Statens forurensningstilsyn
Norwegian Pollution Control Authority

Greenhouse Gas Emissions 1990-2007

National Inventory Report 2009 Norway

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Preface

The United Nations Framework Convention on Climate Change (UNFCCC) was adopted in 1992 and entered into force in 1994. According to Articles 4 and 12 of the Convention, Parties are required to develop and submit to the UNFCCC national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol on an annual basis.

To comply with the above requirement, Norway has prepared the present National Inventory Report (NIR) for the year 2009. The report and the associated Common Reporting Format (CRF) tables have been prepared accordance with the UNFCCC Reporting Guidelines on Annual Inventories as adopted by the COP by its Decision 18/CP. 8. The methodologies used in the calculation of emissions are based on the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC Guidelines) and the *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* prepared by the Intergovernmental Panel on Climate Change (IPCC).

This National Inventory Report 2009 also includes the reporting of emissions and removals from Land Use, Land Use Change and Forest according to the Decision 15/CP.10 (FCCC/CP/2004/10/Add.2). Norway has chosen commitment-period accounting on the activities under Article 3.3 and for the activity “forest management” under Article 3.4.of the Kyoto Protocol.

The Norwegian Pollution Control Authority (SFT), a directorate under the Norwegian Ministry of Environment, is responsible for the reporting. Statistics Norway (SSB) has been the principle contributor to the preparation of the report, while the Norwegian Forest and Landscape Institute has contributed to the chapters regarding Land Use, Land Use Change and Forestry.

Oslo, 15. April 2009

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Picture front page: Blåsjømagasinet, Statkraft SF

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E.S Executive Summary

E.S.1. Background

The 1992 United Nations Framework Convention on Climate Change (UNFCCC) requires that the Parties to the Convention develop, update and submit to the UNFCCC annual inventories of greenhouse gas emissions by sources and removals by sinks. This report documents the Norwegian National Inventory Report (NIR) 2009 for the period 1990-2007.

The report and the associated Common Reporting Format (CRF) tables have been prepared in accordance with the UNFCCC Reporting Guidelines on Annual Inventories as adopted by the COP by its Decision 18/CP. 8. The methodologies used in the calculation of emissions are based on the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC Guidelines) and the *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (Good Practice Guidance) prepared by the Intergovernmental Panel on Climate Change (IPCC). As recommended by the IPCC Guidelines country specific methods have been used where appropriate.

Emissions of the following greenhouse gases are covered in this report: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulphur hexafluoride (SF_6). In addition, the inventory includes calculations of emissions of the precursors NOx, NMVOC, and CO, as well as for SO_2. Indirect CO_2 emissions originating from the fossil part of CH_4 and NMVOC are calculated according to the reporting guidelines to the UNFCCC, and accounted for in the inventory.

In December 2006, Norway submitted the Initial Report according to Decision 13/CMP.1 on "Modalities for accounting of assigned amounts under Article 7.4 of the Kyoto Protocol". This report includes a description of the national system for greenhouse gas inventory in Norway, in accordance with the guidelines for national systems as defined by the COP/MOP. This National Inventory Report has been prepared according to the system described in this report.

The National Inventory Report of 2007 has been reviewed. However, Norway has not yet received a report from this review in time for the preparation of this report.

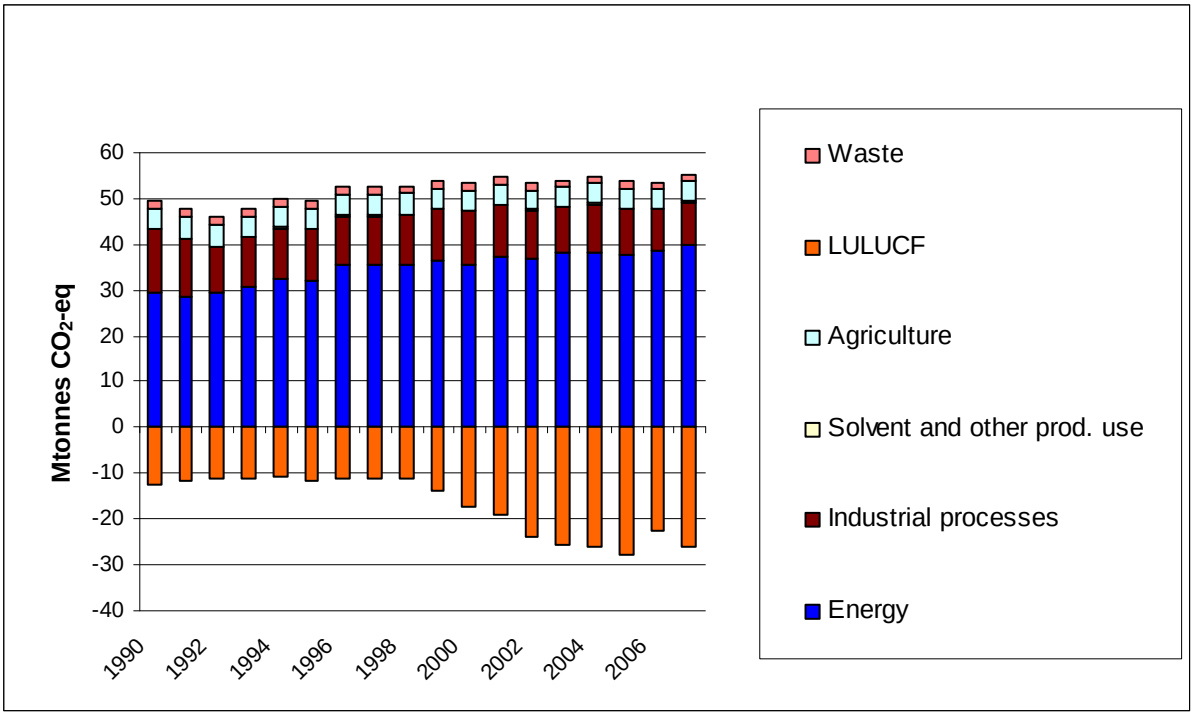
E.S.2 Summary of national emission and removal related trends

In 2007, the total emissions of greenhouse gases in Norway amount to 55.1 million tonnes CO_2-equivalents, without emissions and removals from Land-Use, Land-Use Change and Forestry (LULUCF). From 1990 to 2007 the total emissions increased by almost 11 per cent. Norway has experienced economic growth since 1990, with only minor setbacks in the early nineties, which explains the general increase in emissions until 2007. Between 2006 and 2007 the emissions increased by 3 per cent. The increase was mainly due to large emissions from the new liquid natural gas plant at Melkøya in Finmark. Growth in road traffic, sea transport and other mobile sources also contributed to the increased emissions.
In 2007, CO_2 contributed with 82 per cent of the total emission figures, while methane and nitrous oxide contributed 8 per cent each. PFCs, HFCs and SF_6 together accounted for approximately 3 per cent of the total GHG emissions.

2007 the land-use category forest land contributed with a total amount of sequestration of 28 million tonnes CO_2. The remaining land-use categories showed net emissions totalled to a about 2 million tonnes CO_2. Of these, the most important category was grassland with total emissions of almost 1.9 million tonnes of CO_2. This gave a net CO_2 removal from the LULUCF sector of 25.9 million tonnes.

The net greenhouse gas emissions, including all sources and sinks were 29.2 million tonnes in 2007, a decrease of almost 22 per cent from the net figure in 1990.

Figure 0.1 Total emissions of all GHG calculated as CO_2-equivalents from the different sectors. Source: Statistics Norway/SFT



E.S.3 Overview of source and sink category emission estimates and trends

Table 0.1 shows the overall trend in the total emissions by gas during the period 1990-2007.

Table 0.1 Emissions and removals of greenhouse gases 1990-2007. Source: Statistics Norway/SFT

Gas	CO2	CH4	N2O	PFC			SF6	HFC							Total without LULUCF	LULUCF	Total with LULUCF
				14	116	218		23	32	125	134a	143a	152a	227ea			
Year	Mtonnes	ktonnes	ktonnes	tonnes			tonnes	tonnes							Mt CO2-eq	Mt CO2-eq.	Mt CO2-eq.
1990	34,8	219,7	15,2	467,4	36,2	0,0	92,0	0,0	0,0	0,0	0,0	0,0	0,1	0,0	**49,7**	**-12,3**	37,4
1991	33,4	222,0	14,8	416,5	31,0	0,0	87,0	0,0	0,0	0,0	0,0	0,0	0,4	0,0	**47,7**	**-11,5**	36,2
1992	34,2	225,0	12,9	321,6	21,4	0,0	29,5	0,0	0,0	0,0	0,2	0,0	0,7	0,0	**45,9**	**-11,1**	34,8
1993	35,9	228,3	13,7	324,3	20,6	0,0	30,9	0,0	0,0	0,0	1,8	0,0	0,8	0,0	**48,0**	**-11,3**	36,7
1994	37,9	231,8	14,0	286,9	18,3	0,0	36,7	0,0	0,0	0,5	5,4	0,2	0,8	0,0	**50,0**	**-10,8**	39,2
1995	37,8	230,8	14,2	283,3	18,1	0,0	25,4	0,0	0,0	2,4	10,2	1,5	1,0	0,0	**49,7**	**-11,7**	38,0
1996	40,9	231,8	14,4	258,5	16,2	0,0	24,0	0,0	0,0	5,5	16,7	3,9	1,5	0,0	**52,7**	**-11,0**	41,7
1997	41,0	232,8	14,4	229,9	15,1	0,0	24,3	0,0	0,1	9,7	24,6	6,9	2,4	0,1	**52,6**	**-11,3**	41,3
1998	41,1	226,9	14,7	209,8	13,3	0,0	30,4	0,1	0,3	14,8	35,7	10,5	5,6	0,1	**52,8**	**-11,2**	41,6
1999	42,0	220,1	15,3	196,2	12,3	0,0	36,6	0,1	0,6	20,0	50,2	14,9	8,7	0,2	**53,8**	**-13,8**	40,0
2000	41,6	226,6	14,6	186,4	11,6	0,0	39,1	0,1	1,0	26,2	64,4	20,5	12,4	0,2	**53,4**	**-17,1**	36,3
2001	43,0	227,2	14,3	187,5	11,9	0,0	33,1	0,1	1,5	33,4	78,8	27,1	16,4	0,3	**54,6**	**-18,9**	35,7
2002	42,0	219,2	14,9	201,3	14,0	0,0	10,0	0,1	2,3	39,2	95,2	32,3	19,3	0,5	**53,3**	**-23,7**	29,6
2003	43,4	220,4	14,4	125,6	10,1	0,0	9,8	0,1	3,0	42,4	111,8	34,3	22,8	0,8	**54,0**	**-25,7**	28,3
2004	43,9	218,8	14,9	122,1	9,4	0,0	11,5	0,1	3,8	45,3	127,6	35,9	27,0	1,0	**54,7**	**-25,9**	28,8
2005	42,9	211,1	15,3	116,7	7,6	0,0	13,1	0,1	4,5	47,8	149,1	37,3	34,5	1,1	**53,7**	**-27,9**	25,8
2006	43,3	202,8	14,2	102,1	8,6	0,0	8,9	0,1	5,3	50,1	169,3	38,6	38,4	1,2	**53,5**	**-22,5**	31,0
2007	45,0	210,1	13,7	108,7	10,3	0,0	3,2	0,1	6,4	52,4	193,7	40,0	34,9	1,2	**55,1**	**-25,9**	29,2

The proportion of CO_2 emissions to the national total greenhouse gas emissions has increased from about 70 per cent in 1990 to 82 per cent in 2007. The increased proportion of CO_2 relative to other gases is due to growth in the CO_2 emissions as well as a reduction in emissions of PFCs and SF_6 gases because of implemented environmental measures and/or technological improvements. This trend is illustrated in Table 0.2.

Table 0.2 Emissions in million tonnes CO_2-equivalents in 1990, 2006, 2007 and changes (per cent) between 1990-2007 and 2006-2007 (without LULUCF)

Year	CO_2	CH_4	N_2O	PFCs	SF_6	HFCs	Total
1990	34,8	4,6	4,7	3,4	2,2	0,0	**49,7**
2006	43,3	4,3	4,4	0,7	0,2	0,5	**53,5**
2007	45,0	4,4	4,2	0,8	0,1	0,6	**55,1**
Changes 1990-2007	29 %	-4 %	-10 %	-76 %	-97 %	-	**11 %**
Change 2006-2007	4 %	4 %	-4 %	8 %	-64 %	8 %	**3 %**

The decrease in PFC emissions was 8 per cent from 2006 to 2007, resulting in a total reduction of 76 per cent since 1990. PFC emissions originate primarily from the production

of aluminium, where technical measures have been undertaken to reduce them. CO_2 emissions from aluminium production have increased since 1990.

SF_6 emissions have been reduced by 97 per cent from 1990 to 2007, mainly because of technological improvements and the closure of a magnesium production plant and a magnesium recycling foundry.

HFC emissions increased by 8 per cent compared to 2006. The emissions in 1990 were insignificant, hence no descriprion of trends from 1990. But the emissions increased significantly from mid-ninetynineties until 2002, when a tax on HFC was introduced in 2003. After that the increase has been somewhat smaller.

In 2007, agriculture contributed 49 per cent and nitric acid production 33 per cent to the total emission of N_2O. The total emissions of N_2O have decreased by 10 per cent since 1990.

As mentioned earlier, the net CO_2 sequestration from the LULUCF category was 25.9 million tonnes in 2007. Since 1990 there has been an increase in carbon stored in living biomass, dead organic matter and in soils in Norway, doubling the net sequestration of CO_2 since 1990. The increase in carbon stored is a result of an active forest management policy over the last 50 years. The annual harvests have been much lower than the annual increments, thus causing an accumulation of wood and other tree components.

Figure 0.2 shows the various sectors' share of the total greenhouse gas emissions in Norway in 2007.

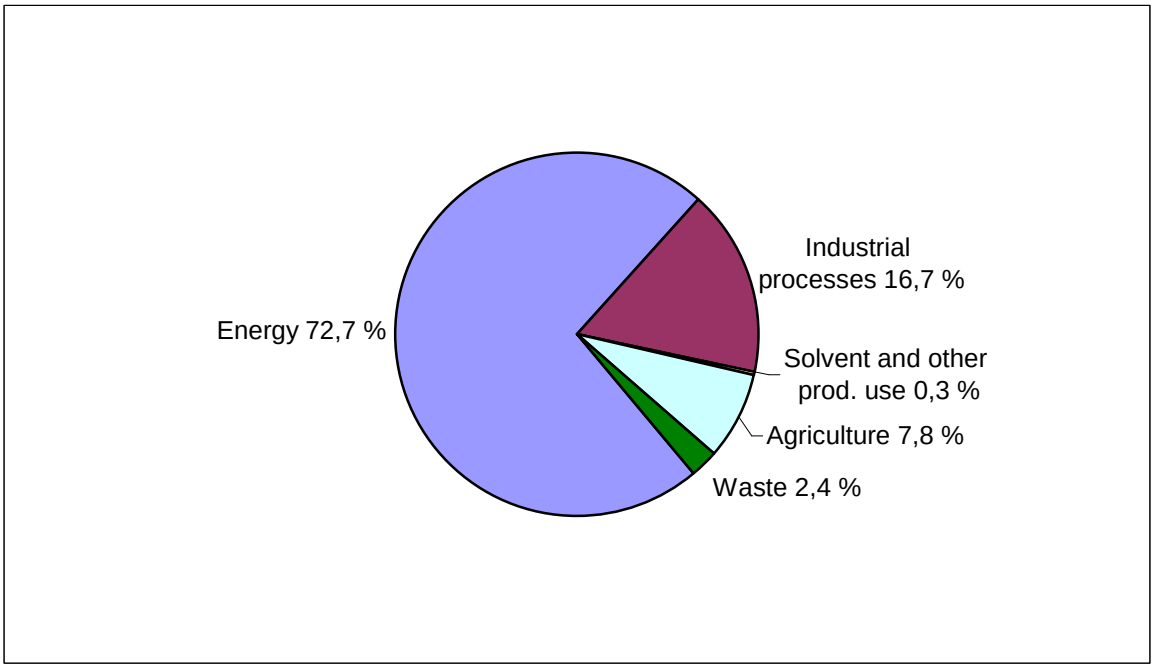


Figure 0.2 Emissions by IPCC sector in 2007. Source: Statistics Norway/SFT

The most important sector in Norway with regard to the emissions of greenhouse gases is the energy sector, accounting for 73 per cent of the total Norwegian emissions. The energy sector includes the energy industries (including oil and gas extraction), the transport sector, energy use in manufacturing and constructing, fugitive emissions from fuels and energy combustion in other sectors. 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.

Figure 0.3 shows the percentage change in emissions of greenhouse gases from 1990 to 2007 for the various IPCC sectors, compared to emissions in 1990. The development for each of the sectors since 1990 with regards to greenhouse gas emissions, and the most important sources, are described briefly in the following.

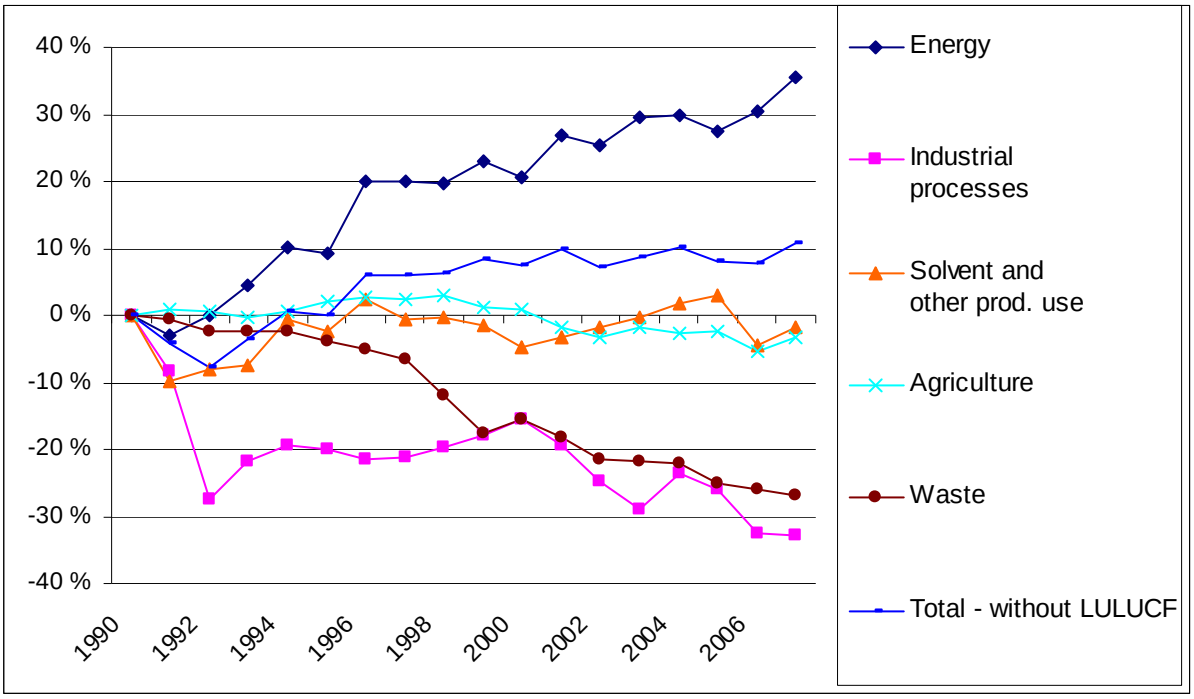


Figure 0.3 Changes in greenhouse gas emissions by UNFCCC sector 1990-2007 compared to 1990. Source: Statistics Norway/SFT

From 1990 to 2007 the increase in the emissions from the energy sector was 35 per cent, or 10.5 million tonnes. During most of the 1990s and until 2007 energy related emissions have been increasing, mainly due to higher activity in the offshore- and transport sectors. In 2007, the emissions from the energy sector increased by 1.5 million tonnes, This can be explained mainly by increase in use of energy in transportation and the consumption of heating oil in the manufacturing industries. The increase was mainly due to large emissions from the new liquid natural gas plant at Melkøya in Finmark. Growth in road traffic, sea transport and other mobile sources also contributed to the increased emissions

Industrial processes contributed 17 per cent of the total national emissions of greenhouse gases. Production of metals and chemicals is the main source of process-related industrial emissions of both CO_2 and other greenhouse gases such as N_2O (fertiliser production) and PFCs (aluminium production). Between 1990 and 2007 emissions from industry experienced an overall decrease of 33 per cent. This is mainly due to reduced PFC emissions from the production of aluminium and SF_6 from the production of magnesium.

The agricultural sector contributes about 8 per cent to the total emissions of greenhouse gases. This corresponds to 4.3 million tonnes CO_2-equivalents, which is 2 per cent higher than in 2006. This is due to more livestock and somewhat higher use of fertilizers. This sector has experienced a reduction of 3 per cent in emissions over the period 1990-2007. The dominant

sources of GHG's are enteric fermentation (CH_4) from domestic animals and agricultural soils (N_2O). These contributed about 44 and 46 per cent respectively.

The waste sector contributed 2 per cent of total Norwegian greenhouse gas emissions. The emissions of greenhouse gases from the waste sector were relatively stable during the 1990s. From 1998 emissions declined and in 2007 they were about 27 per cent lower than in 1990. Waste volumes have increased significantly over the period, but this has been offset by increased recycling and incineration of waste as well as increased burning of methane from landfills.

Solvent and other product use accounts for only 0.3 per cent of the total emissions of greenhouse gases in the country. This contribution has been practically unchanged since 1990.

Emissions from transport showed an overall increase of about 40 per cent from 1990 to 2007, while the emissions increased by 6 per cent from 2006 to 2007. The share of transport in the total GHG emissions has increased from 20 per cent in 1990 to 29 per cent in 2007. Road transportation accounts for more than 65 per cent of the total mobile emissions, while emissions from navigation and civil aviation accounts for 17 and 6 per cent respectively. Due to the fact that most railways are electrified in Norway, emissions of GHG from this source are insignificant. Other transportation (off-road vehicles and other machinery and other non-specified) accounts for more than 12 per cent of the emissions from the source transport.

E.S.4 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, in particular ozone. Sulphur dioxide (SO_2) also has an indirect impact on climate, as it increases the level of aerosols with a subsequent cooling effect. Therefore, emissions of these gases are to some extent included in the inventory.

The overall NO_x emissions have decreased by approximately 7 per cent from 1990 to 2007, primarily because of stricter emission regulations directed towards road traffic, which counteracted increased emissions from oil and gas production and from navigation. The total NO_x emissions increased by approximately 2 per cent from 2006 to 2007. The emissions of NMVOC experienced an increase in the period from 1990 to 2001, mainly because of the rise in oil production and the loading and storage of oil. However, the emissions have decreased by 50 per cent from 2001 to 2007, and are now 34 per cent lower than in 1990. From 2006 to 2007 the emissions of NMVOC decreased by 1.3 per cent.

Emissions of CO decreased by 54 per cent over the period 1990-2007. This is explained primarily by the implementation of new emissions standards for motor vehicles. Emissions of SO_2 were reduced by 62 per cent from 1990 to 2007. This can mainly be explained by a reduction in sulphur content of all oil products and lower process emissions from ferroalloy and aluminium production, as well as refineries.

1. Introduction

1.1. Background

The 1992 United Nation Framework Convention on Climate Change (UNFCCC) was ratified by Norway on 9 July 1993 and entered into force on 21 March 1994. One of the commitments of the Convention is that Parties are required to report their national inventories of anthropogenic emissions by sources and removals by sinks of the greenhouse gases CO_2, CH4, N_2O as well as fluorinated greenhouse gases not controlled by the Montreal Protocol (HFCs, PFCs and SF_6), using methodologies agreed upon by the Conference of the Parties to the Convention (COP).

With the adoption of the Kyoto Protocol in 1997, Norway is faced with the requirement to limit its total greenhouse gas emissions to 1 per cent above the 1990 level during the commitment period 2008-2012. On 30 May 2002 Norway ratified the Kyoto Protocol, which entered into force on 16 February 2005.

In compliance with its reporting requirements, Norway has submitted to the UNFCCC national emission inventory reports on an annual basis since 1993. In December 2006, Norway submitted the Initial Report according to Decision 13/CMP.1 on "Modalities for accounting of assigned amounts under Article 7.4 of the Kyoto Protocol". This report includes a description of the national system for greenhouse gas inventory in Norway, in accordance with the guidelines for national systems as defined in the Annex to the COP/MOP decision under COP decision 20/CP.7 (FCCC/CP/2001/13/Add.3). This report ”National Greenhouse Gas Inventory System in Norway” is attached to this report as Annex VI. This National Inventory Report has been prepared according to the system described in this report.

Since the introduction of annual technical reviews of the national inventories by independent experts in 2000, Norway has undergone five desk/centralized reviews, in 2000, 2001, 2003, 2004, 2005 and 2008. An in-country review was held in Oslo in October 2002. The Initial Report and Norway’s 2006 greenhouse gas inventory submission was reviewed in an in-country review 23-28 April 2007. The recommendations from these reviews have been incorporated in this report to the extent possible. However, the report from the review in 2008 has not been finalized in time for the preparation of this NIR.

The National Inventory Report 2009 together with the associated Common Reporting Format (CRF) tables is Norway’s contribution to the 2009 round of reporting under the Convention, and it covers emissions and removals for the period 1990-2007. The report is prepared in accordance with the UNFCCC Reporting Guidelines on Annual Inventories as adopted by the COP by its Decision 18/CP. 8. The methodologies used in the calculation of emissions and removals are based on the Revised 1996 Intergovernmental Panel on Climate Change Guidelines for National Greenhouse Gas Inventories (Revised 1996 IPCC GL), the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC 2000), IPCC Good Practice Guidance for Land-Use, Land-Use Change and Forestry sector (IPCC 2004), and to some extent the new 2006 Guidelines from IPCC. As

recommended by the IPCC Guidelines country specific methods have been used where appropriate and where they provide more accurate emission data.

The greenhouse gases or groups of gases included in the national inventory are the following:

- Carbon dioxide (CO_2);
- Methane (CH_4);
- Nitrous oxide (N_2O);
- Hydrofluorocarbons (HFCs);
- Perfluorocarbons (PFCs);
- Sulphur hexafluoride (SF_6).

Aggregated emissions and removals of greenhouse gases expressed in CO_2-equivalents are also reported. We have used Global Warming Potentials (GWP) calculated on a 100-year time horizon, as provided by the IPCC in the Second Assessment Report.

This National Inventory Report 2009 also includes the reporting of emissions and removals from Land Use, Land Use Change and Forest according to the Decision 15/CP.10 (FCCC/CP/2004/10/Add.2). Norway has chosen commitment-period accounting on the activities under Article 3.3 and for the activity "forest management" under Article 3.4.of the Kyoto Protocol. The report is included as Annex IX.

Indirect CO_2 emissions originating from the fossil part of CH_4 and NMVOC are calculated according to the reporting guidelines to the UNFCCC, and accounted for in the inventory. This includes emissions from fuel combustion and non-combustion sources, such as fugitive emissions from loading of crude oil, oil refineries, distribution of oil products, and from solvents and other product use.

The report also contains calculations of emissions of the precursors and indirect greenhouse gases NO_x, NMVOC, CO and SO_2, which should be included according to the reporting guidelines. However, we have not in this submission included detailed descriptions of the calculation methodologies for these gases. This information is available in the report Statistics Norway (2008). 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.

Norway also submits the Standard Independent Assessment Report for the Norwegian Registry (SIAR). SIAR is not a part of this National Inventory report 2009, but is submitted together with the NIR and can be downloaded from the same site (http://cdr.eionet.europa.eu/no/un/UNFCCC/envsds5g). The SIAR contains information on the following items:

a) SEF, Standard Electronic Format for reporting Kyoto Protocol units, as per decision 14/CMP.1 and decision 15/CMP.1 section I.E.
b) Reports on discrepancies, notifications, replacements, commitment period reserve calculation, as detailed in paragraphs 12 to 20 of the Section I.E of the annex to decision 15/CMP.1
c) Changes in the national registry, as per section I.G of the annex to decision 15/CMP.1

The information reported in the SEF covers the calendar year of 2008.

1.2. Institutional arrangement for inventory preparation

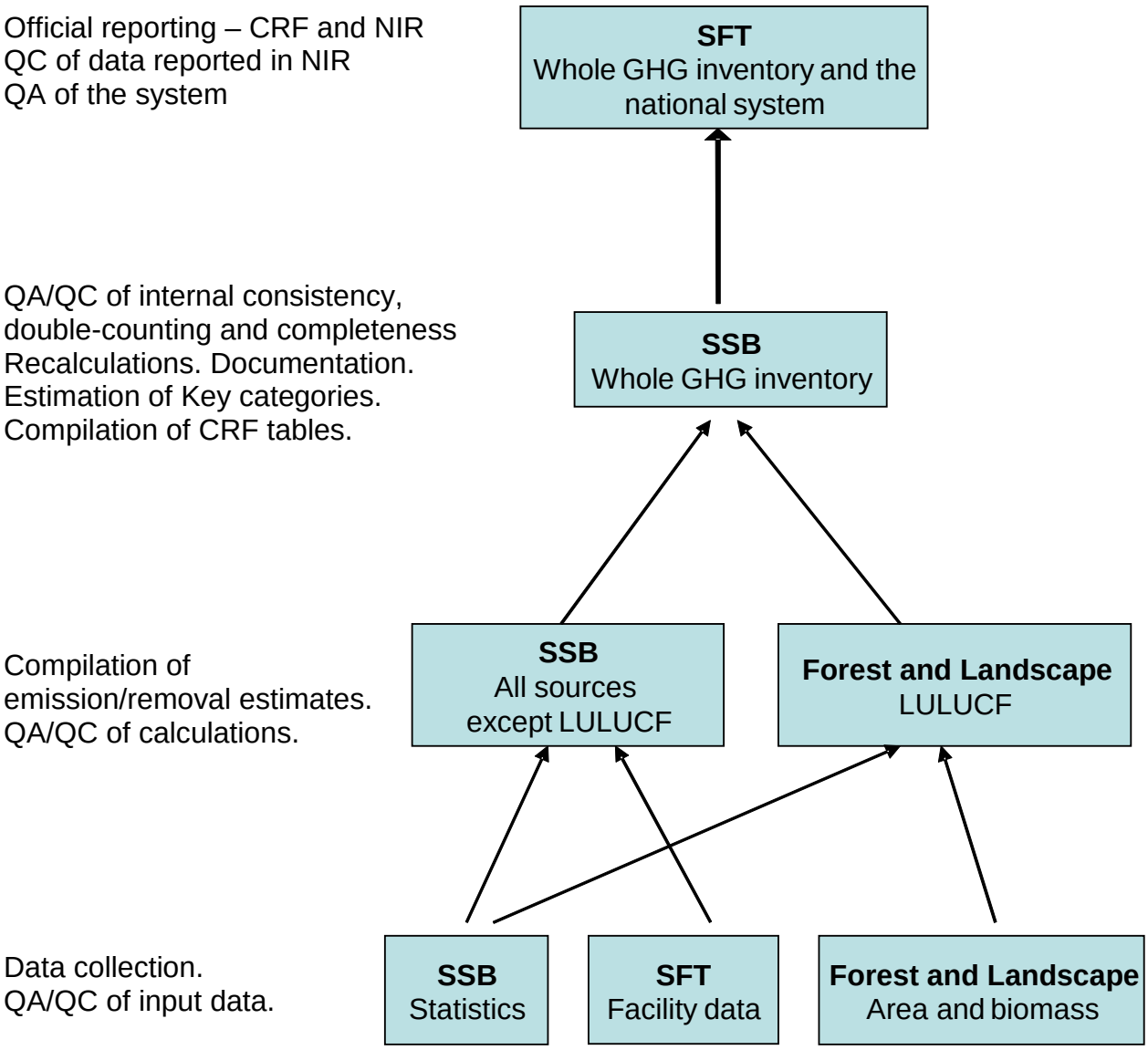
The Norwegian greenhouse gas inventory has been produced in more than two decades as a collaboration between Statistics Norway (SSB) and the Norwegian Pollution Control Authority (SFT). The reporting to the UNFCCC has been based on this greenhouse gas inventory.

