volatilises during use of synthetic fertiliser and manure. Climate and fertiliser type influence the ammonia volatilisation. The N_2O emission is given by multiplying the amount of N from deposition with the IPCC default emission factor.

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,b) proposes a default value of 30 per cent, but in the Norwegian inventory a national factor of 18 per cent (JORDFORSK 1998) is used, that 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 get the emission of N_2O.

Activity data

In Table 8, activity data for process emissions of N_2O in the agriculture and the activity data sources are given.

Table 8. *Activity data for process emissions of N_2O in the agriculture. 1999*

	Value (ktonnes N)	Source
Synthetic fertilizer	106	Norwegian Agricultural Inspection Service
Manure (fertilizer)	56.4	Statistics Norway and Sundstøl and Mroz (1988)
Biological N-fixation	8	Aakra and Bleken (1997)
Crop residues	78	Aakra and Bleken (1997)
Industrial and urban wastes	1.73	Statistics Norway (2001)
Cultivation of organic soils	175	Aakra and Bleken (1997)
N deposited during grazing	18.7	Statistics Norway, manure balance
Ammonia volatilisation	18	Statistics Norway, ammonia model
N leaching	35	JORDFORSK (1998)

Sale of nitrogen fertiliser: The Norwegian Agricultural Inspection Service calculates annual consumption of synthetic fertilisers in Norway.
Amount of manure: The numbers of the various kinds of animals (Table 3) are taken from Statistics Norway's livestock statistics. These are based on the register of production holders applying for governmental grants. Almost 100 per cent of all livestock are registered here. Factors for N in excreta for each kind of animal are given by Sundstøl and Mroz (1988) in (Table 1).
Fate of manure: The estimation of total N in animal excreta comes from Statistics Norway's manure balance. The allocation of manure between what is used as fertiliser and droppings on pastures was estimated in 1994 (Aakra and Bleken 1997), and the same fractions are used every year (ca. 3:1). NH_3 volatilisation from excreta deposited during grazing is calculated in Statistics Norway's ammonia model.

Biological N-fixation: A yearly biological N-fixation has been estimated by Aakra and Bleken (1997).
Nitrogen left after harvest: 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 is given in Table 8.
Industrial and urban wastes: The amount of sewage sludge and a N-content of 2.82per cent in the sludge are given by Statistics Norway's water statistics.
Cultivation of organic soils: An approximation of the area of cultivated organic soil in Norway is made by Aakra and Bleken (1997).
Deposition of other agricultural emissions: The amount of N from deposition is given from Statistics Norway's ammonia model.
Leakage of nitrogen: The amount of nitrogen lost to leaching has been estimated from a runoff model by JORDFORSK (Norwegian Centre for Soil and Environmental Research).

Emission factors

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 two exceptions. Emission of N_2O from animals on pastures is 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 is calculated 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 ammonia volatilised. The IPCC default emission factor of 0.025 kg N_2O-N/kg N leaching/runoff is used.

Uncertainties

Activity data

There are several types of activity data entering the calculation scheme:
Sale of nitrogen fertiliser: The data are based on sales figures (The Agricultural Control Authority). Two methodologies are used for data collection and the outputs agree very well. The uncertainty is within ±5 per cent. Another error, which will be averaged over time, is that sale does not equal consumption in a particular year due to storage.
Amount of manure: The figures are generated by, for each animal type, multiplying the number of animals with a nitrogen excretion factor. The nitrogen excretion factors are uncertain. However, due to nitrogen leakage problems in parts of Norway these have been improved over time (the range is considered to be within ±15 per cent). 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. The Norwegian factors are far away from the IPCC default factors (by 40 to several hundred per cent). The uncertainty connected to the estimate of the amount of manure is higher than the figure for 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 left after harvest: Norwegian factors have been used. These are lower than the IPCC default factors by 40 per cent. The harvest of nitrogen is determined within ±10 per cent, but

the expansion factor to account for nitrogen left is very uncertain. Assessed uncertainty range is about ±50 per cent.
Deposition of other agricultural emissions: The data are based on national NH_3 emission figures. These are within ±30 per cent.
Leakage of nitrogen: The upper limit for the leakage is the applied nitrogen. The uncertainty is roughly about ±70 per cent.
Cultivation of organic soils: Data are based on a one-year survey, and are uncertain by more than a factor of three.