The Norwegian national system for greenhouse gas inventories is based on existing cooperation. SFT, Statistics Norway and the Norwegian Forest and Landscape Institute are the core institutions in the national system. Statistics Norway is responsible for the official statistics on emissions to air. The Norwegian Forest and Landscape Institute is responsible for the calculations of emission and removals from Land Use and Land Use Change and Forestry.

SFT has been appointed by the Ministry of the Environment as the national entity through the budget proposition to the Norwegian parliament (Stortinget) for 2006.

The three core institutions; SFT, Statistics Norway and The Norwegian Forest and Landscape Institute, work together to fulfill the requirements for the national system. The allocation of responsibilities for producing estimates of emissions and removals, QA/QC and archiving is presented in more detail in Annex VI. An overview of institutional responsibilities and cooperation is shown in Figure 1.1.

Figure 1.1. Overview of institutional responsibilities and cooperation



To ensure that the institutions comply with their responsibilities, Statistics Norway and The Norwegian Forest and Landscape Institute have signed agreements with SFT as the national entity. Through these agreements, the institutions are committed to implementing the QA/QC and archiving procedures, providing documentation, making information available for review, and delivering data and information in a timely manner to meet the deadline for reporting to the UNFCCC.

1.3. The process of inventory preparation

1.3.1. Introduction

The core institutions, SFT, Statistics Norway and the Norwegian Forest and Landscape Institute have agreed on a "milestone" production plan. This plan is further described in Annex VI. The plan is supplemented by internal production plans in the three core institutions.

1.3.2. Data collection, processing and archiving

The three core institutions of the national system have defined areas of responsibility for data collection. This is further described in Annex VI.

All three core institutions are responsible for archiving the data they collect and the estimates they calculate with associated methodology documentation and internal documentation on QA/QC.

Due to the differences in the character of data collected, Norway has chosen to keep archiving systems in the three core institutions, which means that not all information is archived at a single location. These archiving systems are, however, consistent, and operate under the same rules. Although the data are archived separately, all can be accessed efficiently during a review. In addition, SFT will build up a library with the most important methodology reports. The archiving systems in all three institutions will be further developed, see Annex VI for further documentation.

The common rules for archiving of data are the following:

- Data and information are archived for each submission year
- Data and information are archived in a single location within each institution (this may imply double archiving)
- Archiving for a submission year includes
    - All input data
    - All estimated emissions
    - All partly filled-in or final CRF
    - All technical documentation
    - Recalculations of previous estimates, if any
    - The NIR (where relevant)
- The file structure is documented
- The platform at which the data and information is archived undergoes a daily backup and the backup is securely saved.

1.4. Methodologies and data sources used

1.4.1. Introduction

Details of the methods and framework for the production of the emission inventory are given in the reports "The Norwegian Emission Inventory 2008. Documentation of methodologies for estimating emissions of greenhouse gases and long-range transboundary air pollutants." Statistics Norway (2008) and "Emissions and removals of greenhouse gases from land use, land-use change and forestry in Norway" (NIJOS, 2005). These reports are updated annually in conjunction with important methodological changes and used as a basis for the NIR. A revised, draft version of Statistics Norway (2008) which is due to be published in 2009 has also been used in the preparation for this inventory.

Norway has an integrated inventory system for producing inventories of the greenhouse gases included in the Kyoto Protocol and the air pollutants SO_2, NO_x, non-methane volatile organic compounds (NMVOC), ammonia, CO, particulate matter, heavy metals and persistent organic pollutants reported under the LRTAP Convention. The data flow and QA/QC procedures are to a large extent common to all pollutants.

The emission estimation methodologies are being improved continuously. Statistics Norway and SFT have carried out several studies on specific emission sources. Usually, such projects are connected to an evaluation of emission reduction measures. An important element in Statistics Norway'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.

1.4.2. The main emission model

The model was developed by Statistics Norway (Daasvatn et al. 1992, 1994). It was redesigned in 2003 in order to improve reporting to the UNFCCC and LRTAP, and to improve QA/QC procedures.

The model is called "Kuben" ("the Cube"). Several emission sources – e.g. road traffic, air traffic, waste and solvents – are covered by more detailed satellite models. Aggregated results from these side models are used as input to the general model.

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

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

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

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

Emissions of some pollutants from major manufacturing plants (point sources) are available from measurements or other plant-specific calculations (collected by SFT).

When such measured data are available, the estimated values are replaced by the measured ones:

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

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

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

The model uses approximately 130 *industries* (economic sectors). The classification is common with the Energy Accounts and is almost identical to that used in the National Accounts, which is aggregated from the European NACE (rev. 1) classification (Daasvatn et al. 1994). The large number of sectors is an advantage in dealing with important emissions from manufacturing industries. The disadvantage is an unnecessary disaggregation of sectors with very small emissions. To make the standard sectors more appropriate for calculation of emissions, a few changes have been made, e.g. "Private households" is defined as a sector. Information about the geographical distribution of emissions is useful for modelling and control purposes.

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.

1.4.3. The LULUCF model

The Norwegian Forest and Landscape Institute is in charge of estimating emissions and removals from LULUCF for all categories where area statistics is the activity level. They have developed a calculation system in the form of computer programs that uses SAS system software and Fortran for the implementation of the IPCC good practice guidance for the LULUCF.

The system uses input data from different sources and creates final output datasets. The final datasets include all data needed for reporting tables (CRF) of the LULUCF.

Land use, land use change and forestry are based on statistics from National Forest Inventory (NFI). The sampling design is based on a systematic grid of georeferenced sample plots with 3 x 3 km spacing under the coniferous limit. The NFI utilizes a 5-year cycle based on a re-sampling method of the permanent plots. The current report is based on this design. To confirm the extent of the area of forest and other wooded land at higher altitudes and in Finnmark County, NFI started in 2005 to establish NFI plots above the coniferous forest limit and in the coniferous forest in Finnmark in a 3 x 9 km and 3 x 3 km grid, respectively. A complete forest inventory is conducted on these plots. In the rest of Finnmark the plan is to

use a less dense plot grid for forest land and other wooded land that are mainly stocked with birch. The land use of mountainous areas is also planned to be assessed according to the NFI manual. The plan is that the inventories of these areas be completed in 2013, and planned to be included in the 2014 report.

Calculations of biomass and carbon stock in forest are based on single tree measurements and stand attributes from the permanent sample plots on forest and other wooded land under the coniferous forest limit. Biomass is calculated using single tree biomass equations developed in Sweden for Norway spruce, Scots pine and birch (Marklund 1987, 1988 and Petersson and Stähl 2006). These equations provide biomass estimates for various tree biomass components: stem, stem bark, living branches, dead branches and needles, stumps and roots.

The dynamic soil model YASSO as described in detailed by Liski et al. 2005 and applied to Norwegian conditions by de Wit et al. (2006), are used to calculated changes in carbon stock in dead organic matter and forest soil. The model requires estimates of dead organic matter and basic climate data. The model has two litter compartments that relate to physical fractions of litter and five soil components that differentiate microbial decomposition and humification processes. The litter and soil compartments are viewed as “dead wood” and “soil organic matter”. The model requires regular input of different biomass components over years, and it is assumed that equilibrium of input and output is reached after some time. Change in carbon stock of dead organic matter due to litter from standing biomass, un-recovered fellings, harvested residues and natural mortality, stumps and roots from harvested trees have been calculated from the growing stock and annual harvest volume. The volume and increment estimates and amount of dead wood are taken from NFI and removals as forest harvest are from Statistics Norway. Dry matter biomass of different litter compartment (foliage, fine roots, branches, coarse roots, stems and stumps) are calculated using biomass expansion factors described for Norway in FAO/ECE (1985) and in Lethonen et al. (2004).

1.4.4. Data sources

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

Activity levels – these normally originate from official statistical sources available internally in Statistics Norway and other material available from external sources. When such information is not available, research reports are used or extrapolations are made from expert judgments.

Emission factors – these originate from reports on Norwegian conditions and are either estimated from measurements or elaborated in 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 defined in 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’ responsible (based on measurements or calculations at the plants).

1.5. Key Categories

According to the IPCC definition, key categories are those that add up to 90 per cent of the total uncertainty in level and/or trend. In the Norwegian greenhouse gas emission inventory key categories are primarily identified by means of a Tier 2. A description of the methodology as well as background tables and the results from the analyses is presented in Annex 1. In this chapter a summary of the analyses and the results are described.

According to the IPCC Good Practice Guidance (IPCC 2000) it is good practice to give the results at the Tier 2 level if available. The advantage of using a Tier 2 methodology is that uncertainties are taken into account and the ranking shows where uncertainties can be reduced. However, in the 2006 IPCC guidelines it is suggested that good practice reporting should include key categories from both the Tier 1 and Tier 2.

The Tier 2 and Tier 1 analyses was performed at the level of IPCC source categories and each greenhouse gas from each source category was considered separately with respect to total GWP weighted emissions, except land-use, land-use change and forestry.

Some aspects of aggregation have been changed since the previous NIR. Emissions from mobile sources in 1A4 *Other sectors* are now treated as a separate category. Fishing vessels and agricultural machinery are the most important subcategories. In the previous NIR these emissions were grouped together with stationary emissions in 1A1, 1A2 and 1A4. The uncertainty in activity data for the new category has been estimated at 10 per cent. Previously, these emissions where assigned to the category 1A – stationary – liquid fuels, where activity data uncertainty was estimated at 3 per cent.

In the LULUCF sector, data are now given for both biomass gains and losses for several of the "living biomass" categories. However, in the key category analyses only data for net gain/loss were used. This means that categories with small net changes in theoretically will not be identified as key even though the fluxes may be considerable. In practice, only "5.A.1.1 – Forest remaining forest" has gains and losses of the same order. However, even when using net gain only, this category has the highest contribution to total inventory level and trend uncertainty. Treating gains and losses separately would only reinforce this conclusion. However, marginal key categories might drop below the threshold because more of the total uncertainty would be assigned to 5.A.1.1.

A revised method for the emissions from source 3 - Solvents - has lead to a reduction in estimated uncertainty from 30% to 3%. However, this is a small GHG source, and the effects on the key category analysis have been negligible.

The results from the key category analyses are summarized in Table 1.1 below. The Tier 2 analysis identified 29 key categories which are arranged primarily according to contribution to the uncertainty in level. In addition we have also included in Table 1.1 those source categories that according to Tier 1 key category analysis or qualitative criteria in the NIR are defined as key categories. Altogether this is 38 key categories. Key categories in the Land use, land use change and forestry sector (LULUCF) were identified in separate analyses and are summarized in Table 1.2.

The complete Tier 1 analysis is included in Annex 1 together with background data and the complete analyses including LULUCF.

Fugitive emissions from coal mining and handling is included as a key category due to change in trend in the coal production and the fact that the national emission factors used is an order of magnitude less than IPCC's default factors. The last identified key category is CO_2 capture and storage. This removal category is considered key since there is presently no methodology as such defined in the IPCC guidelines and because these operations are unique internationally.

Table 1.1. Summary of identified emission key categories. Excluding LULUCF.
Per cent contribution to the total uncertainty in level and/or trend in the tier 2 analysis.

	Source category	Gas	Level assessment Tier 2 1990	Level assessment Tier 2 2007	Trend assessment Tier 2 1990-2007	Calculation method (Tier) 2007
Tier 2 key categories (large contribution to the total inventory uncertainty)						
4D1	Direct soil emissions	N_2O	**27.65**	**24.16**	**9.15**	Tier 1a
1A3b	Road Transportation	CO_2	**8.03**	**9.52**	**4.51**	Tier 2
1A	Stationary Fuel Combustion (1A1-1A2-1A4), Gaseous Fuels	CO_2	**4.20**	**8.35**	**12.04**	Tier 2
4D3	Indirect emissions	N_2O	**5.72**	**5.09**	**1.65**	Tier 1a
4A	Enteric Fermentation	CH_4	**5.00**	**4.30**	**1.88**	Tier 1/2*
1B2a	Oil (incl. oil refineries, gasoline distribution)	CO_2	**4.63**	**4.12**	**1.35**	Tier 2
6A	Solid Waste Disposal on Land	CH_4	**6.13**	**3.84**	**6.40**	Tier 2
1B2c	Venting and Flaring	CH_4	**1.57**	**3.54**	**5.72**	Tier 2
1A3e	Other (snow scooters, boats, motorized equipment)	CO_2	**1.58**	**3.22**	**4.76**	Tier 2
2F	Consumption of Halocarbons and Sulphur Hexafluoride	HFCs	0.00	**2.55**	**7.31**	Tier 2
1A3d	Navigation	CO_2	**2.03**	**2.44**	**1.24**	Tier 2
1B2c	Venting and Flaring	CO_2	**1.63**	**2.43**	**2.36**	Tier 2
2C3	Aluminium Production	CO_2	**1.49**	**2.05**	**1.64**	Tier 2
1A	Stationary Fuel Combustion (1A1-1A2-1A4), Liquid Fuels	CO_2	**2.63**	**1.89**	**2.06**	Tier 2
1A3e	Other (snow scooters, boats, motorized equipment)	N_2O	0.67	**1.67**	**2.92**	Tier 2
1A3a	Civil Aviation	CO_2	**1.39**	**1.65**	**0.82**	Tier 2
1A3b	Road Transportation	N_2O	0.48	**1.51**	**2.98**	Tier 2
2C3	Aluminium Production	PFCs	**6.87**	**1.46**	**15.33**	Tier 2
4D2	Animal production	N_2O	**1.69**	**1.46**	0.61	Tier 1a
1A4	Other sectors - Mobile Fuel Combustion	CO_2	**1.93**	**1.46**	**1.29**	Tier 2
1A	Stationary Fuel Combustion (1A1-1A2-1A4), Biomass	CH_4	**0.94**	**0.99**	0.17	Tier 2
6B	Wastewater Handling	N_2O	**0.88**	**0.96**	0.27	Tier 1
2B2	Nitric Acid Production	N_2O	**1.46**	**0.87**	**1.66**	Tier 2
4B	Manure Management	N_2O	**1.02**	**0.84**	0.48	Tier 1
1A	Stationary Fuel Combustion (1A1-1A2-1A4), Solid Fuels	CO_2	**0.97**	0.73	**0.66**	Tier 2
2C2	Ferroalloys Production	CO_2	**0.77**	0.58	0.54	Tier 2
1A3d	Navigation	CH_4	0.04	0.27	**0.67**	Tier 2
1B2b	Natural Gas	CH_4	0.02	0.25	**0.68**	Tier 2

2B4	Carbide Production	CO_2	0.42	0.07	**1.00**	Tier 2
Tier 1 key categories (large contribution to the total emissions)						
1B2a	Oil (incl. oil refineries, gasoline distribution)	CH_4	0.66	0.78	0.35	Tier 2
4B	Manure Management	CH_4	0.77	0.72	0.11	Tier 2
2A1	Cement Production	CO_2	0.46	0.55	0.28	Tier 2
2B1	Ammonia Production	CO_2	0.38	0.21	0.50	Tier 2
1A5b	Military - Mobile	CO_2	0.28	0.11	0.47	Tier 2
2C1	Iron and Steel Production	CO_2	0.04	0.06	0.06	Tier 2
2C4	SF6 Used in Aluminium and Magnesium Foundries	SF_6	0.05	.	.	Tier 2
Qualitative key categories						
1B1a	Coal Mining and Handling	CH_4	0.41	0.43	0.06	Tier 2
	Capture and storage	CO_2				CS (Tier 2)

Bold figures indicate whether the source category is key in the tier 2 analysis.
* Tier 2 used for the significant animal groups

Several of the changes in the list of key categories are related to the separation of mobile emissions in 1A4 from stationary emissions. The separation has two different effects. The primary effect is that 1A4 – "Other sectors - Mobile Fuel Combustion" – CO_2 appears as a new key category, whereas 1A "Stationary Fuel Combustion (1A1-1A2-1A4) Liquid fuels" – N_2O is no longer key. Most of the 1A4 mobile emissions were removed from the 1A-liquid category.

The other effect is caused by the estimated uncertainty of the 1A4 – mobile category. This has led to a slight increase in the estimate of total uncertainty in the GHG inventory. As a result, the share of uncertainty to all other sources has been reduced, and several marginal key categories have dropped below the threshold. This applies to

- 1A "Stationary Fuel Combustion (1A1-1A2-1A4)" Other fuels – CO_2 (no longer key)
- 1A "Stationary Fuel Combustion (1A1-1A2-1A4)" Gaseous fuels – CH_4 (no longer key)
- 1A3b "Road Transportation" – CH_4 (no longer key)
- 1B2a "Oil (incl. oil refineries, gasoline distribution)" –CH_4 (now only key at tier 1).

CH_4 from 1A3d "Navigation" was identified as a new key category in the tier 2 trend analysis. Methane emissions from navigation increased strongly in 2007 due to the launch of several new gas-fuelled car ferries.

2D2 – "Food and Drink" – CO_2 is no longer in the list of tier 1 key categories. This category has been in and out of the list for several years.

Table 1.2 shows the LULUCF key categories identified. There have been several changes due to the changes in methodology. All changes are among categories derived from the forest inventory. 5E1 *Forest land converted to settlements* is a new key category because the biomass loss rate for these conversions was changed from 75 per cent to 100 per cent, leading to higher emissions. 5A2 *Land converted to forest land* is now only a key category according to the Tier 1 analysis and 5B1 *Cropland remaining cropland, liming* is a new Tier 1 key. 5D1 *Wetland remaining wetland is* no longer a key category. Previously, the net biomass gain was calculated as the total increase in forest biomass due to the reclassification of the areas. Thus, all biomass on the areas at the time of reclassification was recorded as a gain. In the revised

method, only the biomass change in the inventory year is recorded. The key categories relating to soils remain unchanged.

Table 1.2. Summary of identified LULUCF key categories Tier 2.

IPCC Category		Gas	Level assessment		Trend assessment	Method (Tier)
			1990	2007	1990-2007	2007
Tier 2 key categories (large contribution to the total inventory uncertainty)						
5A1	Forest Land remaining Forest Land, Forest inventory area, Living Biomass	CO_2	**9.15**	**16.76**	**26.19**	Tier 3
5C1	Grassland remaining Grassland, Histosols, Soils	CO_2	**13.29**	**11.12**	**6.09**	Tier 2*
5A1	Forest Land remaining Forest Land, Forest inventory area, Dead Biomass	CO_2	**6.22**	**6.35**	**5.61**	Tier 3
5A1	Forest Land remaining Forest Land, Forest inventory area, Soils, Mineral	CO_2	**4.66**	**4.39**	**3.32**	Tier 3
5A1	Forest Land remaining Forest Land, Forest inventory area, Soils, Organic	CO_2	**2.34**	**2.07**	**1.35**	Tier 1
5B1	Cropland remaining Cropland, Histosols, Soils	CO_2	**1.48**	**1.24**	0.68	Tier 2
5E1	Forest Land converted to Settlements, Living biomass	CO_2	**1.40**	0.30	**1.47**	Tier 3
Tier 1 key categories (large contribution to the total emissions)						
5A2	Land converted to Forest Land, Living biomass	CO_2	0.27	0.42	0.59	Tier 3
5B	Cropland remaining Cropland, Liming	CO_2	0.48	0.13	0.45	Tier 1

1.6. Quality assurance and quality control (QA/QC)

1.6.1. Quality assurance and quality control (QA/QC)

Several quality assurance and quality control procedures for the preparation of the national emission inventory have been established in Norway during the past years. Statistics Norway made its first emission inventory for some gases in 1983 for the calculation year 1973. The emission estimation methodologies and the QA/QC procedures have been developed continuously since then.

Norway is implementing the formal quality assurance/quality control plan. The detailed description of this can be found in Annex VI. All three institutions have prepared a QA/QC report, according to the plan. These document to what extent the QA/QC procedures have been followed. These reports are available for the Expert Review Team for inspection.

Based on these reports, the three institutions collaborate on which actions to take to further improve the QA/QC of the inventory.

1.6.2. Verification studies

In general, the final inventory data provided by Statistics Norway are checked and verified by SFT.

In the following, some verification studies which have been previously performed are briefly described.

Emission estimates for a source are often compared with estimates performed with a different methodology. In particular, Norway has conducted a study on verification of the Norwegian emission inventory (SFT/Statistics Norway 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. We do 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 (for details, see Chapter 6 on Agriculture).

1.6.3. Confidentiality issues

In general, the data contained in the Norwegian emission inventory are available to the public, both activity data and emission factors. Confidentiality could be an issue for some of the data collected by Statistics Norway when there are few entities reporting for a source-category. However, confidential data used in the inventory are now almost entirely replaced by non-confidential data collected by the SFT. All emission data and activity data necessary for the CRF are publicly available.

1.7. Uncertainty evaluation

1.7.1. Introduction

The uncertainty in the Norwegian emission inventory was investigated systematically again in 2006 for the NIR 2006 and the Initial Report. The analysis and the results are described in Annex II. Norway has not undertaken a new uncertainty analyses for this year’s Inventory Report. Several further improvements are being planned for the inventory in the near future. When these have been finalized, the uncertainty analysis will be updated, probably in time for the 2011 submission (see section 1.9.2).

The analysis from 2006 was an update of the uncertainty analysis *Uncertainties in the Norwegian Greenhouse Gas Emission Inventory*, documented in (Rypdal and Zhang 2000), which also include more detailed documentation of the analysis method used, and result discussions. In this note we mainly focus on the changes since (Rypdal and Zhang 2000). This

includes new methodology for several source categories as well as revised uncertainty estimates.

The national greenhouse gas (GHG) emission inventory is compiled from estimates based on emission factors and activity data and direct measurements by plants. All these data and parameters will contribute to the overall inventory uncertainty. The uncertainties and probability distributions of the inventory input parameters have been assessed based on available data and expert judgements. Finally, the level and trend uncertainties of the national GHG emission inventory have been estimated using Monte Carlo simulation. The methods used in the analysis correspond to an IPCC Tier 2 method, as described in (IPCC 2000). Analyses have been made both excluding and including the sector LULUCF (land use, land-use change and forestry).

1.7.2. Uncertainty in emission level

The estimated uncertainties of the level of total emissions and in each gas are shown in Table 1.5 and 1.6.

Table 1.5 Uncertainties in emission level. Each gas and total GWP weighted emissions. Excluding the LULUCF sector.

1990	**μ (mean)**	**Fraction of total emissions**	**Uncertainty 2σ (per cent of mean)**
Total	50 mill. Tonnes	1	7
CO_2	35 mill. Tonnes	0.69	3
CH_4	4.8 mill. Tonnes	0.10	15
N_2O	5.0 mill. Tonnes	0.10	57
HFC	18 tonnes	0.00	49
PFC	3.4 mill. Tonnes	0.07	21
SF_6	2.2 mill. Tonnes	0.04	2
2004	**μ (mean)**	**Fraction of total emissions**	**Uncertainty 2σ (per cent of mean)**
Total	55 mill. Tonnes	1	6
CO_2	44 mill. Tonnes	0.80	3
CH_4	4.8 mill. Tonnes	0.09	14
N_2O	4.9 mill. Tonnes	0.09	59
HFC	401 ktonnes	0.01	51
PFC	880 ktonnes	0.02	20
SF_6	274 ktonnes	0.00	15

Table1.6. Uncertainties in emission level. Each gas and total GWP weighted emissions. Including the LULUCF sector.

1990	**μ (mean)**	**Fraction of total emissions**	**Uncertainty 2σ (per cent of mean)**
Total	35 mill. Tonnes	1	14
CO_2	20 mill. Tonnes	0.56	20
CH_4	4.9 mill. Tonnes	0.14	16
N_2O	5.0 mill. Tonnes	0.14	59
HFC	18 tonnes	0.00	51
PFC	3.4 mill. Tonnes	0.10	20
SF_6	2.2 mill. Tonnes	0.06	2

2004	**μ (mean)**	**Fraction of total emissions**	**Uncertainty 2σ (per cent of mean)**
Total	34 mill. Tonnes	1	14
CO_2	23 mill. Tonnes	0.67	18
CH_4	4.8 mill. Tonnes	0.14	14
N_2O	4.9 mill. Tonnes	0.14	53
HFC	401 ktonnes	0.01	52
PFC	880 ktonnes	0.03	20
SF_6	274 ktonnes	0.01	15

The total national emissions of GHG in Norway in 1990 are estimated with an uncertainty of 7 per cent of the mean. The main emission component CO_2 is known with an uncertainty of 3 per cent of the mean. In 2004, the total uncertainty has decreased to 6 per cent of the mean.

By including the LULUCF sector the results from the analysis show a total uncertainty of 14 per cent of the mean both in 1990 and in 2004. The doubling of uncertainty is caused mainly by forest biomass and grassland histosoils.

In the uncertainty analysis carried out in the year 2000 (Rypdal and Zhang 2000), the uncertainty for the total national emissions of GHG (LULUCF sector excluded) in 1990 was estimated to be 21 per cent of the mean. In the new analysis the uncertainty estimate is reduced to one third. There are several reasons for the new lower estimate. One reason is that Statistics Norway and the Norwegian Pollution Control Authority have increased the inventory quality by using higher tiers for some key categories and also improved methodologies for other sources. But the main reason for the reduced uncertainty is that Statistics Norway has collected new and lower uncertainty estimates for some activity data and emission factors that contributed substantially to the total uncertainty in the emission estimate. This means that the total uncertainty of the inventory have not been reduced as much as the estimates indicates, since it is partly the uncertainty estimates themselves that have been improved. The main reduction lies is in the estimate of the uncertainty for the N_2O emissions. In 2000 the uncertainty in this components estimate was estimated to 200 per cent of the mean. In last years' analysis the uncertainty estimate is reduced to 57 per cent of the mean, see explanation to this reduction in the paragraph below. For CO_2 the uncertainty estimate is unchanged between the two analyses (3 per cent), while all the other emission components show a decrease in the uncertainty estimates in the 2006 analysis compared to the analysis from 2000.

The main reason for the high uncertainty estimate for the N_2O emissions in the 2000 analysis was the high uncertainty estimate used for the emission factor used for estimating N_2O from agricultural soils (2 orders of magnitude). This uncertainty is in the new analysis reduced to an uncertainty of factor 5 for direct soil emission, factor 2 for animal production and factor 3 for indirect soil emission. These new uncertainty estimates are collected from the guidelines IPCC (2000) and IPCC (1997b), where also the emission factor used is collected.

As mentioned above, another reason for the reduced uncertainty is that in the years between the two analyses important inventory improvement work has been carried through.

1.7.3. Uncertainty in emission trend

The estimated uncertainties of the trend of total emissions and each gas are shown in Table 1.7 and 1.8.

Table 1.7. Uncertainty of emission trend. 1990-2004. Excluding the LULUCF sector.

	per cent change $((\mu_{2004}-\mu_{1990})*100/\mu_{1990})$	**Uncertainty** $(2*\sigma*100/\mu_{1990})$
Total	10	4
CO_2	26	4
CH_4	-1	11
N_2O	-2	18
HFC	-	-
PFC	-74	15
SF_6	-88	0

Table 1.8. Uncertainty of emission trend. 1990-2004. Including the LULUCF sector.

	Per cent change $((\mu_{2004}-\mu_{1990})*100/\mu_{1990})$	**Uncertainty** $(2*\sigma*100/\mu_{1990})$
Total	-2.1	7
CO_2	18	11
CH_4	-1	12
N_2O	-2	20
HFC	-	-
PFC	-74	15
SF_6	-88	0

The result shows that the increase in the total GHG emissions from 1990 to 2004 is 10 ±4 per cent when the LULUCF sector is not included. Norway has by the ratification of the Kyoto Protocol obliged to limit the emissions of greenhouse gases in the period 2008-2012 to 1 per cent over the emissions in 1990 after trading with CO_2 quotas and the other Kyoto mechanisms is taken into account. It is important to keep in mind that the emission figures reported in connection to the Kyoto Protocol has an uncertainty connected to the reported values.

In (Rypdal and Zhang 2000) the increase from 1990 to 2010 (in a given projection scenario) was 21 ±4 per cent. It is reasonable that the emission increase was higher in the 2000 analysis, since it was estimated for a longer period.

With the sector LULUCF included in the calculations there has been a decrease in the total trend uncertainty with -2 ±7 per cent.

1.8. General assessment of the completeness

An assessment of the completeness of the emission inventory should, according to the IPCC Good Practice Guidance, address the issues of spatial, temporal and sectoral coverage along with all underlying source categories and activities. Confidentiality is an additional element of relevance, which has been addressed in Section 1.6.3.

Norway has undergone six desk/centralized reviews, in the years 2000- 2008. An in-country review was held in Oslo in 2002. The Initial Report and Norway's 2006 greenhouse gas inventory submission was reviewed in an in-country review in April 2007.

The ERTs conclusions from the review of the 2006 inventory are:
"The ERT concluded that in general the 2006 submission of Norway provides the information needed to assess the inventory. The inventory is largely complete in terms of years, sectors and gases and is in general accurate, as defined in the "Guidelines for the preparation of national communications by Parties included in Annex I to the Convention, Part I: UNFCCC reporting guidelines on annual inventories", and consistent with the Revised 1996 IPCC Guidelines and the IPCC good practice guidance. The ERT appreciated the efforts made by Norway to use improved data and methodologies. This was reflected in the levels of uncertainties, which have decreased in general compared to the previous (2005) submission.

During the in-country review the ERT identified a few categories where the methods or EFs used are not fully in accordance with the IPCC good practice guidance (fugitive emissions of CO_2 from coal mining, CO_2 emissions from combustion of natural gas, CO_2 emissions from glass production, and N_2O emissions from cultivation of histosols). The ERT recommended Norway to revise its estimates for these categories. After the in-country review, Norway provided revised estimates for these categories for the base year and 2004 in accordance with the recommendations of the ERT and in line with the IPCC good practice guidance.

In its 2006 submission Norway has made significant improvements since the 2005 submission, most of them in response to recommendations from the 2005 review. The major improvements include:
(a) A thorough review of the point source data, the use of a higher-tier method for CH_4 from enteric fermentation, the updating of the N_2O EF for road transport, the elimination of double counting of N2O emissions reported under agriculture and LULUCF, and thetransparent reporting of CO_2 capture and storage;
(b) The implementation of category-specific QA/QC procedures on input data and emission estimates, which was very limited in some sectors in the 2005 submission;
(c) The provision of information on how the uncertainty estimates are derived for some categories, which was not provided in the 2005 submission.

In the course of the review, the ERT formulated a number of recommendations related to the QA/QC and transparency of the information presented in the 2006 submission. Most of these recommendations were implemented during the review process, and those which referred to potential problems that could have led to the underestimation of the emissions in 2004 have been resolved.

The ERT identified that some minor categories were missing in the original 2006 submission. These sources have been included in the inventory since the 2008 submission.

In terms of spatial coverage, the emission reporting under the UNFCCC covers all activities within Norway's jurisdiction. There is an exception of minor sources/sinks, which are not covered. These are:

- Emissions of CH_4 from agricultural waste, after it is applied to soils. In the IPCC Guidelines it is written that "Agricultural soils may also emit CH_4", but no calculation methodology is proposed.
- Carbon stock change of harvested wood products (HWP). The IPCC default method is used, where harvested wood is counted as emissions the year the harvest takes places. For this NIR, Norway has decided to report on net removals from HWP following the stock change approach. The reported net removals is however not included in the LULUCF category "5G-Other", but reported separately in Annex VIII to this report.

A complete set of CRF tables is submitted for all years 1990-2007.

1.9. Implemented and planned improvements

1.9.1. Implemented improvements since NIR 2008

The table below gives a brief overview of the improvements implemented since the 2008 submission.

Recommended improvements	**Improvement in NIR 2008**
Improve working procedures internally	Is being improved continuously
Further strengthen QA/QC procedures in three institutions	Is being improved continuously. Dedicated projects has been established in the Forest and Landscape institute and Statistics Norway
Improvements in transparency and consistency of CRF and NIR	Several improvements in reducing number of empty cells, better use of notation keys and documentation boxes, better explanations of trends etc.
Transparency: More explanations in trends and on background data	Improved somewhat in this submission. Trends are mainly described in Chapter 2, and to some extent in the sector chapters.
Industry: Limestone	The minor emissions of CO_2 from a brick producing plant, previously not estimated, have been included.
Solvent: Improvement in methodology	The methodology for the solvent balance has been updated. The updated solvent balance has been used for this submission.
Agriculture: More information on the country specific methods and models used.	Included in this submission in Chapter 6.
Harvested Wood Products	Methodology has been implemented and emissions and removals have been calculated, but are not part of the inventory. See Section 7.10 and Annex VIII.

1.9.2. Planned improvements

The national greenhouse gas inventory has undergone substantial improvements over the recent years, and the inventory is now considered to be largely complete and transparent.

Some areas for further improvements have been identified by Norway and some relevant issues have been identified by the ERT during the desk review in 2008. The key elements are listed in the table below.

Issues for improvements	**Plan for improvements**
Independent peer reviews, and for industrial associations and relevant research institutions to review the NIR	Independent peer review will be considered for the reporting of the 2008 data (in 2010). In doing methodological changes, relevant associations and institutions are being consulted.
Comparing data with data from other countries	Will be considered for 2009/2010. In doing methodological changes, data is compared with those of other countries.
QA/QC routines	Project to elaborate further QA/QC routines to compare point source data with independent calculations has been established in Statistics Norway. This is expected to be finalized in 2010.
Elaborate the QC reports further	The reports have been evaluated, and will be somehow changed for next submission. Need to be evaluated further to assess whether quality objectives have been met
Inventory management: All staff to be familiar with archiving and documentation structure	Will be improved continuously and in particular in connection with new personnel taking part in the inventory preparation.
Completeness: Further reduce number of subcategories not estimated	The number of subcategories has been reduced for this NIR 2009, but will be further considered for future submissions
Uncertainty: Improve the links between methodological changes and uncertainty estimates	This link is being identified when undertaking methodological improvements. Improvements in methodology for road transportation and navigation are in progress. Improved data for uncertainty for the plants included in the emission trading system will be available as from 2008. A new uncertainty analysis including these improvements is expected to be undertaken for NIR 2010 or 2011.
Energy: Differences between sectoral and reference approach	Statistics Norway will further investigate this issue in order to possibly reconcile the methods used. Have been commented upon in CRF-boxes in this submission.
Energy: Road transportation	The Norwegian road emission model is being evaluated this year and the intention is to have a new model in operation before next year submission.
Energy: Navigation	The emission inventory for shipping in general will be evaluated this year primarily due to need for updating the NO_X inventory. However, this will also have influence on the GHG emissions from shipping.
Agriculture	Improve explanations of emission factors and activity data used in NIR.
LULUCF: The extent of the area of forest and other wooded land at higher altitudes	A project has been initiated to confirm the extent of the area of forest and other wooded land at higher altitudes. It has yet not been decided how this will be finalized.
LULUCF: Including Finnmark	A full forest inventory on plots in the 3x3 km grid in

County	coniferous forest in Finnmark County started in 2005. The plan is that the inventories of these areas will end in 2013, and can be included in the 2014 report.
LULUCF: Assessing plots from the 3×3 km grid that was not assessed as forest in earlier inventories	In 2007 national aerial photographs started to be used to supplement the field survey to update and check land cover statistics and land cover change statistics This method will also be used for wooded land above the coniferous forest limit, in mountainous areas and for Finnmark county.
LULUCF: Cropland and grassland	During 2009 it is planned to evaluate the methods used for assessing emissions and removals for cropland and grassland.
LULUCF	Include trees with diameters less than 50mm after 2010.
LULUCF: Cropland and grassland	Evaluate methods used for assessing emissions and removals for cropland and grassland.

2. Trends in Greenhouse Gas Emissions

2.1. Emission trends for aggregated greenhouse gas emissions

Total greenhouse gas emissions in Norway, expressed in carbon dioxide equivalents, were 55.1 million tonnes in 2007, which is an increase of 1.6 million tonnes compared to 2006. The emissions in 2007 have reached its highest level since 2004, and the emissions have been fluctuating between 53.5 and 55,1 in the period 2000-2007. The total greenhouse gas emissions have increased by 5.4 million tonnes between 1990 and 2007, or by almost 11 per cent.

Norway will have to reduce its national GHG emissions by about 9 per cent from the level in 2007 in order to achieve the emission target of 1 per cent higher than the emissions in 1990 required by the Kyoto Protocol by the period 2008-2012 if the emissions stabilise at the level of 2007.

In 2006 the land-use category forest land remaining forest land was the major contributor to the total amount of sequestration with 26.3 million tonnes CO_2. Land converted to forest land contributed with 4.0 million tonnes CO_2. The remaining land-use categories showed net emissions, which totalled 2.5 million tonnes CO_2. This gave a net CO_2 removal from the LULUCF sector of 27.9 million tonnes.

The net greenhouse gas emissions including all sources and sinks are 24.2 million tonnes in 2006. The total contribution from different sources from 1990 to 2007 is illustrated in Figure 2.1 and in Table 2.1.

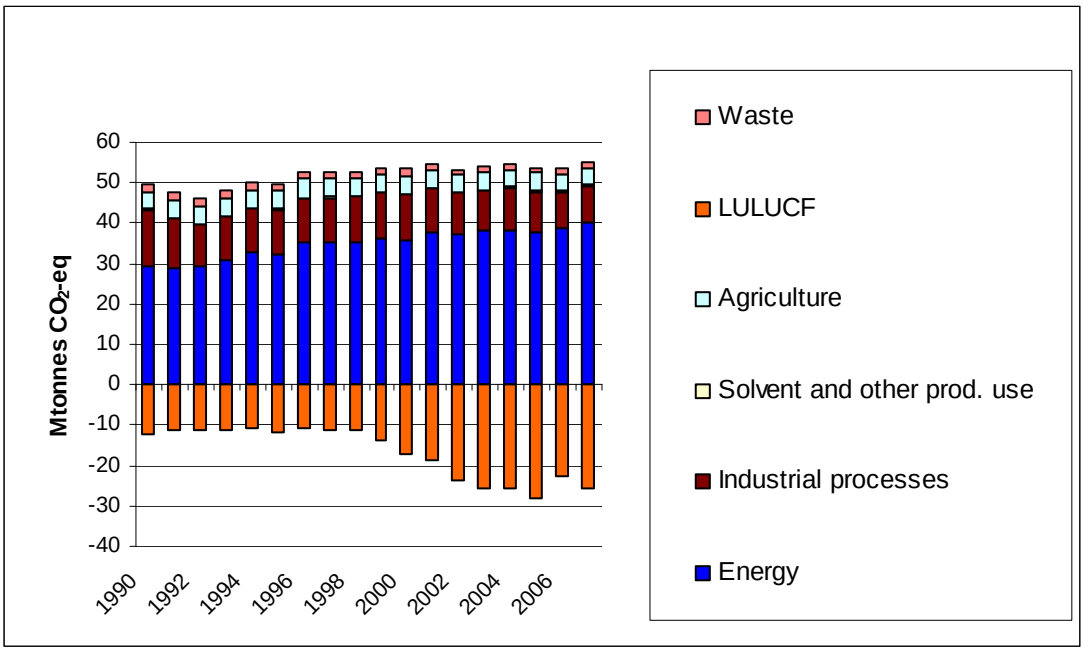


Figure 2.1 Total emissions of all GHG emissions calculated as CO_2-equivalents from the different sectors. Source: Statistics Norway/SFT

Year	Energy	Industrial processes	Solvent and other prod. use	Agriculture	LULUCF	Waste	Total - with LULUCF	Total - without LULUCF
1990	29,5	13,7	0,2	4,4	-12,3	1,8	37,4	49,7
1991	28,6	12,6	0,2	4,5	-11,5	1,8	36,2	47,7
1992	29,6	9,9	0,2	4,5	-11,1	1,8	34,8	45,9
1993	30,9	10,7	0,2	4,4	-11,3	1,8	36,6	48,0
1994	32,5	11,0	0,2	4,5	-10,8	1,8	39,2	50,0
1995	32,3	11,0	0,2	4,5	-11,7	1,8	38,0	49,7
1996	35,4	10,8	0,2	4,6	-11,0	1,7	41,7	52,7
1997	35,4	10,8	0,2	4,5	-11,3	1,7	41,3	52,6
1998	35,4	11,0	0,2	4,6	-11,2	1,6	41,6	52,8
1999	36,3	11,3	0,2	4,5	-13,8	1,5	40,0	53,8
2000	35,6	11,6	0,2	4,5	-17,1	1,5	36,3	53,4
2001	37,5	11,1	0,2	4,4	-18,9	1,5	35,7	54,6
2002	37,1	10,3	0,2	4,3	-23,7	1,4	29,6	53,3
2003	38,3	9,7	0,2	4,4	-25,7	1,4	28,3	54,0
2004	38,3	10,5	0,2	4,3	-25,9	1,4	28,8	54,7
2005	37,7	10,1	0,2	4,3	-27,9	1,4	25,8	53,7
2006	38,5	9,3	0,2	4,2	-22,5	1,4	31,0	53,5
2007	40,0	9,2	0,2	4,3	-25,9	1,3	29,2	55,1

Table 2.1 Total emissions of greenhouse gases by sources and removals from LULUCF in Norway 1990-2007. The emissions are given in million tonnes CO_2-equivalents. Source: Statistics Norway/SFT

Figure 2.2 illustrates the development of emissions of greenhouse gases from various sectors (disregarding LULUCF) in changes in per cent.

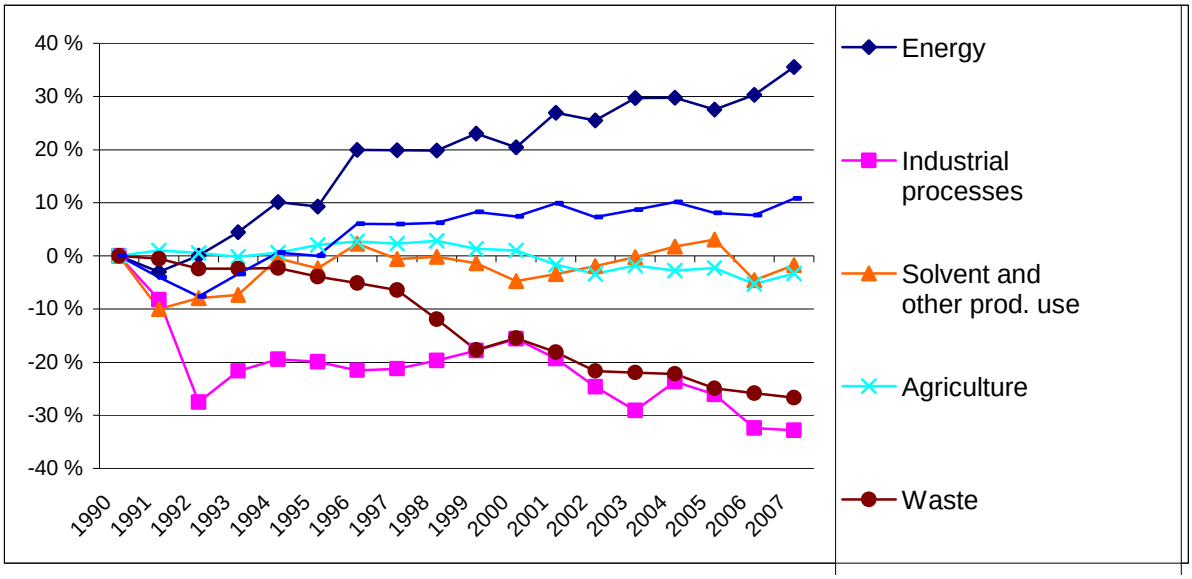


Figure 2.2 Changes in total greenhouse gas emissions by UNFCCC source categories during the period 1990-2007 compared to 1990. Source: Statistics Norway/SFT

Norway has experienced economic growth since 1990, which explains the general growth in emissions. This has resulted in higher CO_2 emissions from most sources, but in particular from the energy use, both in energy industries and energy use in transportation.

The total emissions (disregarding LULUCF) show a marked decrease between 1990 and 1992 and an increase thereafter with small interruptions in 1995, 2000 and 2002. Looking at the overall trend from 1990 to 2007, it can be seen that the emissions increased by about 11 per cent. Also in 2007, the highest level of greenhouse gas emissions were recorded.
The downward trend in the early 1990's has been 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 CO_2-tax, which was implemented with effect from 1991.
The total emissions decreased by about 2.4 per cent from 2001 to 2002. This decline is primarily a result of close-downs and reductions in the ferro alloy industry 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 fertilizer as well as from aluminum production and from the consumption of HFCs.
Emissions in 2003 moved again upward by 1.3 per cent explained by an increase in economic activity, including transportation, but especially in the petroleum sector. A cold winter combined with low generation of hydropower due to a long dry period increased the consumption of oil for heating.

In 2004, the emissions increased by 1.3 per cent since 2003. This increase came as a result of higher emissions in industrial processes, in particular from metal production and chemicals. The total emissions were reduced by 1.9 per cent from 2004 to 2005. The reduction are mainly due to reduction in the use of heating oil, as a result of high prices on heating oil and decrease in the emissions from industry, because of lower production volumes. In 2006 the emissions have decreased by 0.5 per cent. The emissions from industrial processes (chemical industries and metal production) have decreased while emissions from energy use in transportation have increased. From 2006 to 2007 the emissions increased by 2,9, mainly because emissions from energy use have increased.

2.2. Emission trends by gas

As shown in Figure 2.3, CO_2 is by far the largest contributor to the total GHG emissions, followed by N_2O and CH_4, and then the fluorinated gases PFCs, SF_6 and HFCs. In 2007 the relative contributions to the national totals from the different gases were: CO_2: 81,7 per cent, CH_4: 8,0 per sent, N_2O: 7,7 per cent and fluorocarbons (PFCs, SF_6 and HFCs) 2,6 per cent. The relative share of CO_2 has increased from 81,1 per cent in 2006.

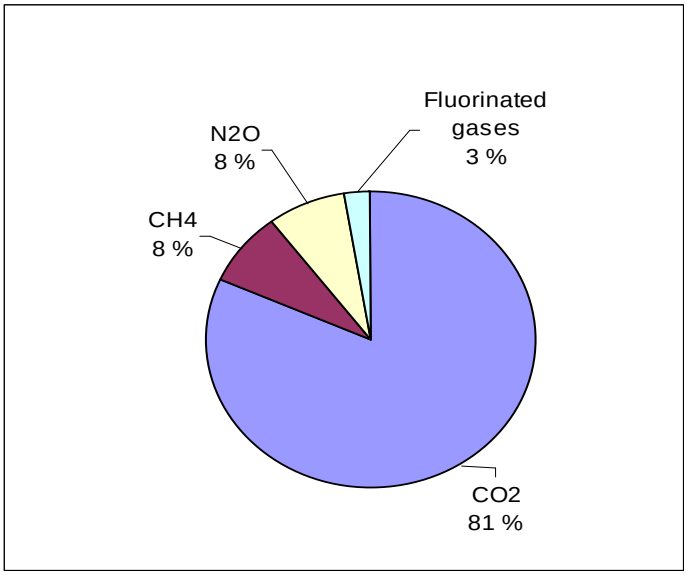


Figure 2.3 Distribution of emissions of greenhouse gases in Norway by gas, 2007. Source: Statistics Norway/SFT

Table 2.2 presents emission figures for all direct greenhouse gases, expressed in absolute emission figures and total CO_2 equivalents.

Table 2.2 Emissions of greenhouse gases in Norway during the period 1990-2007. Units: CO_2 and CO_2–eq. in Mtonnes (Mt), CH_4 and N_2O in ktonnes (kt) and other gases in tonnes (t). Source: Statistics Norway/SFT

Gas	CO2	CH4	N2O	PFK			SF6	HFK							Total without LULUCF
				14	116	218		23	32	125	134a	143a	152a	227ea	
Year	Mtonnes	ktonnes	ktonnes	tonnes			tonnes	tonnes							Mt CO2-eq
1990	34,8	219,7	15,2	467,4	36,2	0,0	92,0	0,0	0,0	0,0	0,0	0,0	0,1	0,0	49,7
1991	33,4	222,0	14,8	416,5	31,0	0,0	87,0	0,0	0,0	0,0	0,0	0,0	0,4	0,0	47,7
1992	34,2	225,0	12,9	321,6	21,4	0,0	29,5	0,0	0,0	0,0	0,2	0,0	0,7	0,0	45,9
1993	35,9	228,3	13,7	324,3	20,6	0,0	30,9	0,0	0,0	0,0	1,8	0,0	0,8	0,0	48,0
1994	37,9	231,8	14,0	286,9	18,3	0,0	36,7	0,0	0,0	0,5	5,4	0,2	0,8	0,0	50,0
1995	37,8	230,8	14,2	283,3	18,1	0,0	25,4	0,0	0,0	2,4	10,2	1,5	1,0	0,0	49,7
1996	40,9	231,8	14,4	258,5	16,2	0,0	24,0	0,0	0,0	5,5	16,7	3,9	1,5	0,0	52,7
1997	41,0	232,8	14,4	229,9	15,1	0,0	24,3	0,1	0,1	9,7	24,6	6,9	2,4	0,1	52,6
1998	41,1	226,9	14,7	209,8	13,3	0,0	30,4	1,3	0,3	14,8	35,7	10,5	5,6	0,1	52,8
1999	42,0	220,1	15,3	196,2	12,3	0,0	36,6	1,6	0,6	20,0	50,2	14,9	8,7	0,2	53,8
2000	41,6	226,6	14,6	186,4	11,6	0,0	39,1	1,0	1,0	26,2	64,4	20,5	12,4	0,2	53,4
2001	43,0	227,2	14,3	187,5	11,9	0,0	33,1	1,5	1,5	33,4	78,8	27,1	16,4	0,3	54,6
2002	42,0	219,2	14,9	201,3	14,0	0,0	10,0	1,3	2,2	39,2	95,2	32,3	19,3	0,5	53,3
2003	43,4	220,4	14,4	125,6	10,1	0,0	9,8	1,0	3,3	42,4	111,8	34,3	22,8	0,8	54,0
2004	43,9	218,8	14,9	122,1	9,4	0,0	11,5	1,8	3,3	45,3	127,6	35,9	27,0	1,0	54,7
2005	42,9	211,1	15,3	116,7	7,6	0,0	13,1	1,5	4,8	47,1	149,1	37,3	34,5	1,1	53,7
2006	43,3	202,8	14,2	102,1	8,6	0,0	8,9	1,3	5,0	50,1	169,3	38,6	38,4	1,2	53,5
2007	45,0	210,1	13,7	108,7	10,3	0,0	3,2	1,4	6,4	52,4	193,7	40,0	34,9	1,2	55,1

Table 2.3 presents the emissions in million tonnes per greenhouse gas and the changes in per cent for each greenhouse gas for the period 1990–2007, and for 2006-2007.

Table 2.3 Emissions in Mtonnes CO_2–eq. and changes in per cent for each greenhouse gas. Source: Statistics Norway/SFT

Year	CO_2	CH_4	N_2O	PFCs	SF_6	HFCs	Total
1990	34,8	4,6	4,7	3,4	2,2	0	**49,7**
2005	42,9	4,6	4,7	0,8	0,3	0,5	**53,8**
2006	43,3		4,4	0,7	0,2	0,5	**53,5**
2007	45	4,4	4,2	0,8	0,1	0,6	**55,1**
Changes 1990-2007	29 %	-4 %	-10 %	-76 %	-97 %	-	**11 %**
Change 2006-2007	4 %	4 %	-4 %	8 %	-64 %	8 %	**3 %**

As seen in table 2.2 and 2.3, there has been a significant increase in CO_2-emissions and a significant decrease in emissions of fluorocarbons in the period from 1990 to 2007.

The fluorocarbons constituted a larger fraction of the greenhouse gas emission total in the early 1990s than that in 2007 while CO_2 represented a smaller share in 1990 than in 2007. The emissions of CH_4 and N_2O have been relatively stable over the same period.

Figure 2.4 illustrate the changes in per cent for the different greenhouse gases for the period 1990 to 2007.

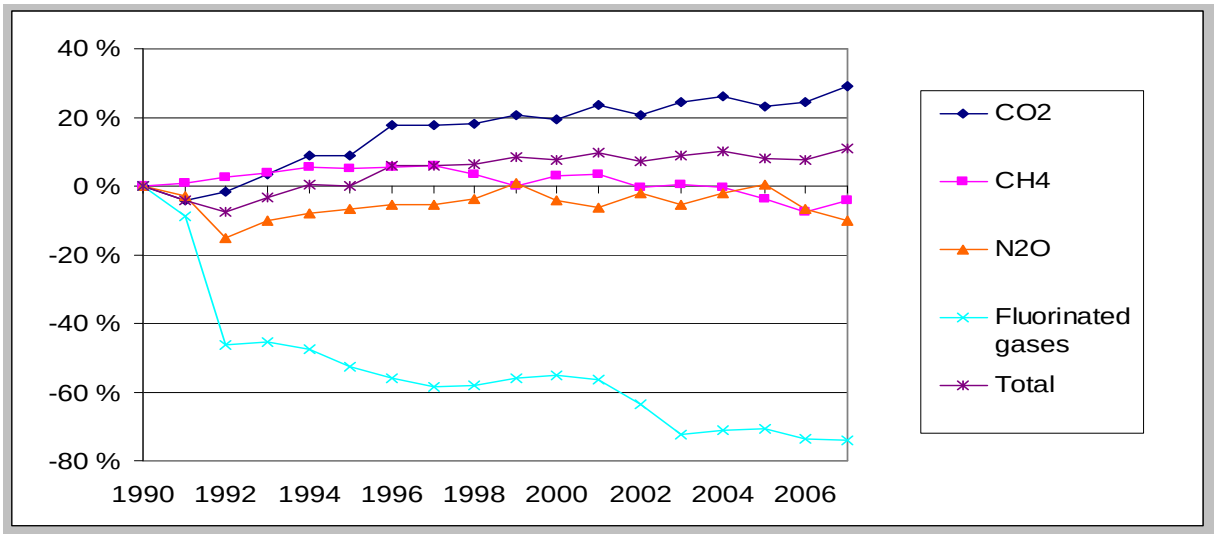


Figure 2.4 Changes in emissions of greenhouse gases by gas in Norway 1990-2007, compared to 1990. Source: Statistics Norway/SFT

Figure 2.4 shows that the overall increasing trend has been weakened by decreased emissions of fluorinated gases. However, the increase in CO_2 emissions in 2007 had a major impact on the total change in greenhouse gas emissions from 2006 to 2007. We will describe these trends further for each of the six greenhouse gases in the following.

Note the fact that the source categories in this chapter are not completely consistent with the IPCC source categories. Note also that since there were no emissions of HFCs in 1990 these gases are not included in this figure.

2.2.1. Carbon dioxide (CO_2)

The Norwegian CO_2 emissions originate primarily from industrial sources related to oil and gas extraction, the production of metals, and 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 on various categories is shown in Figure 2.5.

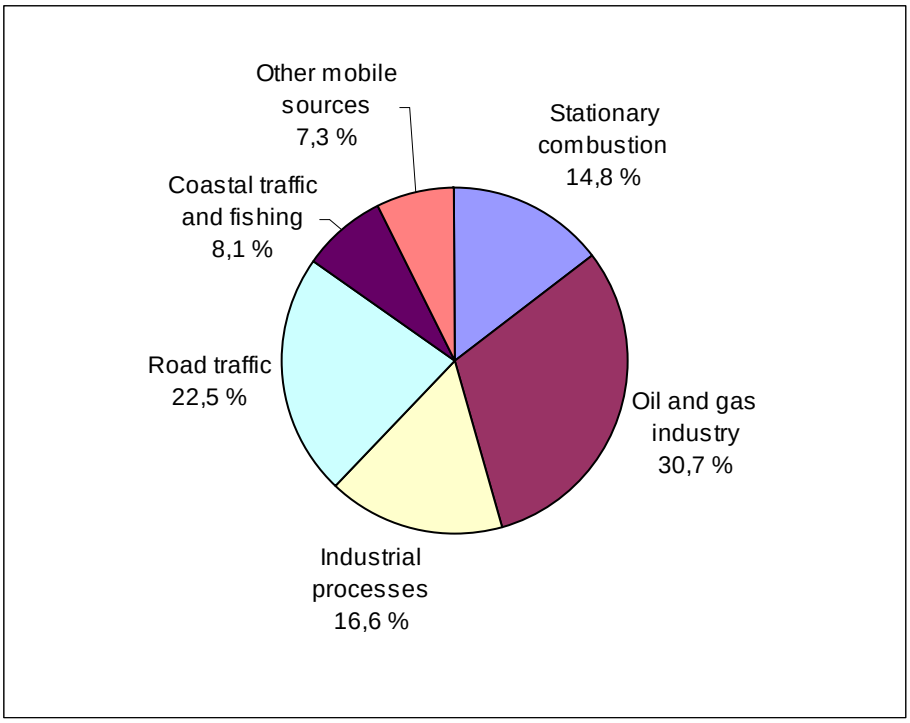


Figure 2.5: Distribution of CO_2 emissions in Norway by source in 2007. Source Statistics Norway/SFT

Table 2.4 lists CO_2-emissions from each source category for the whole period 1990-2007. The change in emissions from 1990 to 2007 compared to 1990 is displayed in Figure 2.6.

Table 2.4 CO_2-emissions from different source categories for the period 1990-2007. Emissions in million tonnes CO_2. Source: Statistics Norway/SFT

Year	Stationary combustion	Oil and gas industry	Industrial processes	Road traffic	Coastal traffic and fishing	Other mobile sources	Total
1990	7,3	7,4	7,0	7,6	3,2	2,3	**34,8**
1991	6,9	7,3	6,4	7,6	3,0	2,2	**33,4**
1992	6,8	7,8	6,6	7,7	3,1	2,2	**34,2**
1993	7,0	8,1	7,1	8,2	3,3	2,1	**35,9**
1994	7,9	8,8	7,5	7,9	3,2	2,5	**37,9**
1995	7,2	9,0	7,5	8,1	3,3	2,6	**37,8**
1996	8,7	9,8	7,7	8,3	3,5	2,8	**40,9**
1997	8,0	10,2	7,8	8,3	3,8	2,8	**41,0**
1998	8,0	9,8	8,0	8,6	4,0	2,8	**41,1**
1999	7,7	10,3	7,9	8,5	4,3	3,2	**42,0**
2000	6,8	11,6	8,4	8,4	3,9	2,5	**41,6**
2001	7,2	12,5	8,0	8,9	3,8	2,7	**43,0**
2002	7,0	12,3	7,4	9,0	3,7	2,7	**42,0**
2003	7,8	12,7	7,6	9,1	3,7	2,5	**43,4**
2004	7,0	12,9	8,0	9,4	3,7	2,8	**43,9**
2005	6,6	12,8	7,6	9,6	3,7	2,7	**42,9**
2006	7,1	12,5	7,3	9,9	3,6	3,0	**43,3**
2007	6,7	13,8	7,4	10,1	3,7	3,3	**45,0**

In the period from 1990 to 2007 the total emissions of CO_2 increased by 29 per cent, or by 10.2 million tonnes. 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 2007 the total Norwegian emissions of CO_2 were 45.0 million tonnes which is an increase of 1.7 million tonnes or about 3.9 per cent from the preceding year. The mayor sectors contributing to increasing emissions were oil and gas industry and road traffic with a combined increase on 1.5 million tonnes. On the other side emissions from stationary combustion were decreasing with 0.4 million tonnes CO_2 from 2006.