Emission factors

N_2O
The uncertainties in the N_2O emission factors are high. In Rypdal and Zhang (2000) it was assumed a factor of two according to IPCC (1996). In IPCC (2001) these uncertainty intervals have been narrowed somewhat. [siter] Aardenne et. al. (1998) have estimated a 95 per cent confidence interval uncertainty (in emissions) of -40-+70 per cent for this source, but this may not contain all systematic errors.

NH_3
The uncertainty in the estimate of emissions of NH3 from use of fertiliser is assessed to be about ±20 per cent. This uncertainty might have been lower if better data on fertiliser composition was obtained. The uncertainty is higher for animal manure (±30 per cent). 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) (SN, 2001).

Completeness

All sources described in the IPCC reporting guidelines are included in the estimates. However, the emission factors might not be reflecting national conditions.

QA/QC

In 2002, a project funded by the Nordic council & Council of ministers was carried out. The study compared the results for emissions of greenhouse gases from the agricultural sector in the national emission inventories of the different Nordic countries with the results using the IPCC default methodology and the IPCC default factors. The results for the Nordic countries are collected in a report by Petersen and Olesen (2002). The main conclusions of the report are that there are currently large differences between the Nordic countries in the application of the IPCC methodology. In some cases the estimates of activities differ considerably, in other cases different emission factors were applied. Furthermore, it was found that there is a great need to improve the IPCC methodology and to make it more locally adapted, but based on common guidelines. Several elements of improvement were suggested; e.g. that the climatic variation within the Nordic countries should be accounted for in the estimates of CH_4 emissions from manure, and that the emission factors for nitrous oxide from both direct and indirect sources should be differentiated more than what is currently the case. For some of the emission sources there is a lot of experimental data available, and there is sufficient knowledge to improve the methodology. But there is a clear need to better link experimental data with the use of systems modeling.

The calculation methodologies for the agricultural soil emission sources have been surveyed in 2002 and one source has been added (industrial and urban waste). Some work is done to find more updated activity data.

Annex 3: Changes in forest and other woody biomass stocks

Calculation of the forest balance is done by the procedure shown in Table 1.

Table 1. Assembling the forest balance. The formulae for the derived items in the forest balance.

Item	Formula
Growing stock Jan 1.	= Growing stock Dec 31. of the previous year (input data for 1997)
Corrections for new inventory	(not used)
Total Gross Depletion	= Felling in total + Other depletion in total
Felling in total	= Commercial consumption exclusive fuel wood + Fuelwood consumption + Other private wood consumption
Commercial consumption exclusive fuel wood	Input data
Fuel wood consumption	Input data
Other private wood consumption	Input data
Other depletion in total	= Logging and sivilcultural waste + Natural losses
Logging residues	= Felling in total * factor
Natural losses	= Gross increment * factor
Gross Increment	= (Growing stock Jan 1. - Felling in total - logging residuals) * growth rate / (1 - growth rate * (1 - natural loss rate)) [=Growing stock Dec 31. * growth rate]
Growing stock Dec 31.	= Growing stock Jan 1. - Total Gross Depletion + Gross Increment

Converting volume data into a carbon balance

The volume data are converted into dry matter using species-specific factors shown in Table 2.