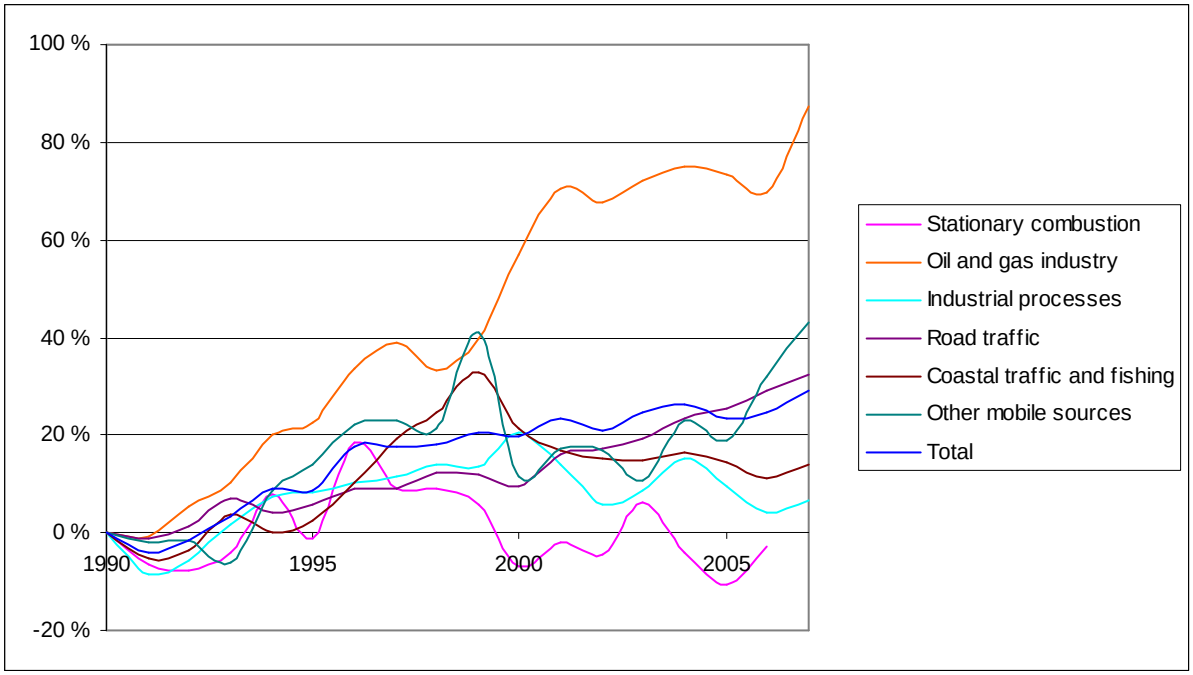


Figure 2.6 Changes in Norwegian CO_2 emissions 1990-2007 for major sources compared to 1990. Source: Statistics Norway/SFT

Emissions from the oil- and gas industry increased by about 86 per cent since 1990 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 established in 1991. Nevertheless, this trend has been counteracted in the last few years, due to technical factors related to a shift to older and more marginal oil-and gas fields and shift in production from oil to gas. Production of gas is more energy demanding than production of oil. The emissions from oil and gas decreased with 0.3 million tones from 2005 to 2006, but in 2007 the total petroleum production in Norway increased, and therefore the CO_2-emissions from this sector also went up 1.3 million tonnes.

Road transportation has had an increase of 33 per cent CO_2 emission from 1990 to 2007. Although emissions from gasoline vehicles decreased by almost 10 per cent during this period, this fall was counteracted by the significant shift from gasoline to diesel vehicles. Although modern cars have lower emissions per driven km, this has been outweighed by more km driven and larger cars.

Emissions of CO_2 from coastal traffic and fishing are 14 per cent higher in 2007 than in 1990, mainly due to higher 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 until 1999, after which the emissions have been quite stable.

CO_2 emissions from industrial processes are about the same level as in 1990, and contribute with 16.6 per cent of total CO_2 emissions. About 63 per cent of the CO_2 emissions from this sector are from metal production.
The CO_2 emissions from stationary combustion are approximately 15 per cent of the total CO_2 emissions, a decrease of 6 per cent compared to 1990. The reduction in CO_2 emissions are mainly caused by increase in the use of electricity rather than oil. However, these emissions are very sensitive to winter temperatures and fuel prices, since many heating systems have the possibility to switch to oil when electricity prices are high.

2.2.2. Methane (CH_4)

About 50 per cent of the methane emissions in 2007 originated from agriculture, and 27 per cent originated from waste treatment. Methane emissions from agriculture are dominated by releases from enteric fermentation. Combustion and evaporation/leakage in the oil- and gas industry accounted for 15 per cent of the total emissions in 2007, the largest fraction of which is releases of methane (venting) during the loading and unloading operations offshore. Other sources include emissions from among others petrol cars, domestic heating, coal mining and oil refineries.

Figure 2.7 illustrates the distribution of Norwegian CH_4-emissions in 2007.

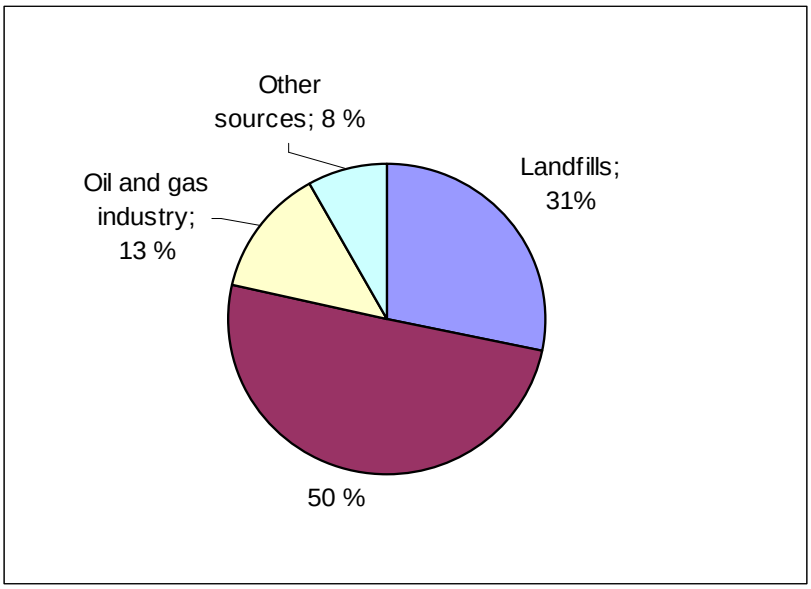


Figure 2.7 Distribution of Norwegian CH_4 emissions in 2007. Source: Statistics Norway/SFT

The methane figures from 1990 to 2007, distributed on the different categories are displayed in table 2.5:

Table 2.5 Emissions of CH_4 in Norway 1990-2007. The emissions are given in ktonnes CH_4. Source: Statistics Norway/SFT

	Sector				
Year	Landfills	Agriculture	Oil and gas industry	Other sources	**Total**
1990	80,4	106,9	15,3	17,2	**219,7**
1991	80,0	108,6	17,4	16,0	**222,0**
1992	78,6	108,8	22,4	15,2	**225,0**
1993	78,3	107,4	26,1	16,6	**228,3**
1994	78,2	109,2	27,7	16,6	**231,8**
1995	76,7	110,4	27,5	16,2	**230,8**
1996	75,4	111,0	28,5	17,0	**231,8**
1997	73,9	110,3	32,0	16,7	**232,8**
1998	69,2	111,3	29,9	16,4	**226,9**
1999	64,2	110,9	28,0	17,0	**220,1**
2000	66,7	109,4	33,0	17,5	**226,6**
2001	64,3	107,4	38,2	17,3	**227,2**
2002	61,7	105,0	34,8	17,6	**219,2**
2003	61,2	107,5	32,5	19,2	**220,4**
2004	60,9	105,3	35,4	17,2	**218,8**
2005	58,4	106,0	30,3	16,4	**211,1**
2006	57,3	102,2	27,1	16,3	**202,8**
2007	56,3	104,1	31,5	18,2	**210,1**

The total methane emissions increased by about 3.6 per cent from 2006 to 2007. During the period 1990-2007 the total CH_4 emissions decreased by 4.7 per cent. Table 2.5 and figure 2.8 show that this decrease is primarily due to decreased emissions from waste treatment which more than compensated for the growth in emissions from the oil- and gas industry.

Small annual fluctuations in the emissions from the oil and gas industry can be explained by changes in production volumes. Measures for mitigating the emissions from combustion and evaporation/leakage in the oil- and gas industry have not been sufficient to compensate for the increase in activity level and change in extraction from oil to gas.

The waste volumes have grown during the period (1990-2007), but this effect has been more than offset by increased recycling and incineration of waste and increased burning of methane from landfills.

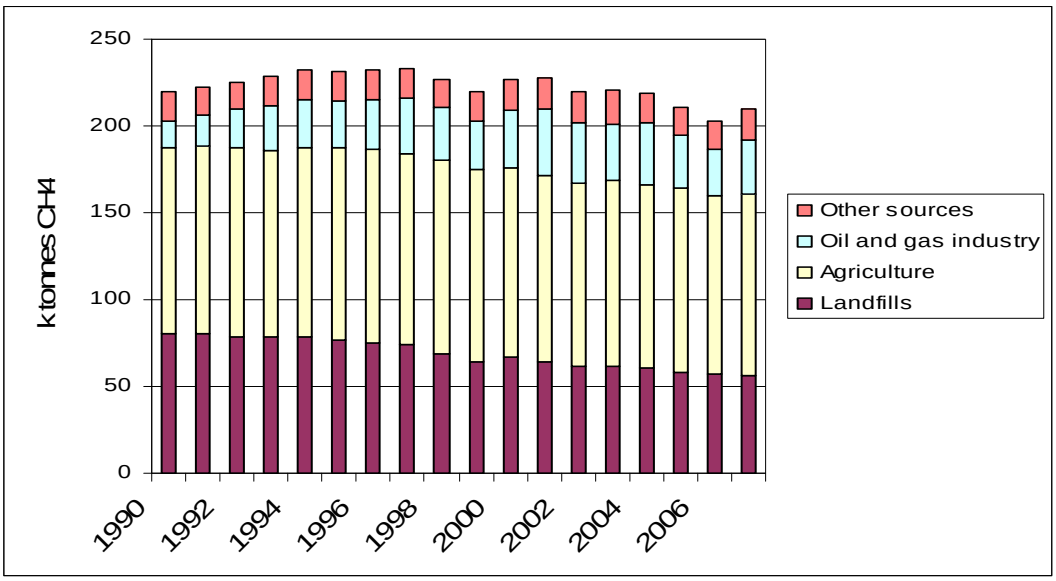


Figure 2.8: Changes in CH_4 emissions for major Norwegian sources between 1990 and 2006. Source: Statistics Norway/SFT

2.2.3. Nitrous oxide (N_2O)

Figure 2.9 shows that 49 per cent of the Norwegian emissions of N_2O are of agricultural origin, with agricultural soils as the most prominent contributor. The second most important source is production of nitric acid from two plants, which is one of the steps in the production of fertilizer. These emissions account for 33 per cent of the total. The contribution from road traffic amounted to 4 per cent in 2007, with emissions originating from the use of catalytic converters in mobile sources. Included under "other" are emissions from e.g. fuel combustion, manure management and waste-water handling.

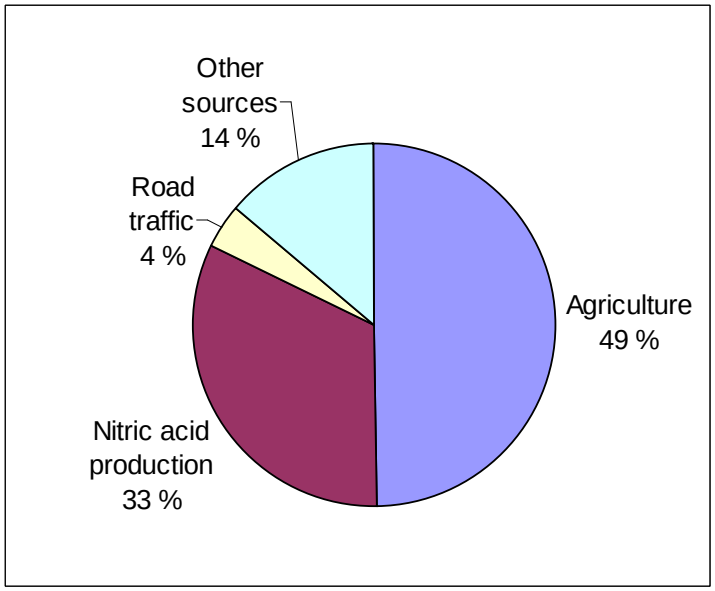


Figure 2.9: Distribution of Norwegian N_2O emissions by major sources in 2006. Source: Statistics Norway/SFT

The emissions of N_2O are rather stable. During the period 1990–2007 the total N_2O emissions decreased by 10 per cent. From 2006 to 2007 there was a decrease in the emission by

approximately 4 per cent, which is due to lower emissions from the fertilizer industry. This and other details are shown in Table 2.6 and Figure 2.10.

Table 2.6 Emissions of N_2O in Norway by major sources 1990-2007. The emissions are given in ktonnes. Source: Statistics Norway/SFT

Year	Agriculture	Nitric acid production	Road traffic	Other sources	**Total**
1990	7,00	6,69	0,15	1,38	**15,22**
1991	7,05	6,18	0,17	1,35	**14,75**
1992	7,01	4,41	0,19	1,34	**12,94**
1993	6,98	5,11	0,23	1,36	**13,68**
1994	6,98	5,29	0,25	1,47	**14,00**
1995	7,09	5,28	0,29	1,54	**14,21**
1996	7,15	5,22	0,34	1,65	**14,37**
1997	7,16	5,18	0,38	1,68	**14,39**
1998	7,16	5,44	0,41	1,64	**14,65**
1999	6,97	6,18	0,44	1,74	**15,33**
2000	7,03	5,59	0,46	1,50	**14,57**
2001	6,79	5,43	0,50	1,57	**14,29**
2002	6,72	6,16	0,52	1,50	**14,90**
2003	6,78	5,52	0,53	1,58	**14,41**
2004	6,79	5,96	0,55	1,62	**14,92**
2005	6,81	6,31	0,55	1,62	**15,28**
2006	6,64	5,25	0,55	1,75	**14,19**
2007	6,79	4,44	0,54	1,88	**13,66**

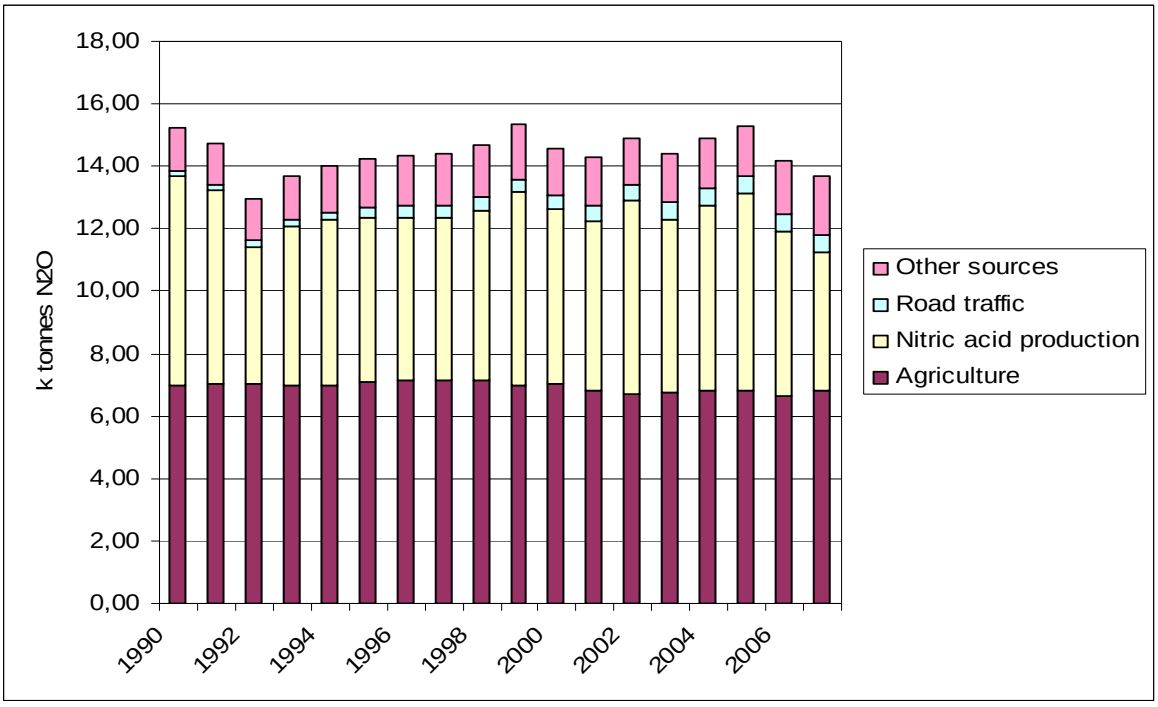


Figure 2.10 Changes in N_2O emissions for major Norwegian sources between 1990 and 2007. Source: Statistics Norway/SFT

Emissions of N_2O from agriculture have been rather stable for the whole period since 1990. Bearing in mind the very high level of uncertainty both in level and trend of the key category "agricultural soils", no conclusions can be drawn about the development in emissions from agriculture.

Changes in the production processes of nitric acid led to decreased emissions from this source in the beginning of the 1990s, while there was a moderate increase in emission in the following years due to increased production volumes. Improvements in the production process brought the emissions down again in 2006, and even further down in 2007, to a level which is 34 per cent lower than in 1990. There has been a decrease by over 15 per cent in emissions from this source from 2006 to 2007.

The increasing use of catalytic converters in light vehicles has increased the emissions of N_2O from road traffic with 0.4 ktonnes, or above 250 percent during the period 1990-2007.

2.2.4. Perfluorcarbons (PFCs)

The emissions of the perfluorcarbons tetrafluoromethane (CF_4) and hexafluoroethane (C_2F_6) from Norwegian aluminium plants in 2007 were reported at 108.7 and 10.3 tonnes respectively, corresponding to a total of 0.8 million tonnes of CO_2-equivalents.

The total emissions of PFCs decreased by 76 per cent in the period 1990-2007 following a steady downward trend as illustrated in Figure 2.11. The emission of CF_4 decreased by 77 per cent, while the emission of C_2F_6 decreased by 72 per cent in the same period. PFCs reduction is caused by improved technology and process control which has led to 84 per cent decrease in the amount of PFCs emitted per tonne aluminium produced during the period 1990-2007. However, there was an increase of 12 per cent from 2006 to 2007. In 1990, the emissions of PFCs were 3.88 kg CO2-equivaltents per tonne aluminium produced. In 2007, this is reduced to 0.60 kg per tonne aluminium.
PFCs may be used as substitutes for ozone-depleting substances. In Norway, the component C_3F_8 (PFC-218) is used for this purpose. The actual emissions of C_3F_8 have been calculated at only 56 kg in 2007, corresponding to about 392 tonnes of CO_2-equivalents. Since a tax on import and production of PFCs was implemented in 2003 the introduction of PFCs in new or modified applications has fallen to an insignificant level.

Consumption of halocarbons is also described in Section 4.6.

Table 2.7 Emissions of PFCs in Norway 1990-2007 in tonnes. Total CO_2-eq.are in million tonnes. Source Statistics Norway/SFT

YEAR	PFK14 (CF4)	PFK116 (C2F6)	PFK218 (C3F8)	**Total CO2-eq.**
1990	467,4	36,2	0,0	3,4
1991	416,5	31,0	0,0	3,0
1992	321,6	21,4	0,0	2,3
1993	324,3	20,6	0,0	2,3
1994	286,9	18,3	0,0	2,0
1995	283,3	18,1	0,0	2,0
1996	258,5	16,2	0,0	1,8
1997	229,9	15,1	0,0	1,6
1998	209,8	13,3	0,0	1,5
1999	196,2	12,3	0,0	1,4
2000	186,4	11,6	0,0	1,3
2001	187,5	11,9	0,0	1,3
2002	201,3	14,0	0,0	1,4
2003	125,6	10,1	0,0	0,9
2004	122,1	9,4	0,0	0,9
2005	116,7	7,6	0,0	0,8
2006	102,1	8,6	0,0	0,7
2007	108,7	10,3	0,0	0,8

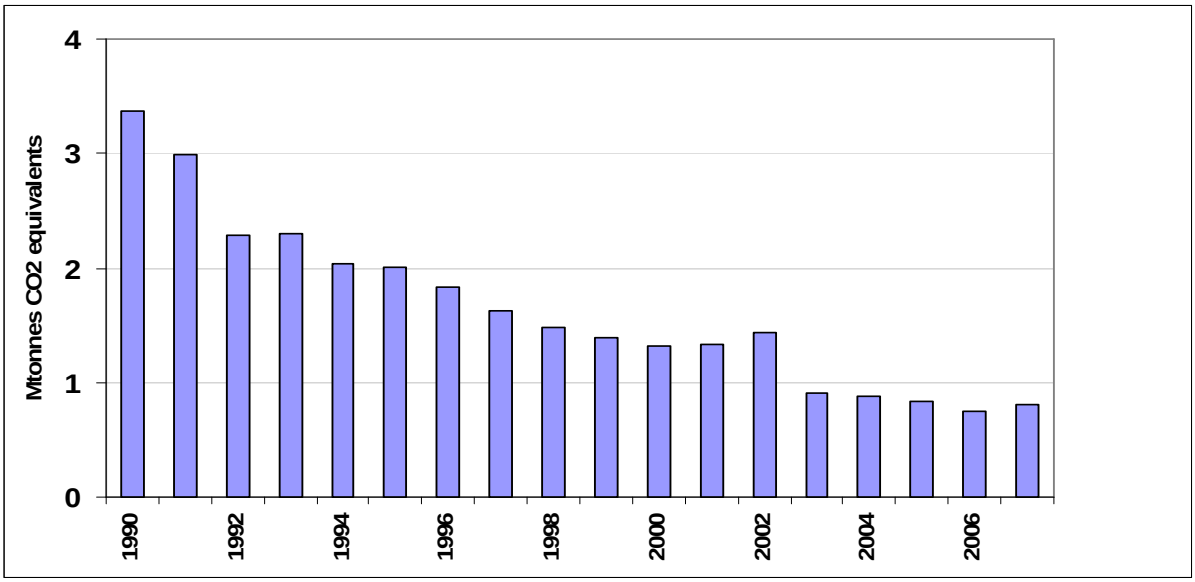


Figure 2.11 Emissions of PFCs in Norway 1990-2007. The emissions are given in million tonnes CO_2-equivalents. Source: Statistics Norway/SFT

2.2.5. Sulphur hexafluoride (SF_6)

Up till 2007 the largest source of SF_6 emissions in Norway was magnesium production, where SF_6 was used to cover the surface of liquid magnesium to prevent it from oxidizing. The covering gas was emitted to air after use and no SF_6 is expected to react with the metal. The consumption of SF_6 was reduced through the 1990s due to improvements in technology and process management and reduced production. However, the process management changes from year to year and consequently also the consumption of SF_6. In 2007, the SF_6 emissions were 97 per cent lower than in 1990. Primary magnesium is produced by one company in Norway. The company decided to retain only the secondary production, and primary

production of magnesium ceased in 2002. This explains the much lower emission level since 2002..

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.

The main other use of SF_6 is in gas insulated switchgears (GIS) and other high-voltage applications. Since the signing of a voluntary agreement in 2002, emissions from this sector have decreased 26 per cent until 2007. However, there was an increase in SF_6-emissions from 2005 to 2006. This increase was mainly due to emissions during large maintenance works as well as two incidents with leakage from gas treatment equipment.

Table 2.8 SF_6 emissions in Norway 1990-2007. The emissions are given in tonnes. Source Statistics Norway/SFT.

Year	GIS	Magnesium and Aluminium Industry	Other	**Total**
1990	0,05	2,14	0,00	**2,20**
1991	0,06	2,02	0,00	**2,08**
1992	0,06	0,64	0,00	**0,71**
1993	0,07	0,66	0,00	**0,74**
1994	0,08	0,79	0,01	**0,88**
1995	0,09	0,51	0,01	**0,61**
1996	0,09	0,47	0,01	**0,57**
1997	0,09	0,44	0,05	**0,58**
1998	0,09	0,58	0,05	**0,73**
1999	0,10	0,73	0,05	**0,87**
2000	0,11	0,77	0,05	**0,93**
2001	0,09	0,65	0,06	**0,79**
2002	0,08	0,14	0,01	**0,24**
2003	0,05	0,17	0,01	**0,23**
2004	0,05	0,21	0,02	**0,28**
2005	0,05	0,24	0,02	**0,31**
2006	0,07	0,12	0,02	**0,21**
2007	0,06	0,00	0,02	**0,08**

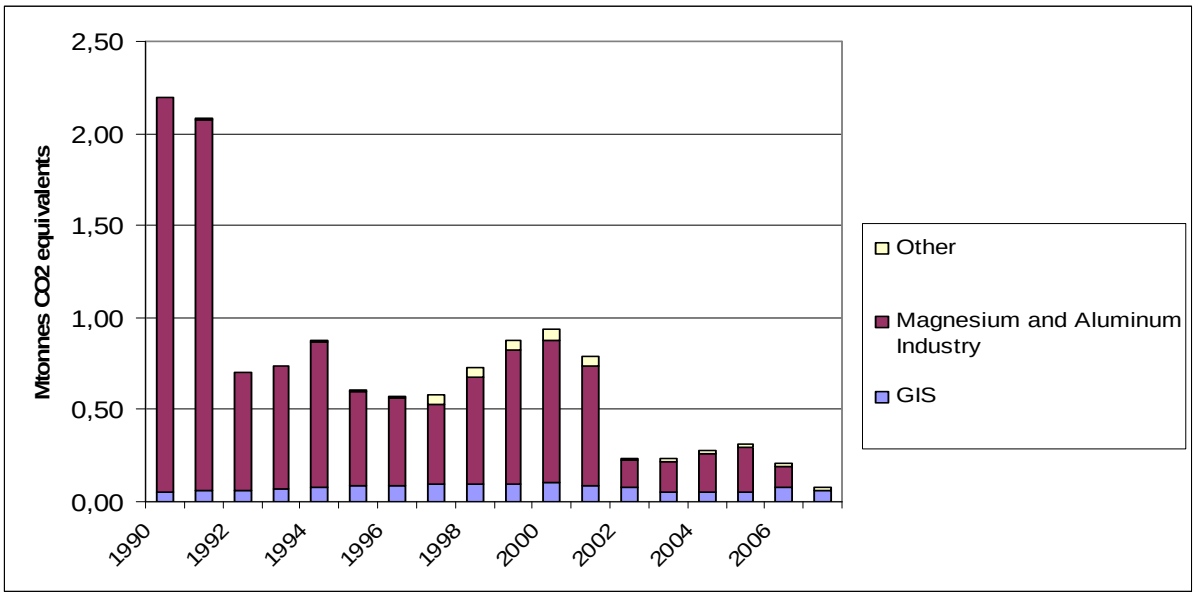


Figure 2.12 Emissions of SF6 in Norway 1990-2007. The emissions are given in Mtonnes CO_2-equivalents. Source: Statistics Norway/SFT

2.2.6. Hydrofluorcarbons (HFCs)

The total actual emissions from HFCs used as substitutes for ozone depleting substances amounted to 0.57 million tonnes of CO_2-equivalents in 2007. Compared to the emissions in 2006, this represents an increase of about 8 per cent. The emissions in 1990 were insignificant. The application category refrigeration and air conditioning contribute by far with the largest part of the HFCs emissions. The other categories foam/foam blowing and fire extinguishing contributed small amounts to the overall emissions. Tier 2 methodology was used to calculate the emissions. Figure 2.13 displays the development of the emissions of HFCs in the period 1990-2007. Table 2.9 shows the actual emissions of different HFCs over the same period. The figure shows that emissions increased exponentially until 2002 due to the strong demand for substitution of ozone depleting substances. When the tax on HFCs was introduced in 2003 the increase slowed down to a linear trend due to more widespread introduction of natural agents and smaller charges (Statistics Norway (2007/8)).

Table 2.9 Actual emissions of HFCs in Norway 1990-2007 calculated using the Tier 2 methodology. The emissions are given in tonnes. The total is in Mtonnes CO2 equivalents. Source Statistics Norway/SFT

Year	HFK23	HFK32	HFK125	HFK134	HFK134a	HFK143	HFK143a	HFK152a	HFK227ea	Total in Mtonnes CO2-eq.
1990	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,13	0,00	**0,00**
1991	0,00	0,00	0,00	0,00	0,04	0,00	0,00	0,41	0,00	**0,00**
1992	0,00	0,00	0,00	0,00	0,19	0,00	0,00	0,65	0,00	**0,00**
1993	0,00	0,00	0,00	0,00	1,78	0,00	0,00	0,79	0,00	**0,00**
1994	0,00	0,00	0,47	0,00	5,43	0,00	0,18	0,81	0,00	**0,01**
1995	0,00	0,01	2,38	0,00	10,17	0,00	1,52	0,99	0,00	**0,03**
1996	0,01	0,02	5,48	0,00	16,70	0,00	3,87	1,47	0,05	**0,05**
1997	0,04	0,15	9,72	0,00	24,64	0,00	6,86	2,44	0,11	**0,09**
1998	0,07	0,33	14,75	0,00	35,71	0,00	10,49	5,62	0,15	**0,13**
1999	0,07	0,64	19,98	0,00	50,17	0,00	14,87	8,72	0,16	**0,18**
2000	0,06	1,04	26,16	0,00	64,41	0,00	20,47	12,43	0,17	**0,24**
2001	0,06	1,51	33,37	0,00	78,84	0,00	27,10	16,41	0,28	**0,30**
2002	0,07	2,26	39,20	0,00	95,18	0,00	32,34	19,32	0,45	**0,36**
2003	0,09	3,00	42,40	0,00	111,84	0,00	34,30	22,82	0,76	**0,40**
2004	0,10	3,83	45,29	0,10	127,55	0,00	35,91	27,01	0,95	**0,44**
2005	0,12	4,54	47,80	0,09	149,14	0,41	37,34	34,47	1,10	**0,48**
2006	0,12	5,34	50,06	0,09	169,27	1,27	38,62	38,38	1,22	**0,52**
2007	0,13	6,41	52,45	0,09	193,73	1,71	40,00	34,93	1,23	**0,57**

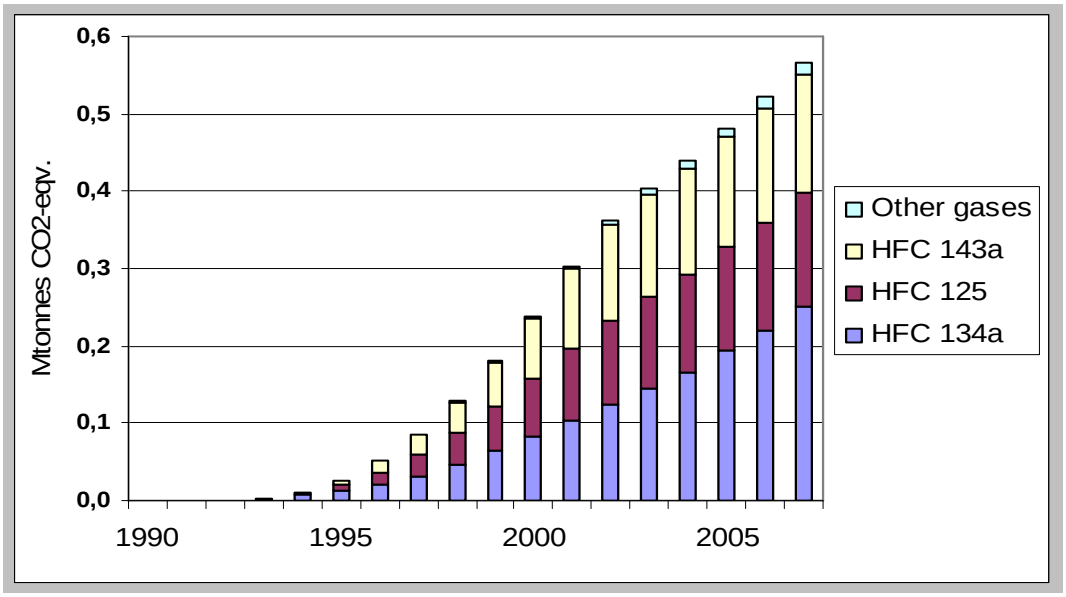


Figure 2.13 Actual emissions of HFCs in Norway 1990-2007. The emissions are given in Mtonnes CO_2-equivalents. Source: Statistics Norway/SFT

2.3. Emission trend by source

2.3.1. Total emissions by source classification

Figure 2.14 illustrates the total emissions of GHG in Norway in 2007 in IPCC classification of sources. The Energy sector is by far the most important, contributing with almost 73 per cent of the total emissions.

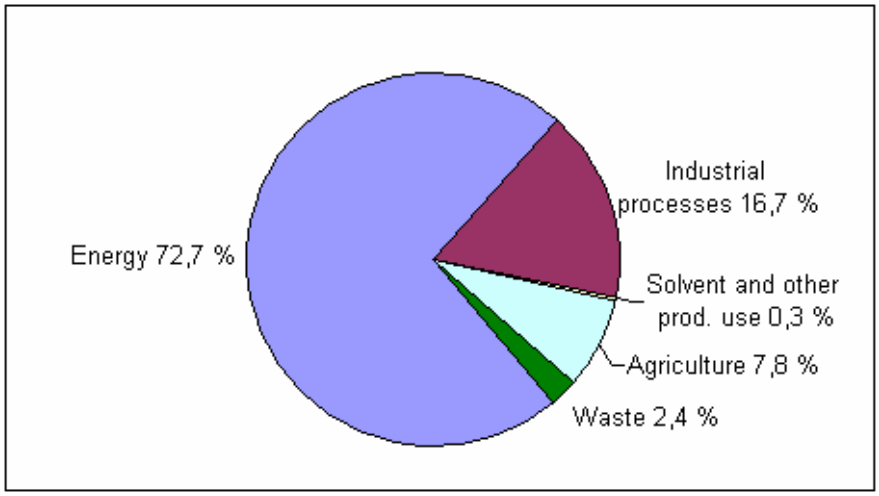


Figure 2.14 Total emissions of GHG in Norway in 2007 by sources. Source: Statistics Norway/SFT

Figure 2.15 shows the changes in greenhouse gas emissions by sectors in the period 1990 to 2007. The Energy sector is divided in its five main sub-sectors: Fuel combustion in energy industries, fuel combustion in manufacturing industries and construction, fuel combustion in transport, and fuel combustion in other sectors. Fugitive emissions from fuels comes in addition.

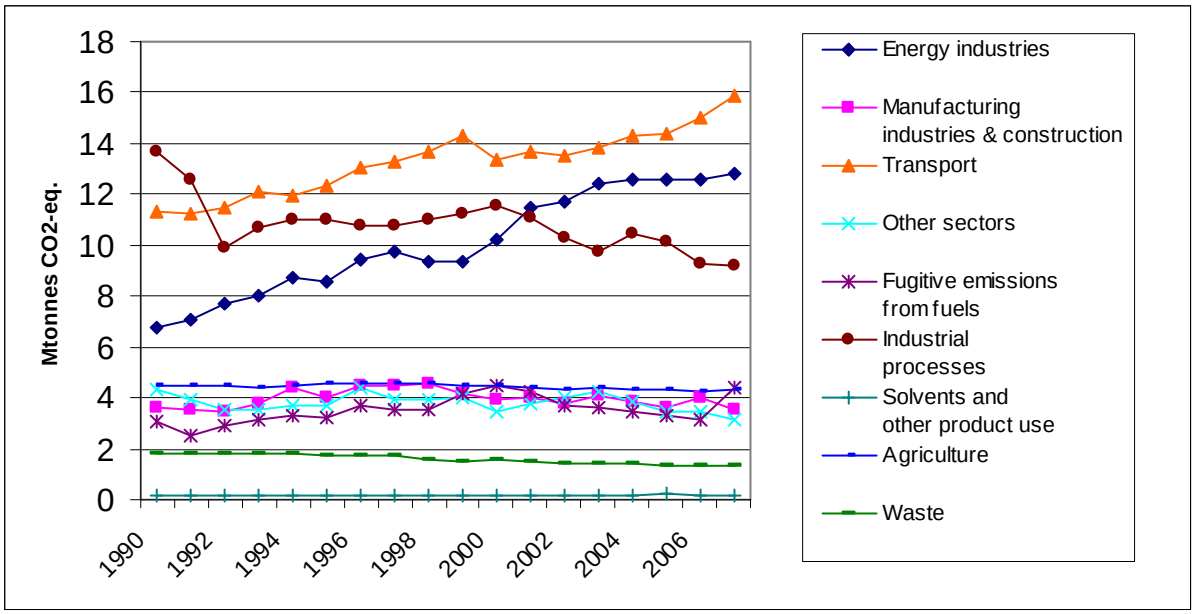


Figure 2.15 Development of emissions of all GHG, given as CO_2-equivalents, from the different sectors. Source: Statistics Norway/SFT

2.3.2. Energy

Figure 2.16 displays the distribution of GHG emissions in 2007 on the main sub categories within the energy sources.

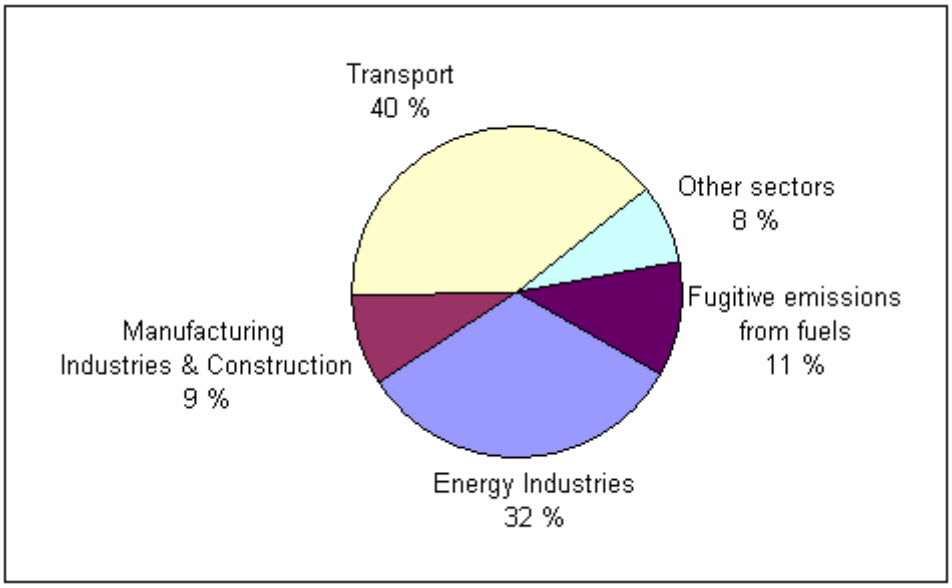


Figure 2.16 Greenhouse gas emissions in 2007 from the energy sector distributed on the different source categories. Source: Statistics Norway/SFT

The Norwegian energy sector has traditionally been dominated by hydroelectric power. As a result of this electricity is normally used in heating and in many manufacturing processes. Within the energy sector the fuel combustion in the Transport sector is the biggest emitter of GHG with a share of 40 per cent in 2007. Number two is fuel combustion in Energy industries, with a share of 33 per cent. This sector is almost completely dominated by fuel combustion in the oil and gas extraction and related activities.

The total emissions of greenhouse gases from the energy sector over the period 1990-2007 are listed in Table 2.10. The emission changes detected in the various source categories in the energy sector between 1990 and 2007 compared to the 1990 level, are illustrated in Figure 2.17 and discussed in the following.

Table 2.10 Total emissions of greenhouse gases from the energy sector in Norway 1990-2007. The emissions are given in Million tonnes CO_2-equivalents. Source: Statistics Norway/SFT

	Energy Industries	Manufacturing Industries & Construction	Transport	Other sectors[1]	Fugitive emissions from fuels	Total
1990	6,7	3,7	11,3	4,3	3,0	29,5
1991	7,1	3,5	11,2	3,9	2,5	28,6
1992	7,7	3,4	11,5	3,6	2,9	29,6
1993	8,0	3,8	12,1	3,5	3,1	30,9
1994	8,7	4,4	11,9	3,7	3,3	32,5
1995	8,5	4,0	12,4	3,7	3,2	32,3
1996	9,4	4,5	13,1	4,4	3,7	35,4
1997	9,8	4,4	13,3	4,0	3,5	35,4
1998	9,4	4,5	13,6	3,9	3,6	35,4
1999	9,3	4,2	14,3	4,0	4,1	36,3
2000	10,2	3,9	13,4	3,4	4,5	35,6
2001	11,5	4,0	13,6	3,8	4,2	37,5
2002	11,7	3,7	13,5	4,0	3,7	37,1
2003	12,4	4,1	13,8	4,3	3,6	38,3
2004	12,5	3,9	14,3	3,8	3,5	38,3
2005	12,6	3,6	14,4	3,5	3,3	37,7
2006	12,6	4,0	15,0	3,5	3,1	38,5
2007	12,8	3,6	15,9	3,1	4,4	40,0

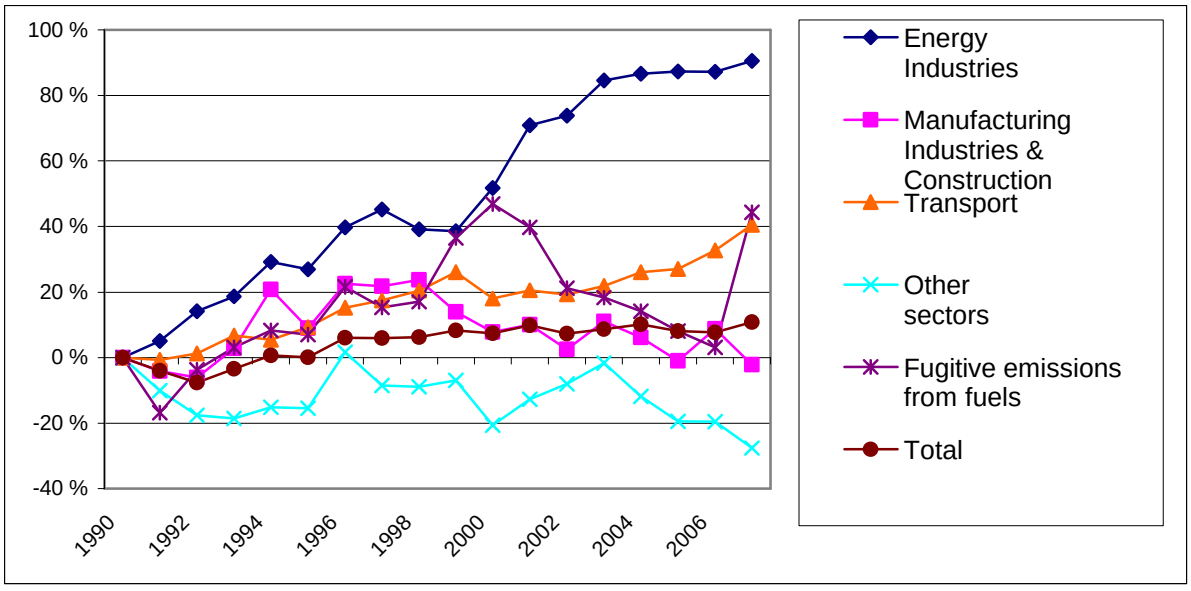


Figure 2.17 Changes in emissions in the various source categories in the energy sector between 1990 and 2007 compared to the 1990 level. Source: Statistics Norway/SFT.

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 2007 the total emission level in the energy sector was 35 per cent higher than in 1990, or almost 10,5 million tonnes higher. There were short, temporary emission reductions in 1991, 1995, 2000, 2002 and 2005 followed by new growth. The reduction in 1991 was caused by a period with

[1] Include CRF key categories 1 A4 (stationary combustion in agriculture, forestry, fishing, commercial and institutional sectors and households, motorized equipment and snow scooters in agriculture and forestry, and ships and boats in fishing) and 1 A5 (fuel used in stationary and mobile military activities).

reduced economical activity, in 2000 by a mild winter and tax changes which resulted in reduced use of fuels for heating purposes and reduced fuel sales respectively. The decrease from 2001 to 2002 was due to reduced fugitive emissions from fuels and lower emissions from manufacturing industries and construction, which outpaced the increased emissions from energy industries and transport over the same period. The emission level in 2005 was 1 per cent lower than in 2004. The small decrease in 2005 was due to reduced use of heating oil.

Emissions from fuel combustion in **Energy industries** have increased by 90,5 per cent from 1990 to 2007, and from 2006 to 2007 there was a minor increase. The main source is offshore oil and gas extraction. 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.

In 2007 the emissions from energy use in offshore oil and gas extraction contributed with about 25 per cent of the total GHG emissions in Norway. In 1990 the corresponding contribution was 14 per cent. The growth can be explained by increased production of oil and gas and more energy demanding extraction due to aging of oil fields a transition from oil to gas. During the period 1990-2007 the emissions of CO_2 from energy production offshore has increased from 5.4 million tonnes to 11.0 million tonnes CO_2.

Public generation of electricity is almost completely dominated by hydroelectric generation. The only important exceptions are waste incineration power 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 industries and construction** have decreased 2 per cent from 1990 to 2007, while the decrease from 2006 to 2007 was about 10 per cent.

Emissions from **Transport** showed an overall increase by 40 per cent from 1990 to 2007, while the emissions increased by almost 6 per cent from 2006 to 2007 (see, Table 2.10, Table 2.11 and Figure 2.18). The share of transport in the total GHG emissions has increased from 23 per cent in 1990 to 29 per cent in 2007. Road traffic accounts for 59 per cent of the total mobile emissions, while emissions from navigation and civil aviation accounts for 22 and 6 per cent respectively. Due to the fact that most railways are electrified in Norway, emissions of GHG from this source are insignificant. Other transportation (off-road vehicles and other machinery and other non-specified) accounts for 14 per cent of the emissions from the source transport, and it has increased by 108 per cent in the period 1990-2007. Without this source, the transport sector has had an overall increase by 33 per cent

Emissions of GHG from road traffic increased by 33 per cent from 1990 to 2007. Between 2006 and 2007 emissions increased by 2,5 per cent. Road traffic contributed to the total national GHG emissions by almost 19 per cent.

Emissions from navigation increased by 36 per cent from 1990 to 2007, mainly because of increased activity related to the oil- and gas extraction sector. Navigation contributed to the total national GHG emissions by 4.8 per cent in 2007.

[2] Include 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.

Emissions from civil aviation have increased by 34 per cent since 1990. The substitution of older planes with new and more energy efficient planes has played an important role to limit the emission growth. Civil aviation contributed to the total national GHG emissions by about 1.7 per cent in 2007.

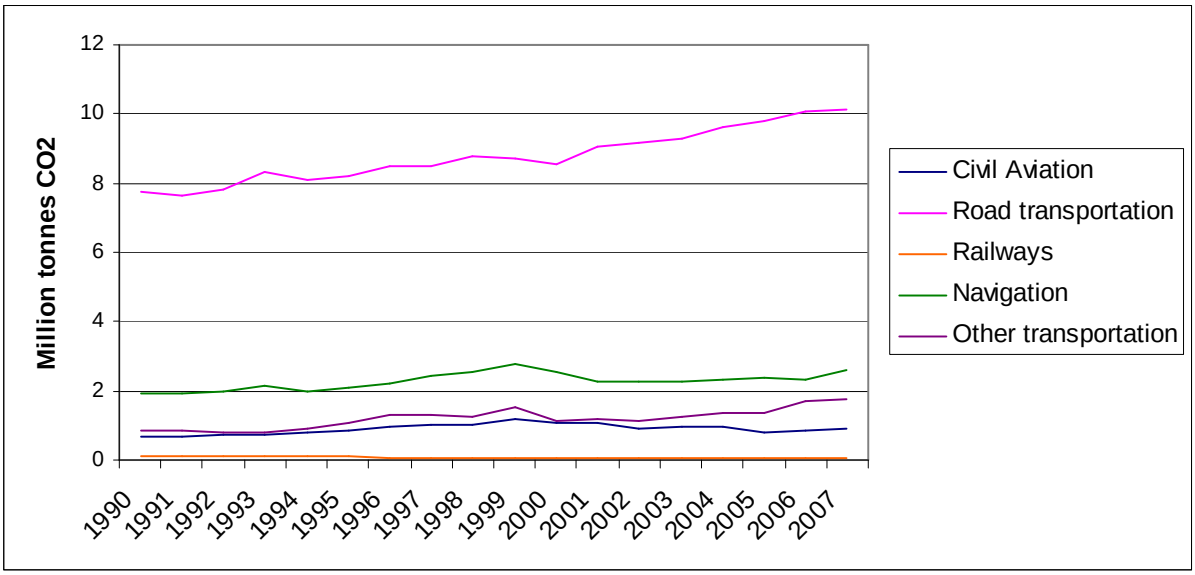


Figure 2.18 Changes in CO_2-emissions from different modes of transport in 1990-2007. Source: Statistics Norway/SFT

Table 2.11 Total emissions of greenhouse gases from the transport sector in Norway 1990-2007. Million tonnes CO_2-equivalents. Source: Statistics Norway/SFT

	Civil Aviation	Road transportation	Railways	Navigation	Other transportation	**Total Transport**
1990	0,686	7,736	0,107	1,947	0,849	**11,3**
1991	0,704	7,663	0,103	1,942	0,830	**11,2**
1992	0,727	7,837	0,109	2,004	0,785	**11,5**
1993	0,723	8,295	0,115	2,167	0,788	**12,1**
1994	0,808	8,074	0,118	2,009	0,929	**11,9**
1995	0,869	8,228	0,116	2,095	1,060	**12,4**
1996	0,965	8,502	0,079	2,210	1,295	**13,1**
1997	0,992	8,513	0,083	2,439	1,278	**13,3**
1998	1,016	8,759	0,064	2,556	1,250	**13,6**
1999	1,167	8,714	0,061	2,790	1,555	**14,3**
2000	1,067	8,544	0,055	2,554	1,140	**13,4**
2001	1,074	9,061	0,053	2,290	1,171	**13,6**
2002	0,923	9,156	0,049	2,256	1,124	**13,5**
2003	0,964	9,305	0,045	2,250	1,247	**13,8**
2004	0,955	9,625	0,049	2,296	1,359	**14,3**
2005	0,803	9,791	0,048	2,368	1,382	**14,4**
2006	0,869	10,086	0,046	2,345	1,687	**15,0**
2007	0,918	10,325	0,049	2,656	1,970	**15,9**

The source category **Other Sectors** (table 2.10) includes fuel combustion in agriculture, forestry and fisheries, fuel combustion from residential sources and fuel combustion from commercial/institutional sources (CRF key categories 1A4 and 1A5)**.** The total emission from this sector was 3.1 million tonnes CO_2-equivalents in 2007. Fuel combustion in agriculture, forestry and fisheries accounts for about 35 per cent of the emissions of this

sector. Since 1990 the emissions from the fuel combustion in agriculture, forestry and fisheries has been reduced by almost 9 per cent.

Greenhouse gas emissions from residential sources accounted in 2007 for about 49 per cent of other sector's total. Emissions were 6.5 million tonnes less in 2007 than 1990 due to electrification of heating infrastructure. However, new technologies and occasional electricity shortages have at times reversed this trend. Recent examples of fluctuations are the relatively low emissions from residential sources in 2000 due to the mild winter which led subsequently to relatively low consumption of fuels. In 2003, the emissions from residential sources increased due to a dry and cold winter combined with extraordinary high electricity prices. From 2003 to 2006 the emissions from residential sources decreased by 43 per cent, and from 2006 to 2007 the emissions went down another 11 per cent. This can be explained by a reduction in electricity prices since 2003, but also an increase in energy conservation and more use of wooden fuel in households.

Emissions from commercial/institutional sources make up the last 16 per cent of this category. There has been 4 per cent decrease from 1990 to 2007, and a decrease of 6 per cent from 2006 to 2007.

The source category termed **Fugitive emissions from fuels** refers to emissions from oil and gas activities such as 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. These emissions are reported to 4.4 million tonnes CO_2-equivalents in 2007. In order to minimize 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 per cent from 1990 to 2006. However, the increase from 2006 to 2007 was 40 per cent, leading to an overall increase by 44 per cent from 1990 to 2007.

2.3.3. Industrial processes

The industrial process sector accounted for 17 per cent of the national greenhouse gas emissions in 2007. The emissions from this source category have decreased by almost 33 per cent from 1990 to 2007 and decreased by 1 per cent from 2006 to 2007.

Metal production 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), contributing with about 61 per cent of the total emissions from Industrial processes. Chemical industry contributes with 20 per cent of the emissions from Industrial processes.

Figure 2.19 shows the variation in the different industries contribution to greenhouse gas emissions from 1990 to 2007. Table 2.11 provides figures for the total greenhouse gas emissions from the Industry sector for the same period.

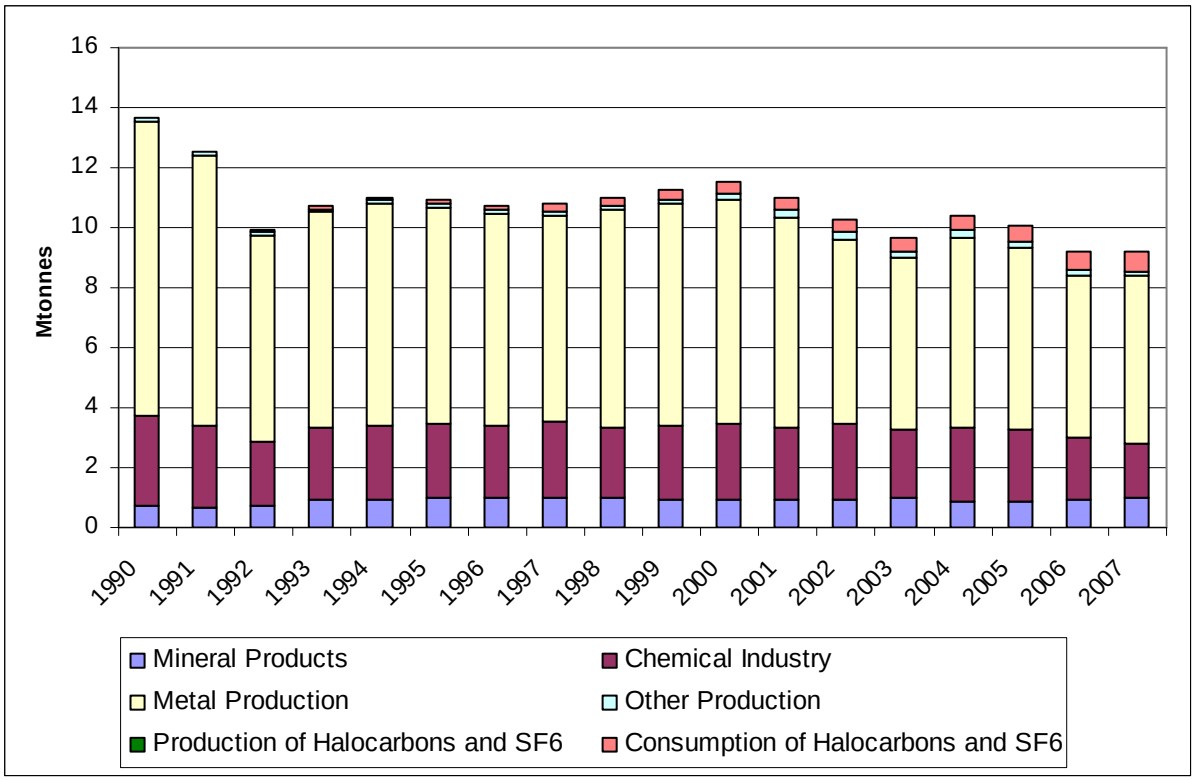


Figure 1. Figure 2.19 Total greenhouse gas emissions in the industrial source categories in Norway during the period 1990-2007. Source: Statistics Norway/SFT

Table 2.12 Total greenhouse gas emissions from the industry sector in Norway 1990-2007. Million tonnes CO_2-eq. Source: Statistics Norway/SFT

Year	Mineral Products	Chemical Industry	Metal Production	Other Production	Consumption of Halocarbons and SF6	Total
1990	0,72	2,98	9,85	0,08	0,06	13,70
1991	0,67	2,72	8,99	0,12	0,06	12,57
1992	0,72	2,13	6,88	0,12	0,07	9,93
1993	0,92	2,40	7,18	0,13	0,08	10,73
1994	0,93	2,47	7,41	0,13	0,10	11,04
1995	0,97	2,49	7,23	0,13	0,12	10,97
1996	0,97	2,45	7,03	0,14	0,15	10,75
1997	1,03	2,48	6,88	0,15	0,23	10,79
1998	0,98	2,35	7,28	0,10	0,27	11,00
1999	0,96	2,43	7,44	0,08	0,33	11,26
2000	0,96	2,50	7,45	0,23	0,40	11,57
2001	0,92	2,38	7,06	0,22	0,45	11,05
2002	0,94	2,51	6,16	0,23	0,46	10,32
2003	0,98	2,31	5,70	0,23	0,47	9,71
2004	0,84	2,48	6,35	0,24	0,51	10,45
2005	0,89	2,40	6,03	0,20	0,55	10,12
2006	0,94	2,09	5,34	0,21	0,64	9,26
2007	1,01	1,80	5,59	0,17	0,64	9,20

During the first half of the 20th century, a large-scale industrialization took place 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 ferro alloys. 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.

Approximately 10 per cent of total GHG emissions in Norway were from **Metal Production** in 2007, and the sector contributed with 61 per cent of the emissions from Industrial Processes. The largest contributor to the GHG emissions from Metal Production in 2007 is aluminium production (53 per cent) and ferroalloys (45 per cent).

There are seven plants in Norway producing aluminium. Both prebaked anode and the Soederberg production methods are used. Production of aluminium leads to emission of various components such as CO_2, SO_2, NO_x, perfluorocarbons (PFCs), heavy metals and persistent organic pollutants. PFCs emissions from production of aluminium contributed in 1990 to 6.7 per cent of the total GHG emissions in Norway. The share of the total in 2007 is reduced to 1.5 per cent. Emissions of PFCs have decreased with 76 per cent from 1990 to 2007 and between 2006 and 2007 the emissions have increased by 8 per cent.

Production of ferro alloys is the second most important source within the metal production category. Norway is a major producer of ferroalloys with 12 plants in operation in 2007. The GHG emissions from ferro alloy production accounted for 4.5 per cent of the national total GHG emissions in 2007, and the emissions have decreased with 10.4 per cent since 1990. From 2005 to 2006 GHG emissions from ferro alloys decreased by 24 per cent due to reduced production. However, in 2007 the emissions increased by almost 14 per cent compared to the level in 2006.

Other metals produced in Norway today are nickel, zinc and magnesium, one plant of each. Emissions from theses sources are minor compared to other metal producers.

The major source of SF_6 emissions is magnesium production. There is one magnesium manufacturing plant in Norway. The plant closed down the production of primary magnesium in 2002 but the production of secondary cast magnesium is continuing. SF_6 from magnesium foundries accounted in 2006 for 0.2 per cent of the total GHG emissions in Norway. In 1990 this sector contributed with 4.3 per cent of the national total GHG emissions. The reduction is mainly due to the closure of the primary magnesium plant in 2002, and improvements in technology and in process management. All magnesium production in Norway stopped in 2002. During 2006 also the production of remelting magnesium stopped, and there were no emissions from this source in 2007.

The chemical industry is the industry sector's second most important category, accounting for almost 20 per cent of the emissions in this sector. The emissions were reduced by about 40 per cent in the period 1990-2007. From 2006 to 2007 the emissions decreased by almost 15 per cent. In Norway, this category includes primarily production of fertilizers and silicon carbide. These processes release N_2O (from nitric acid production) and CO_2 (from production of ammonia and carbides). The N_2O emissions from production of nitric acid accounted for almost 3 per cent of the total GHG emissions in 2007, and 15 per cent of the GHG emissions in sector Industrial processes. The N_2O emissions have decreased with 34 per cent from 1990 to 2007 while the production of nitric acid increased by 22 per cent. The detected reduction is due to improved technology in the nitric acid production.

Production of Mineral products contributed in 1990 by 1.5 percent of the total GHG emissions in Norway and this share has increased to 1.8 per cent in 2007. The emissions from the sector increased with 39 per cent from 1990-2007 and 7.3 per cent from 2006-2007 mainly due to increased production of clinker in the cement production. Cement production is

by far the main source of emissions from mineral products. Cement is produced in two plants in Norway, releasing CO_2 emissions from coal and waste used in direct fired furnaces, and from carbon in limestone. In 2007, the CO_2 emissions from clinker production accounted for 1.6 per cent of the total national GHG emissions and 9.5 per cent of the GHG emissions in the sector. From 1990-2007 the CO_2 emissions from clinker production increased by 35 per cent and from 2006 to 2007 the CO_2 emission increased by almost 9 per cent.

Refrigeration and air conditioning equipment is the most important application category related to emissions of hydrofluorocarbons (HFCs) under the category **Consumption of halocarbons and SF_6**. The emissions constitute almost 7 per cent of the emissions from the industry sector. Substitution of ozone-depleting substances and increased application of air-conditioning systems in cars and buildings amplifies the rapid growth in these emissions. However, the tax on HFCs introduced in 2003 has moderated this growth somewhat (Statistics Norway (2007/8)). Electrical switchgears and the use of SF_6 as trace gas are the most important sources of non-process emissions of SF_6. Norway does not manufacture halocarbons or SF_6.

2.3.4. Solvent and other product use

Use of solvents and products containing solvents result in 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 oxidize to CO_2.

Indirect CO_2 emissions from solvents and N_2O from anaesthesia and propellant represented approximately 0.3 per cent of the total GHG emissions in 2007 equal to the emission level in1990. The share has been more or less unchanged since 1990.

2.3.5. Agriculture

In 2006, about 7.8 per cent of the total Norwegian emissions of greenhouse gases (GHG) originated from agriculture. This corresponds to 4.3 million tonnes CO_2-eqv. The emissions from agriculture are quite stable, with emissions about 3 percent lower in 2007 than in 1990, and 2 per cent higher than in 2006.

The sectors clearly biggest sources of GHGs are “enteric fermentation” (CH_4) from domestic animals, contributing with 44 per cent and “agricultural soils” (N_2O) contributing with 46 per cent of the sectors emissions. These are also key categories. Manure management contributes with 10 per cent.