Table 2. Factors for converting volume into dry matter

Factor	Value	Source
Volume to dry matter		
- Spruce	0.38 t dm/m^3	Lunnan et al. (1991)
- Pine	0.44 t dm/m^3	
- Deciduous	0.503 t dm/m^3	
Dry matter to carbon content	0.5 t C/t dm	IPCC (1997)

The data so far refer to trunk volume under bark only. A biomass expansion factor is used to convert this into total biomass. We have used the default factor of 1.9 for managed forests from the IPCC Guidelines (IPCC 1997). The factor has been applied to both removal and increment data, as both are given as trunk volume. However, the expansion factor is not applied uniformly to the forest balance. The item *total fellings* and the underlying terms refer to biomass which is removed physically from the forest. These items are converted into carbon or CO_2, but not expanded into total biomass. Instead, the expansion of fellings, which covers branches, stumps and roots etc., is added to the item *logging residues*. The relation between biomass carbon data and trunk volume data is given in Table 3.

Table 3. Calculation of biomass carbon data from trunk volume

Item	**To get from trunk volume to total biomass carbon**
Total Gross Depletion	Multiply by dry matter content, carbon content, and biomass expansion factor
Felling in total	Multiply by dry matter content and carbon content
Commercial consumption exclusive fuel wood	Multiply by dry matter content and carbon content
Fuelwood consumption	Multiply by dry matter content and carbon content
Other private wood consumption	Multiply by dry matter content and carbon content
Other depletion in total	(Sum item)
Logging residues	Multiply by dry matter content, carbon content, and biomass expansion factor *plus* leftover biomass from fellings: *felling in total* multiplied by dry matter content, carbon content, and (biomass expansion factor - 1)
Natural losses	Multiply by dry matter content, carbon content, and biomass expansion factor
Gross Increment	Multiply by dry matter content, carbon content, and biomass expansion factor
Net growth	Multiply by dry matter content, carbon content, and biomass expansion factor

The carbon balance for changes in forest and woody biomass stocks and the sectoral background data for the calculation for 2001 are given in Table 4.

Table 4. Sectoral background data for land use change and forestry, changes in forest and woody biomass stocks in 2001

	In total	Spruce	Pine	Deciduous
Depletion and growth of forests 2001		**1000 m^3**		
Growing Stock per 1.1.01	**697 998**	**308 614**	**233 949**	**155 436**
Total Gross Depletion	**11 455**	**7 471**	**2 333**	**1 652**
Felling in total	9 209	6 367	1 839	1 003
Commercial consumption exclusive fuel wood	7 685	5 915	1 716	53
Fuel wood consumption	1 322	292	83	947
Other private wood consumption	202	160	40	3
Other depletion in total	2 246	1 104	493	649
Logging and sivilcultural waste	593	382	110	100
Natural losses	1 654	722	383	549
Gross Increment	23 904	12 033	6 381	5 490
Net Growth	12 448	4 562	4 049	3 838
Growing Stock per 31.12.01	**710 447**	**313 176**	**237 997**	**159 273**
Converting factors				
Tonnes dry matter per m3		0,38	0,44	0,503
Carbon fraction	0,50			
Expansion ratio (to include branches, roots etc.)	1,90			
Carbon uptake		**Gg C**		
Total Gross Depletion	4 461	2 697	975	789
Felling in total	1 867	1 210	405	252
Commercial consumption exclusive fuel wood	1 515	1 124	378	13
Fuel wood consumption	312	55	18	238
Other private wood consumption	40	30	9	1
Other depletion in total	2 595	1 487	570	537
Logging and sivilcultural waste	1 912	1 227	410	275
Natural losses	683	261	160	262
Gross Increment	9 634	4 344	2 667	2 623
Net Growth	**5 173**	**1 647**	**1 692**	**1 834**

Annex 4: CO_2 reference approach and comparison with sectoral approach

National Energy Balance Tables 1990, 2001.