Enteric fermentation contributed with over 89 ktonnes of CH_4 emissions in 2007, corresponding to 1,871 million tonnes CO_2 equivalents, which is 3.4 per cent of the national GHG emissions. Enteric fermentation constitutes 85 per cent of the overall CH_4 emissions from agriculture and 44 percent of the sectors’ GHG emissions. Emissions have been rather stable with minor fluctuations. Emissions decreased almost 4 per cent in the period 1990-2007 but and the emissions increased approximately 2 per cent from 2006-2007.

CH_4-emissions due to **manure management** amounted to almost 15 ktonnes in 2007, corresponding to 0.32 million tonnes CO_2 equivalents. N_2O-emissions due to manure management amounted to about 0.40 ktonnes in 2007, corresponding to 0.12 million tonnes CO_2 equivalents. In 2007, manure management emitted 0.44 million tonnes of CO_2

equivalents, which is 10 per cent of the GHGs from agriculture and 0.8 per cent of the Norwegian emissions of GHGs. Emissions of GHGs from manure management stayed at the same level in the period 1990-2007.

The emissions of N_2O in Norway from **agricultural soils** amounted to 6.4 ktonnes in 2007, or 1.98 million tonnes calculated in CO_2-equivalents. They accounted for about 47 per cent of the total Norwegian N_2O emissions in 2007 or about 3.6 per cent of the total Norwegian greenhouse gas emissions that year.

Emissions of N_2O from agricultural soils are a key category because of uncertainty, both in level and trend. The emissions decreased by 2.6 % in the period 1990-2007 but increased by 2.3 per cent from 2006 to 2007.

Table 2.13 Total greenhouse gas emissions from the agricultural sector in Norway 1990-2007. Million tonnes CO_2-eq. Source: Statistics Norway/SFT

Year	Enteric Fermentation	Manure Management	Agricultural Soils	Field Burning of Agricultural Residues	Total
1990	1,95	0,43	2,04	0,03	4,44
1991	1,97	0,45	2,04	0,02	4,49
1992	1,98	0,45	2,03	0,01	4,47
1993	1,95	0,44	2,03	0,02	4,44
1994	1,98	0,45	2,02	0,01	4,47
1995	2,00	0,46	2,05	0,02	4,53
1996	2,01	0,47	2,07	0,02	4,57
1997	1,99	0,46	2,08	0,01	4,55
1998	2,01	0,47	2,08	0,01	4,57
1999	2,01	0,46	2,02	0,01	4,50
2000	1,98	0,46	2,03	0,01	4,49
2001	1,94	0,46	1,96	0,01	4,37
2002	1,90	0,45	1,94	0,01	4,30
2003	1,95	0,43	1,98	0,01	4,36
2004	1,90	0,43	1,98	0,01	4,32
2005	1,91	0,44	1,99	0,01	4,34
2006	1,84	0,43	1,94	0,01	4,21
2007	1,87	0,44	1,98	0,01	4,30

2.3.6. Waste

The waste sector, with emissions of 1.3 million tonnes CO_2-equivalents in 2007, accounted for 2.4 per cent of the total GHG emissions in Norway this year.

The sector includes emissions from landfills (CH_4), wastewater handling (CH_4 and N_2O) and small scale waste incineration (CO_2 and CH_4). Waste incineration with utilization of energy is treated in the Energy chapter, hence the trifling emissions from waste incineration here.

Solid waste disposal on land (landfills) is the main category within the waste sector, accounting for about 89 per cent of the sector's total emissions. Wastewater handling accounts for 11 per cent, and waste incineration a mere trifling emission.

The emissions of greenhouse gases from the waste sector were relatively stable until 1997. From 1998 emissions declined, and in 2007 the emissions were about 27 per cent lower than in 1990. In spite of increasing amounts of waste the emissions of CH_4 from landfills has decreased because of a combination of increased recycling, incineration and burning of landfill gas.

The development of the emissions from waste is shown in table 2.14 and figure 2.20.

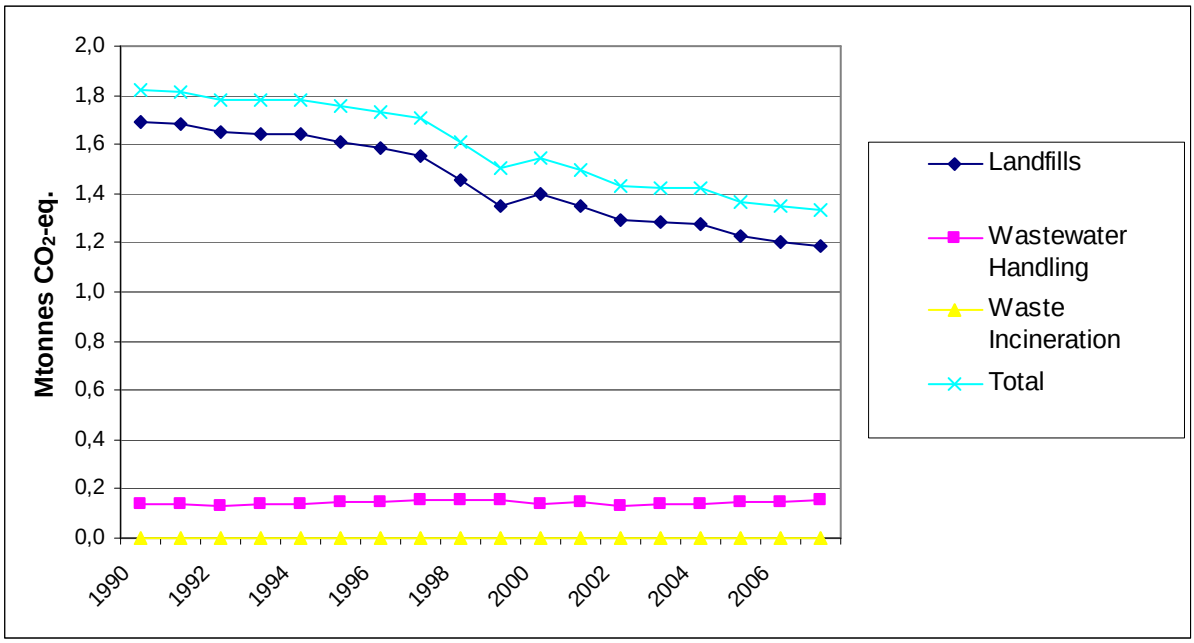


Figure 2.20 Total emissions of greenhouse gases in Norway from the waste sector 1990-2007. Million tonnes CO_2-equivalents. Source: Statistics Norway/SFT

Table 2.14 Emissions from the waste sector in Norway 1990-2007. Mtonnes CO_2 –equivalents. Source:Statistics Norway/SFT

Year	Landfills	Wastewater Handling	Waste Incineration	Total
1990	1,69	0,14	0,00	**1,82**
1991	1,68	0,14	0,00	**1,81**
1992	1,65	0,13	0,00	**1,78**
1993	1,64	0,14	0,00	**1,78**
1994	1,64	0,14	0,00	**1,78**
1995	1,61	0,14	0,00	**1,75**
1996	1,58	0,15	0,00	**1,73**
1997	1,55	0,16	0,00	**1,71**
1998	1,45	0,15	0,00	**1,61**
1999	1,35	0,15	0,00	**1,50**
2000	1,40	0,14	0,00	**1,54**
2001	1,35	0,14	0,00	**1,49**
2002	1,30	0,13	0,00	**1,43**
2003	1,28	0,14	0,00	**1,42**
2004	1,28	0,14	0,00	**1,42**
2005	1,23	0,14	0,00	**1,37**
2006	1,20	0,15	0,00	**1,35**
2007	1,18	0,15	0,00	**1,34**

Figure 2.20 shows that emissions of methane have decreased slightly since 1998. This is 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. In 2007 this tax was 416 NOK per tonne waste disposed at landfill sites with double side and bottom lining (rising to 434 NOK per tonne in 2008 and 447 in 2009), and 541 NOK per tonne waste disposed at landfills without double lining. In addition, landfills receiving biodegradable waste (waste containing degradable organic carbon (DOC)) are required to collect and treat landfill gas. In 2007 a total of 57 landfills had installed a landfill gas extraction system, and approximately 22 ktonnes of methane was recovered. The amount of waste generated has increased by about 45 per cent since 1995, but due to the increase in material recycling and energy utilization in the period there has not been a similar increase in the amount of degradable waste to landfills.

2.4. Land Use Change and Forestry

The average annual net sequestration from the LULUCF sector was about 16.8 million tonnes CO_2-equivalents for the period 1990-2007. The average annual net sequestration was 11.3 million tonnes CO_2-equivalents from 1990 to 1998, and about 22.4 million CO_2-equivalents per year from 1999 to 2007. In 2007 the net sequestration was calculated at 25.8 million CO_2-equivalents, which would offset 47 per cent of the total greenhouse gas emissions in Norway that year. The sequestration increased by about 110 per cent from 1990 to 2007.

The calculated changes in carbon depend upon several factors such as growing conditions, harvest levels, and land use changes. In particular will variations in annual harvest directly influence the variations in changes in carbon stocks and dead organic matter.

Figure 2.21 shows the land areas occupied by the different land-use categories as defined by the IPCC (IPCC 2003) in 1990 and 2007.

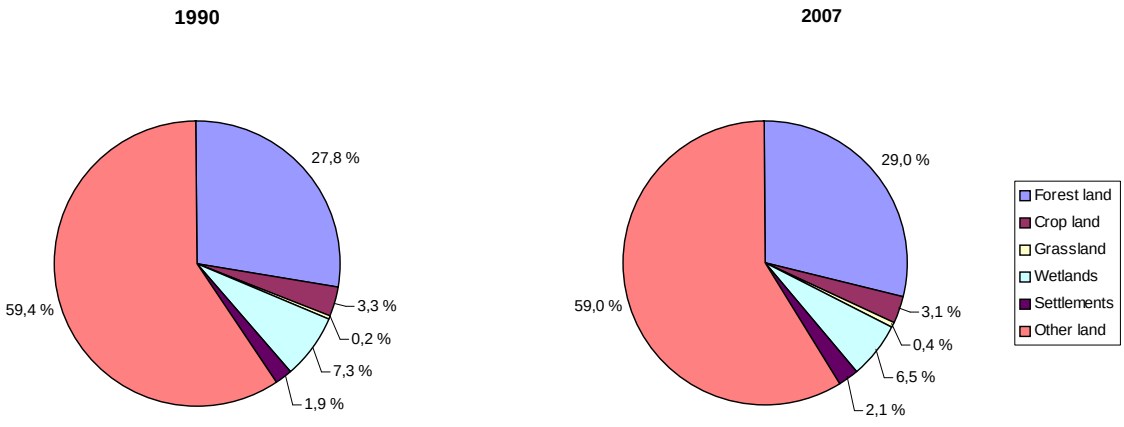


Figure 2.21 Land area by category in 1990 and 2007

As can be seen from Figure 2.21, forest land, which is also the most important land-use category, covers around one fourth of the mainland area of Norway. The changes in land

categories are small. Forest land, grassland and settlement areas are slightly increasing from 1990 to 2007, while cropland and wetland areas are decreasing.

In 2007 the land-use category forest land remaining forest land was the major contributor to the total amount of sequestration with 27.7 million tonnes CO_2. Land converted to forest land contributed with 0.3 million tonnes CO_2. From 1990 to 2007 the total net sequestration of CO_2 increased by 110 per cent. The explanation for this growth is a continued increase in standing volume and gross increment, while the amount of CO_2 emissions due to harvesting and natural losses has been quite stable. The increased sequestration since 1990 is due to an active forest management policy, and to some extent to natural factors. Emissions of CH_4 and N_2O from forest land remaining forest land are negligible compared to the CO_2 sequestration; 0.01 Gg and 0.04 Gg, respectively (corresponding to about 0.21 Gg and 12 Gg of CO_2-equivalents). The emissions of CH_4 and N_2O have remained fairly constant over the period, except for in 2006 when the CH_4-emissions, due to a large number of wildfires, had a peak.

Figure 2.22 illustrates the change in carbon stocks in forest, land to forest, dead organic matter and soil between 1990 and 2007.

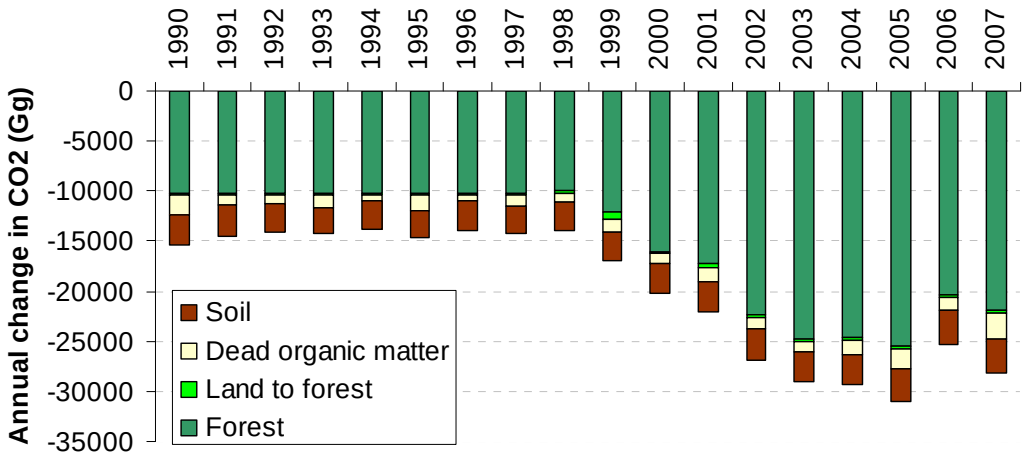


Figure 2.22 Carbon stock changes in forest, land to forest,,, dead organic matter and soil. 1990-2007.

All other land-use categories than forest remaining forest showed net emissions, they were calculated at a total of 2.1 million tonnes CO_2. Of these, the most important category was grassland with total emissions of 1.87 million tonnes of CO_2.

2.5. Emission trends for indirect greenhouse gases 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, in particular ozone. Sulphur dioxide (SO_2) also has an indirect impact on climate, as it increases the level of aerosols with a subsequent cooling effect. Therefore, emissions of these gases are to some extent included in the inventory.

The trend of these pollutants in Norway during the period 1990-2007 is presented below.

The overall **NO_x emissions** have decreased with approximately 7 per cent from 1990 to 2007. This can primarily be explained by stricter emission regulations with regard to road traffic, which has given a reduction of almost 56 per cent since 1990. These reductions counteracted increased emissions from oil and gas production (101 per cent) and from navigation (27 per cent). The total NO_x emissions increased with approximately 2 per cent from 2006 to 2007.

The **emissions of NMVOC** experienced an increase in the period from 1990 to 2001, mainly because of the rise in oil production. However, the emissions have decreased by 50 per cent from 2001 to 2007, and are now 34 per cent lower than in 1990. From 2006 to 2007 the emissions of NMVOC have decreased by 2 per cent. This decrease has been achieved through the implementation of measures to increase the recycling of oil vapour offshore at loading and storage terminals.

Emissions of CO have decreased by 54 per cent over the period 1990-2007. This is explained primarily by the implementation of new emission standards for motor vehicles.

SO_2 emissions were reduced by 62 per cent from 1990 to 2007. This can mainly be explained by a reduction in sulphur content of all oil products and lower process emissions from ferro alloy and aluminium production as well as refineries.

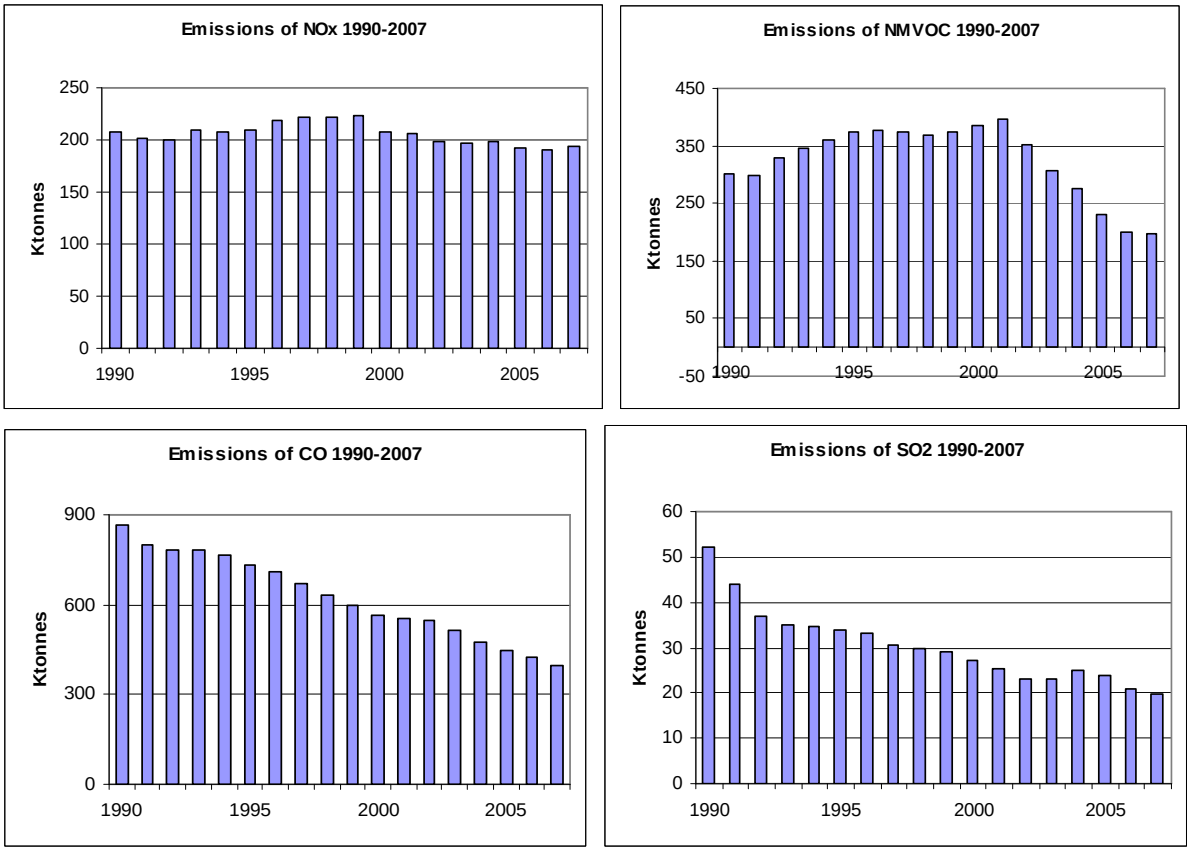


Figure 2.23 Emissions of NOx, NMVOC, CO and SO_2 in Norway 1990-2007. The emissions are given in Ktonnes. Source: Statistics Norway/SFT

3. Energy

3.1. Overview

The Energy sector accounted for 72.7 per cent of the Norwegian greenhouse gas emissions in 2007 that is an increase from 59.4 per cent in 1990. Road traffic and offshore gas turbines (electricity generation and pumping of natural gas in pipelines) are the sector's largest single contributors and the sectors that have increased most since 1990. Other important sources are coastal navigation, energy use in the production of raw materials, as well as oil and gas operations which give rise to significant amounts of fugitive emissions.

Despite the short, temporary emission reductions which took place in the years 1991, 1995, 2000 and 2002, GHG emissions in the energy sector increased by 35.5 per cent during the period 1990-2007, primarily due to increased activity in the sectors of oil and gas extraction and transport, specifically road transport. Total sectoral emissions in 2007 were 4 per cent higher than those of 2006.

Key source categories

As indicated in Section 1.5, the Tier 2 key category analysis performed for the years 1990 and 2007 has revealed that in terms of total level and/or trend uncertainty the *key categories* in the Energy sector for 2007 are, in CRF order, the following:

- Stationary Fuel Combustion, Solid Fuels – CO_2 (1A1-1A2-1A4)
- Stationary Fuel Combustion, Liquid Fuels – CO_2 (1A1-1A2-1A4)
- Stationary Fuel Combustion, Gaseous Fuels – CO_2 (1A1-1A2-1A4)
- Stationary Fuel Combustion, Biomass – CH_4 (1A1-1A2-1A4)
- Other sectors, Mobile Fuel Combustion – CO_2 (1A4)
- Civil Aviation – CO_2 (1A3a)
- Road Transportation – CO_2 (1A3b)
- Road Transportation – N_2O (1A3b)
- Navigation – CO_2 (1A3d)
- Navigation – CH_4 (1A3d) ok
- Other Transportation – CO_2 (1A3e)
- Other Transportation – N_2O (1A3e)
- Fugitive Emissions from Oil – CO_2 (1B2a)
- Fugitive Emissions from Natural gas – CH_4 (1B2b)
- Venting and Flaring – CO_2 (1B2c)
- Venting and Flaring – CH_4 (1B2c)

In addition to source categories defined as key categories according to the Tier 2 key category analysis the following source categories is defined as keys according to Tier 1 key category analysis:

- Fugitive Emissions from Oil – CH_4 (1B2a)
- Military, mobile – CO_2 (1A5b)

Coal mining (1B1a) is not found to be a key category in the key category analysis. However, it is here regarded as a key category on the basis of "qualitative" criteria such as change in trend and uncertainty in the emission factors. This source is described in detail in Section 3.3.

An important issue, which is also elaborated in this sector, concerns the capture and storage of CO_2 emissions at the offshore gas-condensate field called Sleipner Vest. These unique operations are discussed in detail in section 3.5.

Some aspects of aggregation in the key category analyses have been changed since the previous NIR. Emissions from 1A4 *Other sectors, mobile combustion* are now treated as a separate category. Fishing vessels and agricultural machinery are in this sector the most important subcategories. In the previous NIR these emissions were grouped together with stationary emissions in 1A1, 1A2 and 1A4.

Emission allocation

Emissions from waste incineration at district heating plants are accounted for under the energy sector, as the energy is utilized. Methane from landfills used for energy purposes is also accounted for in this sector. Emissions from flaring in the energy sectors are described in Sections 3.4. Coal and coke used as reducing agents and gas used for production of ammonia (non-energy part) are accounted for under industrial processes. Flaring outside the energy sectors is described in Chapter 8 Waste. The same applies to emissions from cigarettes, accidental fires etc. Emissions from burning of crop residues and agricultural waste are accounted for under Chapter 6 Agriculture.

Mode of presentation

The elaboration of the energy sector in the following starts with a description of emissions from the energy combustion sources (Section 3.2), followed by a description of fugitive emissions (Section 3.3) and a discussion on the capture and storage of CO_2 emissions at the offshore gas-condensate field Sleipner Vest (Section 3.5). Cross-cutting issues are elaborated in Section 3.6 and comprise the following elements:

- Comparison between the sectoral and reference approach
- Feedstock and non-energy use of fuels
- Indirect CO_2 emissions from CH_4 and NMVOC

Finally, the memo items of international bunker fuels and CO_2 emissions from biomass, are addressed in Section 3.7.

In the case of energy combustion, emissions from the individual combustion sources are discussed after a comprehensive presentation of the energy combustion sector as a whole (Section 3.2.1). The purpose for such an arrangement is to avoid repetition of methodological issues which are common among underlying source categories, and to enable easier cross-reference.

3.2. Energy Combustion

3.2.1. Overview

This section describes the calculation of GHG emissions from the combustion of fossil fuels and biomass. All known combustion activities within energy utilization in various industries and private households are included.

The fuel combustion sector is dominated by the emissions of CO_2 which in 2007 contributed 97.6 per cent to the totals of this sector (1A).

Emissions from fuel combustion constituted 64.8 per cent of the national GHG total in 2007. The emissions increased by about 34.5 per cent between 1990 and 2007, primarily due to activity growth in oil and gas extraction that is the major part of energy industries sector and transport, mainly road transportation. Emission levels in 2007 increased by 0.8 per cent from the 2006 levels.

This sector hosts twelve source categories defined as keys according to Tier 2 key category analyses and one as key category from the Tier 1 analyses. These, along with the non-key categories, are presented in detail in the following.

3.2.1.1. Methodological issues

Emissions from fuel combustion are estimated at the sectoral level in accordance with the IPCC sectoral approach Tier1/Tier 2/Tier 3. Often total fuel consumption is better known than the sectoral consumption.

The general method to estimate emissions from fuel combustion is multiplication of fuel consumption by source and sector by an appropriate emission factor. Exceptions are road and air transport where more detailed estimation models are used, involving additional activity data (see sections 3.2.5 and 3.2.4. respectively). Fuel consumption figures are taken from the Norwegian energy balance. The mean theoretical energy content of fuels and their density are listed in table 3.1.

*Table 3.1. Average energy content and density of fuels**

Energy commodity	Theoretical energy content	Density
Coal	28.1 GJ/tonne	..
Coal coke	28.5 GJ/tonne	..
Petrol coke	35.0 GJ/tonne	..
Crude oil	42.3 GJ/tonne = 36.0 GJ/m^3	0.85 tonne/m^3
Refinery gas	48.6 GJ/tonne	..
Natural gas (2007)[1]	39.67 GJ/1000 Sm^3	0.85 kg/Sm^3
Liquefied propane and butane (LPG)	46.1 GJ/tonne = 24.4 GJ/m^3	0.53 tonne/m^3
Fuel gas	50.0 GJ/tonne	..
Petrol	43.9 GJ/tonne = 32.5 GJ/m^3	0.74 tonne/m^3
Kerosene	43.1 GJ/tonne = 34.9 GJ/m^3	0.81 tonne/m^3
Diesel oil, gas oil and light fuel oil	43.1 GJ/tonne = 36.2 GJ/m^3	0.84 tonne/m^3
Heavy distillate	43.1 GJ/tonne = 37.9 GJ/m^3	0.88 tonne/m^3
Heavy fuel oil	40.6 GJ/tonne = 39.8 GJ/m^3	0.98 tonne/m^3
Methane	50.2 GJ/tonne	..
Wood	16.8 GJ/tonne = 8.4 GJ/solid m^3	0.5 tonne/solid m^3
Wood waste (dry wt)	16.25-18 GJ/tonne	..
Black liquor (dry wt)	7.2-9.2 GJ/tonne	..
Waste	10.5 GJ/tonne	..

* The theoretical energy content of a particular energy commodity may vary; Figures indicate mean values.

[1] Sm^3 = standard cubic metre (at 15 °C and 1 atmospheric pressure).

Source: Energy statistics, Statistics Norway.

*Table 3.2. Overview of estimated and reported greenhouse gases CO_2, CH_4 and N_2O for energy combustion activities**

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

5. Other (Military)	E	E	E

* R means that emission figures in the national emission inventory are based on figures reported by the plants; reported figures are by and large available for all years in the period 1990-2007. E means that the figures are estimated by Statistics Norway (Activity data * emission factor).

However, for some major manufacturing plants (in particular offshore activities, refineries, gas terminals, cement industry, production of plastics, ammonia production), emissions of one or more compounds reported by the plants to the Norwegian Pollution Control Authority are used instead of figures calculated as described above. In these cases, the energy consumption of the plants in question is subtracted from the total energy use before the general method is used to calculate the remaining emissions of the compound in question, in order to prevent double counting. Reported figures are used for a relatively small number of plants, but as these contribute to a large share of the total energy use, a major part of the total emissions are based on such reported figures. E.g. for source categories energy industries and manufacturing industries and constructions a rough estimate indicate that maybe as much as 90 per cent of the sectors emissions is based on reported data from plant. The reports is from the mandatory reporting obligation that is a part of the plants permits given by the authorities and from 2005 emission data from the emission trading system. An overview of the type of emissions (i.e. estimated and/or reported) used in the inventory for the different sectors is given in table 3.2 for the greenhouse gases CO_2, CH_4 and N_2O.

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

3.2.1.2. Activity data

The annual energy balance, compiled by Statistics Norway, forms the framework for the calculation of emissions from energy use. However, as explained above a large part of the total emissions are based on reports from plants which use much energy, i.e. offshore activities and energy-intensive industries on shore. Such energy use is included in the energy balance, but is subtracted before the remaining emissions are calculated by the standard method of multiplying energy use by emission factors.

The energy consumption data used in the emission calculations are, with few exceptions, taken from the annual energy balance compiled by Statistics Norway. The energy balance survey the flow of the different energy carriers within Norwegian economic activities. These accounts include energy carriers used as raw materials and reducing agents. The carriers are subtracted from the energy balance and are not included in the data used to estimate emissions from combustion.

As some emissions vary with the combustion technology, a distribution between different sources is required. Total use of the different oil products is based on the Norwegian sales statistics for petroleum products. For other energy carriers, the total use of each energy carrier is determined by summing up reported/estimated consumption in the different sectors. A short summary of the determination of amounts used of the main groups of energy carriers and the distribution between emission sources is given below, followed by an explanation of the difference between energy accounts and the energy balance sheets, including the differences involved in Norway's submissions to international organizations. Energy balance sheets for all years in the period 1990-2007 are presented in Annex IV of this report.

The independent collection of different energy carriers conducted by Statistics Norway, as described below, makes it possible to perform a thorough verification of the emission data reported by the entities to SFT and Norwegian Petroleum Directorate (NPD) and included in the inventory.

Natural gas

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

LPG and other gases

Consumption of LPG in manufacturing industries is reported by the plants to Statistics Norway in the annual survey on energy use. Figures on use of LPG in households are based on sales figures, collected annually from the oil companies. Use in agriculture and construction is based on non-annual surveys; the figure for agriculture is held constant, whereas the figure for construction is adjusted annually, based on employment figures.

Use of refinery gas is reported to Statistics Norway from the refineries. The distribution between the sources direct-fired furnaces, flaring and boilers is based on information collected from the refineries in the early 1990's.

At some industrial plants, excess gas from chemical and metallurgical industrial processes is burned, partly in direct-fired furnaces and partly in boilers. These amounts are reported to Statistics Norway. Two ferroalloy plants sell excess gas (CO gas) to some other plants, where it is combusted for energy purposes. Amounts sold are annually reported to Statistics Norway. One sewage treatment plant utilizes biogas extracted at the plant, and reports quantities combusted (in turbines) and calculated CO_2 emissions. Other emissions are estimated by Statistics Norway, using the same emission factors as for combustion of natural gas in turbines.

Oil products

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

Stationary use takes place in boilers and, in some manufacturing industries, in direct-fired furnaces. There is also some combustion in small ovens, mainly in private households. Mobile combustion is distributed among different sources, described in more detail under the transport sector (Sections 3.2.4-3.2.8). In addition to oil products included in the sales statistics, figures on use of waste oil are given in Statistics Norway's industry statistics.

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

Statistics Norway also collects additional information directly from a few companies about the use of waste oil as a fuel source.

Coal

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

Wood, wood waste and black liquor

Use of wood waste and black liquor in manufacturing industries is taken from Statistics Norway's annual survey on energy use in these sectors. Use of wood in households is based on figures on the amount of wood burned from the annual survey on consumer expenditure for the years before 2005. The statistics cover purchase in physical units and estimates for self-harvest. The survey figures refer to quantities *acquired*, which do not necessarily correspond to *use*. The survey gathers monthly data that cover the preceding twelve months; the figure used in the emission calculations (taken from the energy accounts), is the average of the survey figures from the year in question and the following year. For 2005 and 2006 the figures are based on responses to questions relating to wood-burning in SSB's Travel and Holiday Survey. The figures from the new survey refer to quantities of wood *used*. The survey gathers quarterly data that cover the preceding twelve months. The figure used in the emission calculations is the average of 5 quarterly surveys. Figures on some minor use in agriculture and in construction are derived from earlier surveys for these sectors. Combustion takes place in boilers and in small ovens in private households. Consumption figures for wood pellets and wood briquettes are estimates, based on annual information from producers and distributors.

Waste

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

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

Energy balance sheets vs energy accounts

There are two different ways of presenting energy balances: *Energy balance* sheets (EBS) and *energy accounts*. The energy figures used in the emission calculations are mainly based on the energy balance sheets. The energy balance sheets for the years 1990-2007 are presented in Annex IV.

The *energy accounts* follow the energy consumption in Norwegian economic activity in the same way as the National accounts. All the energy used by Norwegian enterprises and households is to be included. Energy used by Norwegian transport trades and tourists abroad is also included, while the energy used by foreign transport industries and tourists in Norway is excluded.

The *energy balance sheet* follows the flow of energy within Norway. This means that the figures only include energy sold in Norway, regardless of the users' nationality. This includes different figures between the energy sources balance sheet and the energy account, especially for international shipping and aviation.

The energy balance sheet has a separate item for energy sources consumed for transportation purposes. The energy accounts place the consumption of all energy under the relevant consumer sector, regardless of whether the consumption refers to transportation, heating or processing.

In response to previous year's ERT recommendation, balance sheets in Annex IV are now presented in a way that displays a greater level of disaggregation than that of previous reports. This more detailed presentation concerns, in particular, the years 1992-2007. For 1990 and 1991, balance sheets are presented in the old format, as technical problems did not allow preparation of a corresponding disaggregation in time for the NIR submission.

Figures from the energy sources balance sheet are reported to international organizations such as the OECD and the UN. The energy balance sheet will, therefore, be usually comparable with international energy statistics.

Important differences between figures presented in the energy balance sheet (EBS) and figures used in the emission calculations (EC) are:

- *Fishing*: EC use only fuel sold in Norway, whereas EBS also includes an estimate for fuel purchased abroad.
- *Air transport*: EC use only Norwegian domestic air traffic (excluding military), while EBS includes all fuel sold in Norway for air transport, including military and fuel used for international air transport.
- *Coal/coke for non-energy purposes*: This consumption is included in net domestic consumption in EBS, whereas EC include only energy used for combustion in the calculation of emissions from energy.

3.2.1.3. 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; Norwegian Oil Industry Association – OLF, 1994).

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

The standard emission factors used in the absence of more specific ones are hereafter addressed as *general.*

The general emission factors for CO_2 used in the emission inventory are listed in table 3.3, followed by a more detailed description of the factors used for offshore operations and gas terminals.

Table 3.3. General emission factors for CO_2

	CO_2 tonne/tonne
Coal	2.52
Coke	3.19
Petrol coke	3.59
Motor gasoline	3.13
Aviation gasoline	3.13
Kerosene (heating)	3.15
Jet kerosene	3.15
Auto diesel	3.17
Marine gas oil/diesel	3.17
Light fuel oils	3.17
Heavy distillate	3.17
Heavy fuel oil	3.2
Natural gas (1000 Sm^3)	2.34[1]
LPG	3
Refinery gas	2.8
Blast furnace gas	1.571
Fuel gas	2.5
Landfill gas	0
Biogas	(2.75)[2]
Fuel wood	(1.8)[2]
Wood waste	(1.8)[2]
Black liquor	(1.8)[2]
Municipal waste	0.251
Special waste	3.2

[1] The emission factor for natural gas used in the emission inventory varies as indicated in Tables 3.4 and 3.5.

[2] Non-fossil emissions, not included in the inventory.

Source: Norwegian Petroleum Industry Association, SFT (1990), SFT (1996),.

Offshore operations

For all years up to 2002 emissions of CO_2 from gas combustion offshore are calculated by Statistics Norway on the basis of activity data reported by the oil companies to NPD and SFT and the emission factors shown in Table 3.4. For the years 2003-2007 the data used in the inventory are emissions reported directly by the field operators. The latter are obliged to report these and other emissions annually to NPD and SFT.

The CO_2 emission factor used for all years leading up to 1998 and for all fields except one is one average (standard) factor based upon a survey carried out in the early 1990s (OLF 1993, 1994). From 1999 and onwards the emission factors employed reflect increasingly field

specific conditions as individual emission factors have been reported directly from fields. Table 3.4 displays the time series of such emission factors, expressed as averages.

	Gas turbines offshore kg CO_2/Sm^3 gas burned
1990-1994	**2.34**
1995	**2.29**
1996	**2.30**
1997	**2.30**
1998	**2.31**
1999	**2.50**
2000	**2.48**
2001	**2.47**
2002	**2.45**
2003	**2.46**
2004	**2.43**
2005	**2.45**
2006	**2.43**
2007	**2.40**

Table 3.4 Average emission factors of CO_2 from the combustion of natural gas in turbines at offshore oil fields.

For the years after 2002 reported emissions are used
Source: SFT/NPD

Gas terminals
Emission factors for the two Norwegian gas terminals are based on continuous measurements of fuel combustion. The terminals are from 2005 included in the emission trading system. The average CO_2 emission factors for fuel gas at one gas terminal are shown in Table 3.5. The fuel gas used at the terminal originates from three different gas fields and the emission factors in the table reflect the average carbon content in the respective gases. Emission factors used for the other gas terminal lie within the same range. It should be born in mind that the emission figures used in the inventory for gas terminals are those reported directly by the plants. From 2005 the emission data is from the ETS and before that from the mandatory annual report from the plants to SFT (see also Section 3.2.1).

The general CH_4 and N_2O emission factors used in the emission inventory for this source are listed in Tables 3.6 and 3.8, respectively. Tables 3.7 and 3.9 display the cases where emission factors other than the general ones were used in the calculations.

Table 3.5 Average emission factor for CO_2 from the combustion of gas at one gas terminal.

	Average content of CO_2 in fuel gas t CO_2 / t gas
2007	**2.66**
2006	2.67
2005	2.67
2004	2.68
2003	2.68
2002	2.68
2001	2.68
2000	2.73
1999	2.69
1998	2.73
1997	2.77
1996	2.84
1995	2.93
1994	2.93
1993	2.79
1992	2.94
1991	2.82
1990	2.70

Source: SFT

Table 3.6 General emission factors for CH_4, stationary combustion. Unit: kg CH_4/tonne fuel

Source	Direct-fired furnaces	Gas turbines	Boilers	Small stoves	Flares
Coal	0.028	-	**0.28**	8.4	-
Coke	0	-	0.28	8.4	-
Petrol coke	0	-	0.28	-	-
Charcoal	-	-	-	8.4	-
Kerosene (heating)	-	-	0.17	0.3	-
Marine gas oil/diesel	0.016	0	**0.4**	-	-
Light fuel oils	-	-	**0.4**	0.4	-
Heavy distillate	0.04	-	**0.4**	0.4	-
Heavy fuel oil	0.04	-	**0.4**	-	-
Natural gas (1000 Sm^3)	**0.05**	0.91	**0.2**	-	0.24
Refinery gas	0.054	-	0.24	-	0.28
Blast furnace gas	0.054	-	**0.24**	-	-
Landfill gas	-	-	0.24	-	0.37
Fuel gas	**0.05**	-	0.24	-	-
LPG	-	-	0.17	0.24	-
Fuel wood	-	-	-	5.3	-
Wood waste	-	-	0.25	-	-
Black liquor	-	-	0.25	-	-
Wood pellets	-	-	0.25	5.3	-
Wood briquettes	-	-	0.25	-	-
Municipal waste	-	-	0.23	-	-
Special waste	0.04	-	**0.4**	-	-

Numbers in bold have exceptions for some sectors, see Table 3.7.
Source: IPCC (1997b), SFT (1996), SINTEF (1995) and OLF (1994).

Table 3.7 Exceptions from the general factors for CH_4, stationary combustion. Unit: kg CH_4/tonne fuel.

Emission factor	Fuel	Source	Sectors
0	Natural gas (1000 Sm^3), fuel gas	Direct fired furnaces	Manufacture of other mineral products Manufacture of cement, lime and plaster
0.085	Natural gas (1000 Sm^3)	Direct fired furnaces	Manufacture of plastics and synthetic rubber in primary forms, manufacture of other organic basic materials
0.03	Coal	Boilers	Coal mining Extraction of crude petroleum and natural gas Oil refineries Gas terminals Production and distribution of electricity
0.1	Fuel oils incl. special waste	Boilers	Industry incl. power supply
0.0425	Natural gas (1000 Sm^3)	Boilers	Coal mining Extraction of crude petroleum and natural gas Oil refineries Gas terminals Production and distribution of electricity
0	Blast furnace gas	Boilers	Manufacture of refined petroleum products

Table 3.8 General emission factors for N_2O, stationary combustion. Unit: kg N_2O/tonne fuel

Source	Direct-fired furnaces	Gas turbines	Boilers	Small stoves	Flares
Coal	0	-	0.04	0.04	-
Coke	0	-	0.04	0.04	-
Petrol coke	0	-	0.04	-	-
Charcoal	-	-	0.07	-	-
Kerosene (heating)	-	-	0.03	0.03	-
Marine gas oil/diesel	0.03	0.024	0.03	-	-
Light fuel oils	-	-	0.03	0.03	-
Heavy distillate	0.03	-	0.03	0.03	-
Heavy fuel oil	0.03	-	0.03	-	-
Natural gas (1000 Sm^3)	**0.02**	0.019	0.004	-	**0.02**
Refinery gas	0.024	-	0.005	-	0.024
Blast furnace gas	0.024	-	0.005	-	-
Landfill gas	0.024	-	0.005	-	0.002
Fuel gas	0.024	-	0.005	-	-
LPG	-	-	0.03	0.03	-
Fuel wood	-	-	-	0.032	-
Wood waste	-	-	0.005	-	-
Black liquor	-	-	0.005	-	-
Wood pellets	-	-	0.07	0.032	-
Wood briquettes	-	-	0.07	-	-
Municipal waste	-	-	0.035	-	-
Special waste	0.03	-	0.03	-	-

Numbers in bold have exceptions for some sectors, see Table 3.9.

Source: IPCC (1997b), SFT (1996) and OLF (1994).

Table 3.9Exceptions from the general factors for N_2O, stationary combustion.
Unit: kg N_2O/1000 Sm^3 natural gas

Emission factor	Fuel	Source	Sectors
0.017	Natural gas	Direct-fired furnaces	Manufacture of plastics
0.06	Natural gas	Flares	Oil drilling

3.2.1.4. Uncertainties

Uncertainty estimates for greenhouse gases are presented and discussed in Annex II, as well as under the individual underlying source categories described in the following.

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

3.2.1.5. Source specific QA/QC and verification

The emission sources in the energy sector are subjected to the QA/QC procedures described in section 1.6. In the last years three documentation reports have been published describing the methodologies used for road traffic (SFT 1999c), aviation (Finstad et al. 2002b) and navigation (Tornsjø 2001).

Emission estimates reported by the plants to SFT and included in the inventory is from the annual report each plant with a permit from SFT has to send. From 2005 we have also received an annual report from entities included in the ETS. In connection with establishing the ETS the plants estimates were quality checked for the time series and specific emphasis on the years 1998-2001. During this process a consistent time series were established for the period from 1990. In addition to this SFT also receive emission data through a voluntary agreement between the authority and the industries for sectors that are not yet included in the ETS. Data received by SFT though the different reporting channels described above are controlled very thoroughly by SFT and Statistics Norway. Especially the emission data plants included in the ETS and in the voluntary agreement are verified extensively.

3.2.1.6. Recalculations

The recalculations performed in the energy sector concern primarily the year 2006. This is mainly due to changes in the energy statistics. The figures used in the 2008 submission were based on preliminary figures on energy use. Now the energy statistics include final energy consumption figures from the statistics on energy use in the manufacturing industries. Also some other final energy figures on energy use have been included. Changes in the emission figures due to such changes in the energy statistics will not be commented on specifically under each IPCC code.

3.2.1.7. Planned improvements

There is for the moment no planned activity that will improve the data quality for NIR 2010.

3.2.2. Energy industries (CRF source category 1A1)

3.2.2.1. Description

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

Emissions from the energy industries accounted for 35.9 per cent of the sectoral totals and 23.3 per cent of the total GHG emissions in Norway in 2007. The increase that took place during the period 1990-2007 is as high as 90.5 per cent and is attributed primarily to the increased activity in the oil and gas extraction sector. Emissions in 2007 are 1.8 per cent above the 2006 emissions.

According to the Tier 2 key category analysis for 2007, this sector is, in conjunction with sectors 1A2 and 1A4, a key category with respect to:

- Emissions of CO_2 from the combustion of solid, liquid and gaseous fuels in both level and trend uncertainty
- Emissions of CH_4 from the combustion of gaseous fuels in trend uncertainty and biomass in level only
- Emissions of CO_2 from sector 1A4 Other sectors, mobile combustion is as explained in Chapter 1.5 separated from sector 1A 4 and is identified as key category, see chapter 3.2.9.1.

3.2.2.2. Methodological issues

A description of the general method used for estimation of emissions from fuel combustion is given in Section 3.2.1.1. However, most of the reported emissions in this source category are from the annual report from the entities to SFT and NPD. In the case of waste incineration, further specifications on the methodology are given below.

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

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

3.2.2.3. Activity data

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

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

Coal production
Norway's coal production takes place on Svalbard. The only coal producing company reports its coal consumption and some minor use of oil products annually. In addition to emissions related to Norway's own coal production, emissions from Russian activities are also included in the Norwegian emission inventory. As Russian activity data are scarce, emissions from an estimated quantity of coal combusted in Russian power plants are calculated. Since 1999 there has been only one such plant; in earlier years there were two of those.

Gas terminals
Norway has two gas terminals, where natural gas from the Norwegian continental shelf is landed, treated and distributed. Annual figures on natural gas combusted in turbines and flared are reported to SFT and NPD. Emissions included in inventory for this category are from the gas terminals annual report to SFT.

Oil refineries
The oil refineries annually report their use of different energy carriers to Statistics Norway. Refinery gas is most important, but there is also some use of LPG and oil products. Emissions included in inventory for this category are from the refineries annual report to SFT.

3.2.2.4. Emission factors

The emission factors used for the energy industries are those presented in Section 3.2.1.3. For some industries and components, more information about the derivation of the emission factors is given below.

Waste incineration
The emission factors for combustion of waste (fossil part only) for CO_2, CH_4 and N_2O are displayed in Tables 3.3, 3.6 and 3.8, respectively. Emission factors for CO_2 and CH_4 have been calculated by SFT (1996).

Extraction of oil and natural gas
The CO_2 emission factor for gas combustion offshore used for all years leading up to 1998 and for all fields except one, is an average factor based upon a survey carried out in the early 1990's (OLF 1993, 1994). From 1999 onwards the emission factors employed reflect increasingly field specific conditions (see also Section 3.2.1.3).

3.2.2.5. Uncertainties

The uncertainty analysis performed (Annex II) has shown that for the energy industries the uncertainty in the activity data is ± 3 per cent of the mean for oil, ± 4 per cent for gas and ± 5 per cent of the mean for coal/coke and waste.

In the case of the emission factors for CO_2, the uncertainty is ±3 per cent of the mean for oil, ±7 per cent for coal/coke and gas and ± 30 per cent of the mean for waste.

Emission factors for CH_4 and N_2O are very uncertain. Distributions are strongly skewed with uncertainties which lie below and above the mean by a factor of 2 and 3, respectively.

3.2.2.6. Source specific QA/QC and verification

The energy industries are subjected to the general QA/QC procedures described in Section 1.6. Some source specific QA/QC activities were conducted in the following industries:

Extraction of oil and natural gas
From 2003 onwards field specific emission figures reported from the companies are used directly in the emission model. These figures are compared with emissions calculated on the basis of field specific activity data and emission factors.

Oil refineries
The CO_2 emissions reported from the refineries are compared with the emissions estimated by Statistics Norway on the basis of activity data and emission factors for the different energy carriers used.

Results from the above studies have so far shown that emission estimates are in agreement with the reported figures.

3.2.2.7. Recalculations

1A 1a Public electricity and heat production

- Revised data. Changes in figures for energy use in 2003-2006, due to the inclusion of a plant for which data previously were lacking, have caused a minor increase in the emissions.

1A 1b Petroleum refining

- Reallocation. Emissions erroneously registered as solid have been moved to liquid.

1A 1c Manufacture of solid fuels and other energy industries

- Correction of error. CO_2 emissions from one plant have been reduced 2000-2006, due to the correction of a previous double counting. In addition, there is a marginal reduction in CH_4 emissions 2005-2006, due to the correction of a previous error in registered emissions from one plant.

3.2.2.8. Planned improvements

There is for the moment no planned activity that will improve the data quality for NIR 2010.

3.2.3. Manufacturing industries and construction (CRF source category 1A2)

3.2.3.1. Description

Emissions form the sector of manufacturing industries and construction include industrial emissions originating to a large extent from the production of raw materials and semi-manufactured goods (e.g. iron and steel, non-ferrous metals, chemicals, fertilizers, pulp and paper, mineral industries, food processing industries, building and construction industry). These emissions are related to fuel combustion only, that is, emissions from use of oil or gas for heating purposes. Consumption of coal as feedstock and reduction medium is not included in this sector, but it is accounted for under the industrial processes sector.

Emissions from this sector contributed 6.5 per cent to the national GHG total in 2007. Emission from the sector has decreased by 2.2 per cent from 1990 to2007. Between 2006 and 2007 sectoral emissions decreased by 10.1 per cent, due to decreased emissions in chemical and pulp and paper industry.

According to the Tier 2 key category analysis for 2007 this sector is, in conjunction with sectors 1A1 and 1A4, a key category with respect to:

- Emissions of CO_2 from the combustion of solid, liquid and gaseous fuels in both level and trend uncertainty
- Emissions of CH_4 from the combustion of gaseous fuels in trend uncertainty and biomass in level only.

3.2.3.2. Methodological issues

A description of the general method used for estimation of emissions from fuel combustion is given in Section 3.2.1.1. For a few plants the emission figures are based on reported figures from the plants to SFT. However, in 2007 these plants account for approximately 2/3 of the CO_2 emissions reported for the sector. The general calculation method, amount of fuel combusted multiplied with a fuel specific emissions factor, is valid for both the estimates performed by Statistics Norway and the emissions reported by the plants to SFT in this sector.

3.2.3.3. Activity data

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

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

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

In some sectors auto diesel is mainly used in machinery and off-road vehicles, particularly in mining and construction. This amount of fuel is based on reported consumption of duty-free auto diesel in the manufacturing industries and on reported sales of duty-free auto diesel to construction. The methods for calculating emissions are discussed in section 3.2.8. Emissions from off-road machinery in industry are currently reported under the CRF source category 1A3e – *Other Transportation*. According to the guidelines, they should be included under the source category 1A2.

3.2.3.4. Emission factors

The emission factors used in this source category are those presented in Section 3.2.1.3.

3.2.3.5. Uncertainties

Uncertainties in the activity data and the emission factors in the manufacturing industries and construction are as presented in Section 3.2.2.5. A more detailed description is presented Annex II.

3.2.3.6. Source specific QA/QC and verification

There is no specific QA/QC procedure for this source category. For a description of the general QA/QC procedure, see Section 1.6.

3.2.3.7. Recalculations

1A 2a Iron and steel

- Revised data: CO_2 emissions reported from one plant, which previously were registered as combustion emissions, have now been split between process and combustion for the whole period 1990-2006, thus causing a reduction in combustion emissions. At the same time, the total figures for the plant have been reduced for 1991-2005. For another plant, the figures have been adjusted somewhat downwards for 1998-2001 and 2005.

1A 2 b Non-ferrous metals

- Revised activity data. Figures on LPG use at one plant have been reduced for 2003 and increased for 2004-2005, causing corresponding changes in emissions of CO_2, CH_4 and N_2O.

3.2.3.8. Planned improvements

There is for the moment no planned activity that will improve the data quality for NIR 2010.

3.2.4. Transport – Civil Aviation (CRF source category 1A3a)

3.2.4.1. Description

Civil aviation gives rise to predominantly CO_2 emissions. In 2007 emissions from this source category were about 5.9 per cent of the national total emissions from transport and about 1.7 per cent of the GHG national total. From 1990 to 2007 these emissions increased by 32 per cent due to activity growth. Emission fluctuations over time have been primarily dictated by the activity growth rates. In 2007 emissions were about 4,5 per cent higher than those of 2006. The emissions from aviation were at its highest level in 1998-2001 when the emissions were in average about 9% higher than in 2007.

Civil aviation is a key category with respect to CO_2 emissions in both level and in trend.

Emissions of CH_4 and N_2O from this source category are insignificant.

3.2.4.2. Methodological issues

The calculation methodology applied is described in Finstad et al. (2002b). According to the IPCC Good Practice Guidance the methodology used is Tier 2 based on the detailed methodology described in EEA (2001). This methodology allows estimation of emissions and fuel consumption for different types of aircraft according to the average flying distance and numbers of landings and take-offs (LTO). All movements below 1000 m are included in the "Landing Take Off" (LTO) cycle. Movements over 1000 m are included in the cruise phase. All emissions from international aviation are excluded from national totals, and are reported separate (see Section 3.7.1.3).

3.2.4.3. Activity data

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

3.2.4.4. Emission factors

The emission factors used in the emission inventory for civil aviation are presented in Tables 3.10-3.11.

The Norwegian Petroleum Industry Association provides emission factors for CO_2 for the combustion of jet fuel and gasoline (Finstad et al. 2002b). The CO_2 emission factor used for aviation gasoline is 3.13 tonnes CO_2/tonne fuel and has been applied to all small aircraft. All other aircraft use jet fuel (kerosene) with an emission factor of 3.15 tonnes CO_2/tonne fuel.

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

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

Recalculations performed in connection with last year’s submission were based on a new methodology (EEA 2001 and Finstad et al. 2002b) and led to changes in emission factors for previous years. New emission factors back to 1980 were therefore used in the inventory. Emission factors were calculated with activity data for 1989, 1995, and 2000. Factors for the

years 1990-1994 and 1996-1999 were interpolated. Factors before 1989 and after 2000 were kept constant.

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

Table 3.10 General emission factors for aviation.
Unit: CO_2: tonne/tonne fuel, CH_4 and N_2O: kg/tonne fuel.

	CO_2		CH_4		N_2O
Source	**Aviation gasoline**	**Jet kerosene**	**Aviation gasoline**	**Jet kerosene**	**Aviation gasoline/Jet kerosene**
Charter/scheduled flights					
Domestic					
LTO (0-100 m)		3.15		0.1854 [1]	0.1
LTO (100-1000 m)		3.15		0.0304 [1]	0.1
Cruise (Above 1000)		3.15		0	0.1
Foreign					
LTO (0-100 m)		3.15			0.1
LTO (100-1000 m)		3.15			0.1
Cruise (Above 1000)		3.15			0.1
Helicopters					
LTO (0-100 m)		3.15		3.2 [1]	0.1
LTO (100-1000 m)		3.15		3.2 [1]	0.1
Cruise (Above 1000)		3.15		0	0.1
Small aircraft					
LTO (0-100 m)	3.13		3.61		0.1
LTO (100-1000 m)	3.13		1.55		0.1
Cruise (Above 1000)	3.13		0	-	0.1

[1] Jet kerosene used on aircraft in the Defence Air Forces has an emission factor of 0.35 kg CH_4/tonne.
Source: IPCC (2001) and Finstad et. al (2002)

Table 3.11 Time series of variable CH_4 emission factors from the combustion of jet kerosene in aviation (Factors for 1989, 1995 and 2000 are estimated as given in the table. Factors for 1990-1994 and 1996-1999 are calculated by linear interpolation. Factors before 1989 and after 2000 are kept constant).

		CH_4 Emission Factor (kg/tonne fuel)		
Sector	**Source**	**1989**	**1995**	**2000**
General	0-100 m	0.1558	0.2014	0.1854
	100-1000 m	0.0255	0.033	0.0304
	cruise	0	0	0
Norwegian aviation abroad	0-100 m	0.1567	0.3361	0.3927
	100-1000 m	0.0257	0.055	0.0672
	cruise	0	0	0
Foreign aviation in Norway	0-100 m	0.1567	0.3361	0.3927
	100-1000 m	0.0257	0.055	0.0672
	cruise	0	0	0

3.2.4.5. Uncertainties

Activity data: The uncertainty in the activity data for civil aviation is estimated to be ±20 per cent of the mean, primarily due to the difficulty in separating domestic emissions from emissions from fuel used in international transport (Rypdal and Zhang 2000). In a recent study on emissions from aircraft (Finstad et al. 2002b), fuel consumption was also estimated bottom-up and compared to the reported figures (see also the section below). The estimated and reported data differed by about 10 per cent. However, the reported data are considered most accurate and were used in the calculation. As described above, data before 1995 are more uncertain than for later years.

Emission factors: The uncertainty in the CO_2 emission factors is ±3 per cent. The uncertainty in the emission factors for CH_4 and N_2O lies below and above the mean by a factor of 2 and 3, respectively.

3.2.4.6. Source specific QA/QC and verification

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

3.2.4.7. Recalculations

1A 3 a Civil aviation

- Revised activity data. Changes in the distribution between LTO air traffic under and above 100 metres, has caused alterations for CH_4 emissions, in accordance with differences in emission factors.

3.2.4.8. Planned improvements

There is for the moment no planned activity that will improve the data quality for NIR 2010.

3.2.5. Transport – Road Transportation (CRF source category 1A3b)

Road traffic accounts for more than 2/3 of the total emissions from transport. GHG emissions from road transportation accounted for 18.4 per cent of the national GHG total in 2007. During the period 1990-2007 an increase of 30.9 per cent took place due to activity growth. Between 2006 and 2007 emissions increased by 0.4 per cent. The percentage increase from 2006 to 2007 was low compared to the years before due to switching from petrol to diesel driven personnel cars in 2007. The introduction of a CO_2 differentiated tax on new personnel cars led to this.

According to the Tier 2 key category analysis for 2007, road transportation is a key category with respect to: emissions of CO_2 and N_2O in terms of uncertainty in both level and trend; emissions of CH_4 in terms of trend uncertainty only.

3.2.5.1. Methodological issues

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

Model structure

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

Total emissions (Q) of a pollutant (*j)* from fuel type (*k),* while driving with a warm engine may be calculated from equations (3.1) and (3.2) below:

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

or

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

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

where

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

l_k is the average consumption, kg/km, of fuel (*k)* and is determined by equation (3.3).

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

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

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

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

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

- Pollutants: the same pollutants as in the general emission model, excluding heavy metals and POPs
- Vehicle categories: there are 10 classes, which are different combinations of vehicle type, weight, and fuel, see Table 3.12.
- Vehicle age (0-29 and 30+ years, 31 age classes in all)
- Driving mode: Five modes are considered, namely:

Driving mode	Speed limit
Urban	30 km/h or less
Urban	40 and 50 km/h
Rural	60 and 70 km/h
Rural	80 km/h
Highway	90 km/h

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

The modes apply only to driving with a warm engine. Emissions from cold start and evaporation are calculated separately as described in Section 3.2.5.3.

Table 3.12 Vehicle categories[1,2] in the emission model for road traffic

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

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

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

3.2.5.2. Activity data

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

- Total fuel consumption: the total amounts of fuels consumed are corrected for off-road use (in boats, snow scooters, motorized equipment, etc.). These corrections are estimated either from assumptions about the number of units, annual operation time, and specific fuel consumption, or from assumptions about and investigations into the fraction of consump-

tion used off-road in each sector. The Norwegian Petroleum Industry Association supplies the data for total fuel consumption.

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

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

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

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

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

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

3.2.5.3. Emission factors

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

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

In addition, N_2O factors were revised in 2005, based primarily on Gense & Vermeulen (2002), Riemersma *et al.* (2003), EPA (2004) and TØI (2005).

The emission factors for CO_2 used in the emission inventory are based on the carbon content of the fuel and are presented in Table 3.3. For N_2O and CH_4 the emission factors employed are listed in Tables 3.13-3.15.

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

Table 3.13. General CH_4 and N_2O emission factors from use of natural gas and LPG for passenger cars and heavy duty vehicles

Source	Fuel	CH_4 kg/tonne	N_2O kg/tonne
Passenger cars	Natural gas	0.261	0.0255
	LPG	0.195	0.213
Heavy duty vehicles	Natural gas	4.29	0.0255

Source: SFT (1999c), Riemersma et al. (2003), EPA (2004) and TØI (2005).

Table 3.14 Average N_2O emission factors from road traffic including cold start emissions and evaporation. Unit: g/kg fuel.

	Gasoline					Autodiesel		
	Passenger cars	Other light duty	Heavy duty	Mopeds	Motorcycles	Passenger cars	Other light duty	Heavy duty
1973	0.024	0.017	0.031	0.059	0.061	0.038	0.025	0.146
1980	0.026	0.018	0.032	0.058	0.058	0.037	0.025	0.136
1986	0.029	0.020	0.034	0.059	0.054	0.038	0.025	0.127
1987	0.030	0.020	0.036	0.059	0.054	0.037	0.025	0.128
1989	0.036	0.020	0.039	0.059	0.053	0.037	0.025	0.128
1990	0.049	0.020	0.041	0.059	0.052	0.037	0.025	0.128
1991	0.062	0.020	0.042	0.059	0.052	0.037	0.025	0.128
1992	0.071	0.023	0.043	0.059	0.052	0.038	0.025	0.128
1993	0.087	0.030	0.044	0.059	0.052	0.039	0.025	0.130
1994	0.107	0.040	0.045	0.059	0.051	0.039	0.025	0.128
1995	0.132	0.053	0.045	0.059	0.051	0.040	0.025	0.131
1996	0.161	0.069	0.045	0.059	0.051	0.040	0.025	0.131
1997	0.188	0.086	0.045	0.059	0.051	0.042	0.025	0.133
1998	0.207	0.100	0.045	0.059	0.051	0.044	0.026	0.129
1999	0.228	0.112	0.045	0.059	0.051	0.045	0.028	0.126
2000	0.250	0.125	0.044	0.059	0.051	0.047	0.029	0.126
2001	0.262	0.133	0.044	0.059	0.051	0.052	0.032	0.126
2002	0.273	0.138	0.044	0.059	0.051	0.058	0.036	0.126
2003	0.279	0.143	0.044	0.059	0.051	0.065	0.040	0.126
2004	0.283	0.145	0.045	0.059	0.052	0.072	0.044	0.126
2005	0.287	0.148	0.045	0.059	0.052	0.078	0.048	0.126
2006	0.287	0.149	0.046	0.059	0.052	0.082	0.051	0.126
2007	0.285	0.148	0.046	0.059	0.052	0.082	0.052	0.125

Source: SFT/Statistics Norway (1999c), Gense & Vermeulen (2002), Riemersma et al. (2003), EPA (2004) and TØI (2005)..