Energy balance sheet[8]. 1990. PJ

		Total	Coal	Coke	Fuel wood, black liquor, waste	Crude oil	Petroleum products	Natural gas and other gases	Water-fall energy[9]	Elect-ricity	District heating
1.1	Production of primary energy bearers	5146	9	.	42	3412	50	1119	514	.	.
2	Imports	258	20	28	0	69	140	-	-	1	-
3	Exports	4368	7	4	0	2897	373	1028	-	58	-
4	Bunker oil	19	-	-	-	-	19	-	-	-	-
5	Changes in stocks (+ net decrease, - net increase)	-64	0	-1	..	-62	-1	.	.	.	.
7	Net domestic supply (1.1+2 -3-4+5)	952	21	23	42	521	-204	92	514	-57	-
8	Energy converted	1093	1	1	1	539	36	0	514	1	-
8.1	In blast furnaces	1	-	1	-	-	-	-	-	-	-
8.2	In crude petroleum refineries	575	-	-	-	539	36	-	-	-	-
8.3	In thermal power plants	0	-	-	-	-	0	-	-	-	-
8.4	In combined heat and power plants	1	1	-	1	-	-	-	-	-	-
8.5	In district heating plants	2	-	-	1	-	0	0	-	1	-
8.6	In hydropower plants	514	-	-	-	-	-	-	514	-	-
1.2	Production of derived energy bearers	1037	.	6	.	.	542	45	.	439	5
9	Consumption by energy sector	156	-	-	-	-	4	145	-	7	-
10	Consumption for non-energy purposes	47	.	.	.	.	47	-	-	-	-
11	Losses in transport and distribution	28	..	..	.	..	..	0	-	26	2
12	Statistical differences (7-8+1.2-9-10-11-13)	-43	-1	2	0	-18	0	-24	-	-2	0
13	Net domestic consumption	706	21	26	41	-	251	15	-	349	3
13.1	Manufacturing, mining and quarrying	276	21	26	21	-	30	15	-	163	1
13.2	Transport	161	-	-	-	-	158	-	-	2	-
13.3	Other sectors	269	0	0	20	-	62	0	-	183	2
14	Calculated energy consumption[10]	540	17	21	27	-	109	14	-	349	3
14.1	Manufacturing, mining and quarrying	254	17	21	13	-	26	14	-	163	1
14.2	Transport	42	-	-	-	-	40	-	-	2	-
14.3	Other sectors	243	0	0	13	-	44	0	-	183	2
15	Energy losses in final consumption (13-14)	167	4	5	14	-	142	1	-	-	-
15.1	Manufacturing, mining and quarrying	22	4	5	7	-	4	1	-	-	-
15.2	Transport	119	-	-	-	-	119	-	-	-	-
15.3	Other sectors	26	0	0	7	-	19	0	-	-	-

Source:SN

[8] The energy balance is derived from the energy sources balance sheet.

[9] Electricity is treated as derived energy. Waterfall energy is the primary energy source for the electricity produced in hydropower plants. It is estimated that in average 15 per cent of the potential energy is lost in production.

[10] Line 14, "calculated energy consumption" shows the amount of energy actually utilized. The numbers are estimated by multiplying the values in line 13 by thermal efficiency coefficients.

Energy balance sheet[11]. 2001. PJ
Preliminary data

		Total	Coal	Coke	Fuel wood, black liquor, waste	Crude oil	Petroleum products	Natural gas and other gases	Water-fall energy[12]	Elect-ricity	District heating
1.1	Production of primary energy bearers	9834	50	.	59	6602	271	2340	512	.	.
2	Imports	262	23	27	1	41	131	-	-	39	-
3	Exports	8744	42	0	0	6006	638	2031	-	26	-
4	Bunker oil	34	-	-	-	-	34	-	-	-	-
5	Changes in stocks (+ net decrease, - net increase)	94	-6	1	..	87	12	.	.	.	.
7	Net domestic supply (1.1+2 -3-4+5)	1412	26	27	60	725	-259	308	512	13	-
8	Energy converted	1138	1	1	6	560	56	0	512	2	-
8.1	In blast furnaces	1	-	1	-	-	-	-	-	-	-
8.2	In crude petroleum refineries	615	-	-	-	560	55	-	-	-	-
8.3	In thermal power plants	0	-	-	-	-	0	-	-	-	-
8.4	In combined heat and power plants	3	1	-	2	-	-	-	-	-	-
8.5	In district heating plants	7	-	-	4	-	1	0	-	2	-
8.6	In hydropower plants	512	-	-	-	-	-	-	512	-	-
1.2	Production of derived energy bearers	1092	.	7	.	.	600	37	.	439	8
9	Consumption by energy sector	215	-	-	-	-	8	197	-	10	0
10	Consumption for non-energy purposes	73	.	.	.	.	50	23	-	-	-
11	Losses in transport and distribution	37	..	..	.	..	..	2	-	33	1
12	Statistical differences (7-8+1.2-9-10-11-13)	229	1	9	0	165	-50	103	-	2	0
13	Net domestic consumption	812	24	25	54	-	278	21	-	404	7
13.1	Manufacturing, mining and quarrying	307	24	25	30	-	35	20	-	173	1
13.2	Transport	189	-	-	-	-	187	0	-	3	-
13.3	Other sectors	315	0	0	24	-	56	1	-	228	6
14	Calculated energy consumption[13]	623	19	20	35	-	118	20	-	404	7
14.1	Manufacturing, mining and quarrying	282	19	20	19	-	30	19	-	173	1
14.2	Transport	51	-	-	-	-	49	-	-	3	-
14.3	Other sectors	290	0	0	16	-	40	1	-	228	6
15	Energy losses in final consumption (13-14)	189	5	5	19	-	159	1	-	-	-
15.1	Manufacturing, mining and quarrying	26	5	5	10	-	4	1	-	-	-
15.2	Transport	138	-	-	-	-	138	0	-	-	-
15.3	Other sectors	25	0	0	8	-	17	0	-	-	-

Source:SN

[11] The energy balance is derived from the energy sources balance sheet.
[12] Electricity is treated as derived energy. Waterfall energy is the primary energy source for the electricity produced in hydropower plants. It is estimated that in average 15 per cent of the potential energy is lost in production.
[13] Line 14, "calculated energy consumption" shows the amount of energy actually utilized. The numbers are estimated by multiplying the values in line 13 by thermal efficiency coefficients.

Annex 5: Uncertainty estimates for single sources

Summary of standard deviation and probability density of activity data.

IPCC source category	Pollutant source	Standard deviation (2s). %	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

Summary of standard deviation and probability density of emission factors.

IPCC source category	Pollutant source	Standard deviation (2 s). %	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 (1999)
6B	CH_4 - Waste water treatment	± 70	Lognormal	Expert judgement

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.

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.

Annex 6: Common Reporting Format tables 1990, 2001

CRF tables for 1990, 1998, 1999, 2000 and 2001 can be accessed through the following links:

- 1990: http://www.sft.no/publikasjoner/luft/1976/ta1976_1990.xls
- 1998: http://www.sft.no/publikasjoner/luft/1976/ta1976_1998.xls
- 1999: http://www.sft.no/publikasjoner/luft/1976/ta1976_1999.xls
- 2000: http://www.sft.no/publikasjoner/luft/1976/ta1976_2000.xls
- 2001: http://www.sft.no/publikasjoner/luft/1976/ta1976_2001.xls

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	SFT-department Department of Industry	TA-number 1976/2003

Project responsible Ingrid Bjotveit	Year 2003	No. of pages 141 (excl. tables in Annex 6)	Contract-number - SFT

Publisher Norwegian Pollution Control Authority (SFT)	

Title Greenhouse Gas Emissions in Norway 1990-2001. Reporting according to the UNFCCC guidelines.
Summary The report presents an inventory of greenhouse gas emissions and sinks in Norway from 1990 to 2001. Trends in total greenhouse gas emissions by UNFCCC's sources and gases are described for carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), tetrafluoromethane (CF_4), hexafluoroethane (C_2F_6), sulphur hexafluoride (SF_6) and HFCs. The methodology used in the calculation of emissions from key sources in the Norwegian Emission Inventory is presented. Emissions are reported according to UNFCCC/IPCC common reporting format (CRF).

Subject words	
Climate convention	Klimakonvensjonen
Greenhouse gases	Drivhusgasser
Emission inventory	Utslippskartlegging
Carbon dioxide	Karbondioksid
Key sources	Viktigste utslippskilder