Emissions from evaporation and cold starts

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

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

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

Table 3.15 Average CH_4 emission factors from road traffic including cold start emissions and evaporation. Unit: g/kg fuel.

	Gasoline					Autodiesel		
	Passenger cars	Other light duty	Heavy duty	Mopeds	Motorcycles	Passenger cars	Other light duty	Heavy duty
1973	1.759	1.279	1.983	5.896	4.926	0.119	0.156	0.208
1980	1.684	1.259	1.964	5.843	4.940	0.119	0.154	0.208
1986	1.601	1.043	1.994	5.850	4.946	0.120	0.145	0.193
1987	1.601	1.032	2.014	5.850	4.944	0.121	0.146	0.194
1989	1.615	1.050	2.115	5.855	4.938	0.126	0.151	0.192
1990	1.589	1.052	2.168	5.855	4.939	0.127	0.153	0.190
1991	1.565	1.049	2.234	5.855	4.939	0.126	0.154	0.189
1992	1.610	1.079	2.303	5.855	4.939	0.124	0.150	0.188
1993	1.591	1.056	2.350	5.855	4.939	0.116	0.142	0.183
1994	1.565	1.027	2.395	5.855	4.939	0.107	0.130	0.174
1995	1.537	0.996	2.406	5.855	4.939	0.102	0.118	0.167
1996	1.498	0.951	2.404	5.855	4.939	0.097	0.110	0.158
1997	1.442	0.914	2.388	5.855	4.939	0.090	0.104	0.150
1998	1.382	0.877	2.362	5.855	4.939	0.085	0.098	0.142
1999	1.331	0.833	2.310	5.855	4.939	0.079	0.091	0.136
2000	1.311	0.795	2.154	5.855	4.939	0.074	0.084	0.132
2001	1.247	0.724	1.677	5.855	4.939	0.068	0.077	0.126
2002	1.207	0.679	1.267	5.855	4.939	0.061	0.071	0.118
2003	1.157	0.644	1.038	5.855	4.939	0.055	0.065	0.111
2004	1.102	0.607	0.886	5.855	4.939	0.049	0.059	0.104
2005	1.078	0.588	0.796	5.855	4.939	0.043	0.052	0.097
2006	1.045	0.564	0.788	5.855	4.939	0.039	0.046	0.090
2007	1.019	0.546	0.757	5.855	4.939	0.035	0.040	0.081

Source:SFT/Statistics Norway (1999c), Gense & Vermeulen (2002), Riemersma et al. (2003), EPA (2004) and TØI (2005).

3.2.5.4. Uncertainties

The uncertainty in the activity data and the CO_2 emissions from road transportation is found to be ±10 per cent and ±3 per cent of the mean, respectively. In the case of CH_4 and N_2O the uncertainty in the emission factors lies below and above of the mean by a factor of 2 and 3, respectively. A detailed description of the uncertainty analysis is given in Annex II.

3.2.5.5. Source specific QA/QC and verification

Top down and bottom up data on fuel consumption are compared for gasoline and diesel vehicles on an annual basis. The consumption of gasoline and auto diesel for road traffic is estimated as total sales minus consumption for other uses i.e a top down approach. The emission model for road traffic (SFT 1993; SFT1999c) also makes bottom up estimates of consumption, which can be compared with the top down data. For gasoline, the agreement is very good (difference less than 5 per cent for most years). For auto diesel the agreement is poorer, with the top down estimate up to 40 per cent above the bottom up estimate. The causes are uncertainties in the amount of non-road use on one hand, and uncertainties in mileage and specific consumption on the other.

However, the total consumption of auto diesel, and hence the CO_2 emission from this fuel, is well known. The uncertainty concerns the allocation between road and non-road use. For CH_4 and N_2O the total emission is sensitive to the allocation due to different emission factors.

3.2.5.6. Recalculations

- Revised activity data. Revised figures on vehicle-kilometres and fuel consumption for the period 2003-2006, have caused changes in emissions from road traffic.

3.2.5.7. Planned improvements

The Norwegian road emission model is being evaluated this year and the intention is to have a new model in operation before next year submission.

3.2.6. Transport – Railways (CRF source category 1A3c)

3.2.6.1. Description

Railway traffic in Norway uses mainly electricity (auto diesel is used at a small number of lines, for shunting etc). The greenhouse gas emissions from this source category are therefore insignificant.

3.2.6.2. Methodological issues

The general estimation methodology for calculating combustion emissions from consumption figures and emission factors is used in this source category.

3.2.6.3. Activity data

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

3.2.6.4. Emission factors

The emission factors used in this source category are displayed in Table 3.3 for CO_2 and Table 3.16 for CH_4 and N_2O.

3.2.6.5. Uncertainties

The consumption data are of high quality. Their uncertainty is estimated to be ±5 per cent of the mean. The uncertainty in the emission factors for CO_2 is ±3 per cent of the mean, whereas for CH_4 and N_2O the uncertainty is below and above the mean by a factor of 2 and 3, respectively.

3.2.6.6. Source specific QA/QC and verification

Consumption data from the Norwegian State Railways are compared with sales to railways according to the Petroleum statistics. However, the latter includes some consumption by buses operated by the State Railways. Since 1998, the reported sales of "tax-free" auto diesel to railways have been around 20 per cent higher than the consumption data from the State Railways. Until 1997, the reported sales were around 5 per cent higher. The reason for this discrepancy has not been checked. "Tax-free" auto diesel is only for non-road use, so consumption by buses should not be the cause.

3.2.6.7. Recalculations

There were performed no specific recalculations for this sector.

3.2.6.8. Planned improvements

There is for the moment no planned activity that will improve the data quality for NIR 2010.

3.2.7. Transport – Navigation (CRF source category 1A3d)

3.2.7.1. Description

According to UNFCCC, Norwegian national sea traffic is defined as ships moving between two Norwegian ports. In this connection installations at the Norwegian part of the continental shelf are defined as ports. Emissions from fishing are described in Section 3.2.9.

Emissions from navigation constituted 4.7 per cent of the national GHG total in 2007. They increased by 33 per cent from 1990 to 2007, mainly because of increased activity in the oil and gas extraction sector. Emissions in 2007 were 10.8 per cent higher than those of 2006.

Navigation is a key category with respect to CO_2 emissions in both level and trend uncertainty.

3.2.7.2. Methodological issues

Emissions from navigation are estimated according to the Tier 2 IPCC methodology. The levels and the spatial distribution of emissions from national sea traffic are estimated by an updated and improved methodology presented in Tornsjø (2001). The improvement is due to the collection of new data on fuel use for the different vessel categories and the registration of changes in regular coastal trade (connections/distances). Mobile drilling rigs are also included in the calculations. Emissions from international marine bunkers are excluded from the national totals and are reported separately (see Section 3.6.1), in accordance with the IPCC Good Practice Guidance.

Annual emissions are estimated from sales of fuel to domestic shipping, using average emission factors in the calculations. For 1993 and 1998 emissions have also been estimated based on a bottom up approach (Tornsjø 2001). This was also done for 2004. Fuel consumption data were collected for all categories of ships (based on the full population of Norwegian ships in domestic transport); freight vessels (bulk and tank by size), oil loading vessels, supply/standby ships, tug boats, coastal ferries, military ships and other ships. Emissions were estimated from ship and size specific emission factors and fuel use. From this information, average emission factors were estimated for application in the annual update based on fuel sales. This approach is unfortunately too resource demanding to conduct annually. Sale of fuel to domestic shipping and fishing were about 15 per cent higher, in both 1993 and 1998, than the fuel consumption estimated as described in Section 3.2.7.3 for the same years. Some explanations may be that the sales figures also include sales to foreign vessels bunkering in Norway. Norwegian vessels bunkered abroad are not included.

3.2.7.3. Activity data

The annual sales statistics for petroleum products gives figures on the use of marine gas oil, heavy distillates and heavy fuel oil in domestic navigation. Information on fuel used in freighters is gathered from surveys performed by Statistics Norway. In cases where information on oil related vessels is lacking, data are collected directly. Data on fuel consumed by public road ferries are available from the Directorate of Public Roads, whereas the consumption by other ferries and regular coastal trade vessels is obtained directly from the companies. For 2004 this information is received from the so called *Ferjefaktautvalget*, a Committee of experts looking into issues related to ferry traffic. The consumption figures for other types of ships and boats are mainly taken from Statistics Norway (1996). Information on fuel use at mobile drilling rigs is taken from sale statistics, but information on use i.e. whether

it is used for drilling, stationary combustion etc, is taken from the oil companies' reports to SFT and NPD. These reports are found in the so-called *Environmental Web*, a database operated by OLF, NPD and SFT.

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

3.2.7.4. Emission factors

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

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

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

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

Some natural gas is combusted in ferry transportation; the CH_4 emission factor used in this case is 40.029 kg/1000 Sm^3 fuel.

3.2.7.5. Uncertainties

The estimated bottom-up emission figures are uncertain. The most important sources of error are assumed to be estimation of fuel used by fishing vessels, delimitation of national sea traffic and the emission factors. Generally there is also uncertainty connected to cases where calculations are necessary because of the lack of data on fuel consumption. This applies particularly to large ships, as these usually use more fuel and have accordingly greater significance for the emissions. No analysis on the levels of error has been made. National emission figures are generally more certain than the figures for the different vessel categories. The uncertainty in the activity data is assessed to be ±10 per cent. With regard to emission factors the uncertainty for ships and fishing vessels is ±3 per cent of the mean for CO_2. For CH_4 and N_2O the corresponding uncertainties lie in the ranges -50 to +100 and -66 to +200 (see also Annex II).

3.2.7.6. Source specific QA/QC and verification

In 2001, bottom-up (from surveys) and top down data (from sales) on fuel consumption were compared (Tornsjø 2001). The outcome showed that data from sales were 15 per cent higher than data from reported consumption. As indicated in section 3.2.7.3 above, this can be explained by the fact that the bottom up method does not cover all ships, but it may also be that the domestic/international distinction is not specified precisely enough in the sales statistics. A similar deviation has been found for the years 1993 and 1998. In the calculations, sales figures are used, as they are assumed to be more complete and are annually available. As mentioned, emission estimates for ships have been made bottom up for 1993 and 1998 (Tornsjø 2001). These results have been compared with the annual estimates. The agreement is reasonable, given the uncertainty in the fuel data determined by both methods.

3.2.7.7. Recalculations

No specific recalculations have been performed for this source category.

3.2.7.8. Planned improvements

The emission inventory for shipping in general will be evaluated this year primarily due to need for updating the NO_x inventory. However, this will also have influence on the GHG emissions from shipping.

3.2.8. Transport – Other transportation – (CRF source category 1A3e)

3.2.8.1. Description

This source category includes emissions from pipeline transport of natural gas but primarily motorized equipment. Energy generation for pipeline transport of natural gas mainly take place at the production facilities and is reported in sector 1A1. Motorized equipment used in agriculture, fishing and in military are not accounted for under this source category.

Emissions from this sector were 3.2 per cent of the national GHG total emissions in 2007. In the period 1990-2007, these emissions increased by 108 per cent. In 2007 emission levels were 4.8 per cent lower than those in 2006.

According to the Tier 2 key category analysis for 2007, other transportation is a key category with respect to emissions of CO_2 and N_2O in terms of both level and trend uncertainty.

The calculation of emissions from pipelines and motorized equipment is elaborated in the following.

3.2.8.2. Pipelines

3.2.8.2.1. Methodological issues

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

3.2.8.2.2. Activity data

Figures on natural gas used in turbines for pipeline transport at two separate facilities are reported annually from the Norwegian Petroleum Directorate to Statistics Norway (NPD).

3.2.8.2.3. Emission factors

The emission factors employed are the standard factors used for turbines fired with natural gas (see Tables 3.3, 3.6 and 3.8). The sources for the factors used are SFT/NPD and IPCC (1997b).

3.2.8.2.4. Uncertainties

The uncertainty in the activity data for pipelines and is found to be ±20 per cent of the mean. For CH_4 and N_2O the uncertainty lies below and above the mean by a factor of 2 and 3, respectively (see Annex II).

3.2.8.2.5. Source specific QA/QC and verification

There is no source specific QA/QC procedure for this sector. For the description of the general QA/QC procedure, see Section 1.6.

3.2.8.2.6. Recalculations

No specific recalculations have been performed for this source category.

3.2.8.2.7. Planned improvements

There is for the moment no planned activity that will improve the data quality for NIR 2010.

3.2.8.3. Motorized equipment

3.2.8.3.1. Description

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

Emissions from motorized equipment are reported under several source categories:

- Agriculture/Forestry/Fishing: IPCC 1A4c
- Households: IPCC 1A3e
- Military: IPCC 1A5b
- Other Transportation: IPCC 1A3e

Only consumption of gasoline and auto diesel is considered. A small amount of fuel oil used for equipment in construction is also accounted for.

3.2.8.3.2. Methodological issues

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

3.2.8.3.3. Activity data

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

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

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

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

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

3.2.8.3.4. Emission factors

The emission factors used are given in Tables 3.17-3.18.

Table 3.16.General emission factors for other mobile sources

		CH_4 kg/ tonne	N_2O kg/ tonne
Railway	Auto diesel	0.18	1.2
Small boats 2 stroke	Motor gasoline	5.1	0.02
Small boats 4 stroke	Motor gasoline	1.7	0.08
	Auto diesel	0.18	0.03
Motorized equipment 2 stroke	Motor gasoline	**6**	0.02
Motorized equipment 4 stroke	Motor gasoline	**2.2**	**0.07**
	Auto diesel	**0.17**	1.3
	Light fuel oils	0.17	1.3

Snow scooters have the same emission factors as those for Mopeds, see Tables 3.14-3.15.
Bold figures have exceptions for some sectors, see Table 3.17.

Sources: Bang (1993), SFT (1999c), Finstad et al. (2001), Finstad et al. (2002a) and Finstad et al. (2003).

Table 3.17 Exceptions from the general factors for greenhouse gases and precursors for other mobile sources

Component	**Emission factor (kg/tonne)**	**Fuel**	**Source**	**Sectors**
CH_4	6.2	Motor gasoline	Motorized equipment 2 stroke	Agriculture
CH_4	3.7	Motor gasoline	Motorized equipment 4 stroke	Agriculture
CH_4	7.7	Motor gasoline	Motorized equipment 2 stroke	Forestry and logging
CH_4	8.1	Motor gasoline	Motorized equipment 2 stroke	Private households
CH_4	5.5	Motor gasoline	Motorized equipment 4 stroke	Private households
CH_4	0.18	Auto diesel	Motorized equipment 4 stroke	Private households
N_2O	0.08	Motor gasoline	Motorized equipment 4 stroke	Agriculture and forestry, Fishing, Energy sectors, Mining/Manufacturing

3.2.8.3.5. Uncertainties

The estimates of consumption are considered quite uncertain, particularly for gasoline. However, the total consumption of gasoline and auto diesel is well known (see also Annex II).

3.2.8.3.6. Source specific QA/QC and verification

There is no source specific QA/QC procedure for this sector. For a description of the general QA/QC procedure, see Section 1.6.

3.2.8.3.7. Recalculations

- Revised activity data. The figure on auto diesel used in equipment has been somewhat increased, and thus causing higher emissions.

3.2.8.3.8. Planned improvements

There is for the moment no planned activity that will improve the data quality for NIR 2010.

3.2.9. Other Sectors (CRF source category 1A4)

3.2.9.1. Description

The source category *Other Sectors* includes stationary combustion in agriculture, forestry, fishing, commercial and institutional sectors and households, motorized equipment and snow scooters in agriculture and forestry, and ships and boats in fishing.

Fuel combustion in agriculture, forestry and fisheries accounts for more than half of the emissions of this source category. In 2007 the total emissions from this sector were 3.1 million tonnes CO_2-equivalents and constitute of 5.7 per cent of national total GHG that year. The emissions decreased by 27.6 percent from 1990 to 2007 and 10 percent during 2007. Throughout the period 1990-2007, emissions have fluctuated although with a decreasing trend. The trend is mainly due to reduced consumption of fuel oil in the commercial, institutional and households sectors.

In this year key category analyses sector 1A4, mobile fuel combustion and 1A4 stationary fuel combustion was separated from sector 1A4. According to the Tier 2 key category analysis for 2007, sectors 1A1, 1A2 and 1A4 stationary fuel combustion and 1A4 mobile fuel combustion were define as as key categories with respect to:

- Emissions of CO_2 from the combustion of solid, liquid and gaseous fuels in both level and in trend uncertainty
- Emissions of CH_4 from the combustion of gaseous fuels in trend uncertainty, and biomass in both level and trend uncertainty

Emissions of CO_2 from sector 1A4 mobile fuel combustion is key category both in both level and in trend uncertainty.

3.2.9.2. Activity data

Motorized equipment
Activity data are as described in section 3.2.8.3.

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

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

use of coal was previously collected annually from the only consumer. Since 2002, however, there has been no use of coal in the Norwegian agricultural activities.

Fishing
Figures on the use of marine gas fuel, heavy distillate and heavy fuel oil are identical with the registered sales to fishing in the sales statistics for petroleum products. The figures used in the emission calculations differ from the energy accounts, as the latter include also an estimated quantity on Norwegian use purchased abroad. In addition to these figures on use in large fishing vessels, a minor figure on estimated use of gasoline in small fishing boats is also included.

Commercial and institutional sectors
Figures on energy use in wholesale and retail trade and hotels and restaurants, are based on a survey for 2000, performed by Statistics Norway. For the following years, figures from this survey have been adjusted proportionally to the development in employment in the industries in question. For earlier years, the figures are based on a survey from the mid-1980s. LPG figures for the whole period from 1990 have, however, been estimated separately after consultation with an oil company.

For most other commercial and institutional sectors, the total use of fuel oil appears as a residual after the use in all other sectors has been estimated; the distribution of this residual between sub-sectors is done by using figures on energy use per man-labour year from the energy survey from the mid-1980s.

Use of heating kerosene in commercial industries is calculated by projecting a figure on use from the mid-1980s proportionally with the registered sales to buildings in industrial industries outside the manufacturing industries. The estimated total amount is distributed between sub-sectors by using figures on energy use per man-labour year from the mid-1980s survey.

3.2.9.3. Emission factor

The emission factors used in this source category are presented in Section 3.2.1.3.

3.2.9.4. Uncertainties

Uncertainty in *fishing* is described together with navigation in Section 3.2.7.5.

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

As the total use of the different oil products is defined as equal to the registered sales, use in some sectors are given as a residual. This applies to use of heating kerosene and heavy distillates in households, and total use of fuel oil in commercial and institutional sectors. Accordingly, these quantities must be regarded as uncertain, as they are not based on direct calculations. This uncertainty, however, applies only to the distribution of use between sectors - the total use is defined as equal to registered sales, regardless of changes in stock.

The uncertainty in the activity data for this source category is ±10 per cent of the mean for the commercial/institutional sector, and ±30 per cent of the mean for the residential sector as well as for agriculture/forestry/fishing. Emission factors of CO_2 have an uncertainty that lies between ±3 and ±30 per cent of the mean, depending on the fuel used (see Annex II). Emission factors of CH_4 and N_2O are as usual highly uncertain.

3.2.9.5. Source specific QA/QC and verification

There is no source specific QA/QC procedure for this sector. For a description of the general QA/QC procedure, see Section 1.6.

3.2.9.6. Recalculations

1A 4 a Commercial/institutional

- Revised activity data. Figures on methane flared have been reduced somewhat for 2002-2006, thus causing marginally higher emissions of CH_4 and N_2O for these years from utilised methane.

3.2.9.7. Planned improvements

There is for the moment no planned activity that will improve the data quality for NIR 2010.

3.2.10. Other (CRF source category 1A5)

This source includes solely emissions from fuel use in military stationary and mobile activities. Emissions of CO_2 from the mobile military sub-sector appear to be a key category according to Tier 1 key source analysis.

Figures on fuel oil are annually collected directly from the military administration, while for other energy carriers figures from the sales statistics for petroleum products are used. For stationary activities the emission factors used in this source category are those presented in Section 3.2.1.3. For mobile activities the employed emission factors are those presented in the corresponding transport sectors (see Sections 3.2.4-3.2.8). The stationary and mobile emissions from the Norwegian military activities for the years 1990-2007 are listed in Table 3.18.

There have been large variations in annual sales of military aviation kerosene; as stock changes are not taken into account, the actual annual use is uncertain.

3.2.10.1. Recalculations

No specific recalculations have been performed for this source category.

Table 3.18. Stationary and mobile emissions from military activities
Unit: CO_2 in Mtonnes, CH_4 and N_2O in tonnes.

	CO_2	CH_4	N_2O
1990			
1A5A Military - stationary	62.4	7.9	0.6
1A5B Military - mobile	393.7	15.1	19.1
1991			
1A5A Military - stationary	53.3	6.7	0.5
1A5B Military - mobile	352.5	13.7	17.8
1992			
1A5A Military - stationary	60.1	7.2	0.6
1A5B Military - mobile	426.8	17.7	25.5
1993			
1A5A Military - stationary	44.3	5.6	0.4
1A5B Military - mobile	322.5	13.7	16.0
1994			
1A5A Military - stationary	51.0	6.4	0.5
1A5B Military - mobile	456.7	13.9	21.6
1995			
1A5A Military - stationary	48.1	6.1	0.5
1A5B Military - mobile	406.1	11.5	21.7
1996			
1A5A Military - stationary	62.4	7.9	0.6
1A5B Military - mobile	344.2	10.9	15.5
1997			
1A5A Military - stationary	73.6	9.2	0.7
1A5B Military - mobile	350.9	10.5	20.4
1998			
1A5A Military - stationary	49.6	6.2	0.5
1A5B Military - mobile	309.9	11.5	25.6
1999			
1A5A Military - stationary	50.3	6.3	0.5
1A5B Military - mobile	341.3	10.9	20.0
2000			
1A5A Military - stationary	40.6	5.1	0.4
1A5B Military - mobile	137.5	7.8	11.8
2001			
1A5A Military - stationary	54.4	6.9	0.5
1A5B Military - mobile	240.6	13.1	13.1
2002			
1A5A Military - stationary	44.1	5.5	0.4
1A5B Military - mobile	409.2	9.9	14.4
2003			
1A5A Military - stationary	58.3	7.4	0.6
1A5B Military - mobile	114.2	6.8	4.5
2004			
1A5A Military - stationary	45.5	5.7	0.4
1A5B Military - mobile	284.7	8.7	10.2
2005			
1A5A Military - stationary	37.3	4.7	0.4
1A5B Military - mobile	251.9	5.4	9.0
2006			
1A5A Military - stationary	38.7	4.9	0.4
1A5B Military - mobile	238.9	6.2	8.5
2007			
1A5A Military - stationary	32.1	4.1	0.3
1A5B Military - mobile	177.2	4.9	6.8

3.3. Fugitive Emissions from Coal Mining and Handling – 1B1a – CH_4 (Key Category)

3.3.1. Description

There are today two coal mines at Spitsbergen (the largest island in the Svalbard archipelago) operated by a Norwegian company. They opened the second mine in 2001. As the Norwegian GHG inventory, according to official definitions, shall include emissions from all activities at Svalbard, also emissions from Russian coal production have been estimated. Until 1998, there was production in two Russian coal mines, but since then, production takes place only in the Barentsburg mine. The production there is at present considerably smaller than the Norwegian production. Russian activity data are more uncertain than the Norwegian, which causes a correspondingly higher uncertainty in the emission figures.

At Svalbard there has been a smoldering fire in the Russian mine that was closed down in 1998. At an inspection in 2005, no emissions were registered, which indicates that the fire has burnt out. Due to lack of data, emissions for earlier years from this fire have not been estimated. However, Norwegian authorities assume that these emissions were limited.

The Norwegian coal production was almost unchanged from 1990 to 2000. In 2001 the production more than doubled and in 2004 the Norwegian coal production was almost 10 times higher than in 1990. In 2005 there were a fire in one of the coal mines and this caused that the production was almost halved from 2004 to 2005. In 2007 the production was about 35 per cent over the 2004 production. The emissions from this fire in 2005 are included in the inventory. The CO_2 emissions from the fire are estimated to approximately 3,000 tonne.

CH_4 from coal mining is not defined as a key category in the Tier 2 key category analysis nor in Tier 1 analysis. However, we regard coal mining as a key category due to change in trend in the coal production and the fact that the emission factor used for the Norwegian mines is in an order of magnitude less than IPCC's default factors.

3.3.2. Methodological issues

CO_2
Indirect CO_2 emissions from methane oxidized in the atmosphere are calculated by multiplying the calculated CH_4 emission with the factor 2.74 tonne CO_2 per tonne CH_4. (Section 3.6.3 for more information on indirect CO_2)

CH_4
Emissions of methane from coal mining on Svalbard are calculated by multiplying the amount of coal extracted (raw coal production) with country specific emission factors (Tier 2); the factor for the Barentsburg mine differs from the factor for Norwegian coal production. The calculations are performed by Statistics Norway.

3.3.3. Activity data

Figures on Norwegian production (raw coal production) are reported by the plant to Statistics Norway. Russian figures are reported to the Norwegian authorities on Svalbard; these figures

are, however, regarded as highly uncertain, consisting of a mixture of figures on production and shipments.

3.3.4. Emission factor

CH_4

For Norwegian coal production a country specific emission factor of CH_4 from extraction of coal was determined in 2000 in two separate studies performed by (IMC Technical Services Limited 2000) and (Bergfald & Co 2000).

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

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

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

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

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

For the Russian mine in Barentsburg, the emission factor for CH_4 has been estimated in the same manner as the Norwegian factor, based on measurements by (Bergfald & Co as 2000). This is an underground mine, which causes considerably higher emissions than from the Norwegian mines; we use the factor 7.16 kg methane per tonne coal for this mine. The Russian mine that was closed down in 1998, however, was situated more like the Norwegian mines; accordingly we use the same emission factor for this as for the Norwegian mines.

3.3.5. Uncertainties

The uncertainty in the activity data concerning Norwegian coal production is regarded as being low. The uncertainty in Russian data is considerably higher.

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

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

3.3.6. Source specific QA/QC and verification

Independent methods to estimate the EFs used in the calculations are described above in this chapter.

Statistics Norway and SFT carry out internal checks of the emission time-series and corrections are made when errors are detected, see Section 1.6 for general QA/QC procedures.

3.3.7. Recalculations

There has not been recalculation of the emission estimates since NIR 2008.

3.3.8. Planned Improvements

In the desk review report in 2005 Norway was encouraged to assess the feasibility of applying a measurement-based tier 3 approach to this key category. Norway has considered the advice and has so far no plans of applying a Tier 3 methodology. However, we have on the agenda to evaluate the EF based on measurements that we use in the calculation today.

3.4. Fugitive Emissions from Oil and Natural Gas – 2B

3.4.1. Overview

Fugitive emissions from oil and natural gas contribute 7.8 per cent to the total GHG emissions in Norway in 2007 and with 10.8 per cent of the GHG emissions in the energy sector. The emissions the sector increased by 39.7 percent from 2006 to 2007 due to flaring in connection with start-up problems at a new LNG plant. These problems resulted in about 1.3 million tonne CO_2 emitted from flaring. Under normal operational condition emissions from flaring is expected to be very little.

Without the emissions from flaring at the LNG plant the GHG emissions from oil and gas extraction was decreased by 3.5 per cent from 2006 to 2007 and was in 2007 at the same level as in 1990.

In 2007 CO_2 from flaring off shore contributed with 2 per cent to the total GHG emissions in Norway. Despite increased production of oil and gas the CO_2 emissions from flaring off shore were about 20 per cent lower in 2007 than it was in 1990 which is due to the introduction of tax on gas flared off shore from 1991. The amount of gas flared may fluctuate from year to year due to variation of startups, maintenance and interruption in operation. To minimise emissions from venting and flaring technical measures have been implemented. The venting rate is low due to strict security regulations.

Table 3.19 gives an overview over the calculations of the fugitive emissions of CO_2, CH_4, N_2O and NMVOC. The notation R/E in the table indicates that emission estimates is based on reporting from the entities or calculated by Statistics Norway, see e.g. section 1.4.4.2 about

flaring. Basically the emission estimates are carried out by Statistics Norway up to about 2002.

Table 3.19 Fugitive emissions from oil and natural gas. Emission sources, compounds, methods, emission factors and activity data included in the Norwegian GHG Inventory. Denne må eg komma tilbake til

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

R = emission figures in the national emission inventory are based on figures reported by the plants. E = emission figures are estimated by Statistics Norway (Activity data * emission factor). IE = Included elsewhere, NO = Not occurring, CS = Country specific, PS = Plant specific, Tier = the qualitative level of the methodology used, C=Corinair.

3.4.2. Fugitive Emissions from Oil – CO_2, CH_4 - 1.B.2.a (Key Category)

3.4.2.1. Description

1.B2a covers emissions from loading and storage of crude oil, refining of oil and distribution of gasoline.

Loading, unloading and storage of crude oil on the oil fields offshore and at oil terminals on shore causes direct emissions of CH_4 and indirect emissions of CO_2 from oxidized NMVOC and CH_4. Non-combustion emissions from Norway's two oil refineries (a third was closed down in 2000) include CO_2, CH_4 and NMVOC. Gasoline distribution causes emissions of NMVOC, which lead to indirect CO_2 emissions.

Indirect emissions of CO_2 from loading of crude oil etcetera are *key category* in level and trend in the Tier 2 key category analyses due to uncertainty in emission factors. The source category is for CH_4 emissions defined as key according to the Tier 1 analyses. The contribution to total uncertainty in level and trend is shown in Annex II.

3.4.2.2. Methodological issues

Loading and storage of crude oil off shore and on shore
From 2003, emission of CH_4 and NMVOC from loading and storage of crude oil on shuttle tankers included in the GHG Inventory are based on reported emission figures from the oil companies. Emissions, activity and to some extent emissions factors are reported from each field operator into the database Environmental Web. The database is operated by NPD, SFT and [1]The Norwegian Oil Industry Association (OLF). In addition the field operators each year deliver a report where they describe the activities during the last year.

Before 2003 the reported emissions of CH4 and NMVOC is calculated by Statistics Norway. The calculation was based on the field specific amounts of crude oil loaded and stored multiplied with field specific emission factors. Field specific activity data and emission factors (the latter only to SFT) used in the calculation were annually reported by the field operators to Statistics Norway and SFT. Since year 2000 an increasing share of the shuttle tankers have had installed vapor recovery units (VRU), and emissions from loading of crude oil on shuttle tankers with and without VRU are calculated separately for each field. In addition emission figures were annually reported to SFT and used in the QC of the calculated Statistics Norway emission figures.

Norway considers that the method for calculating the CH_4 and NMVOC emissions from loading and storage of crude oil is consistent for the period 1990-2005.

Only emissions from loading and storage of the Norwegian part of oil production are included in the inventory.

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

The reported indirect CO_2 emissions from the oxidation of CH_4 and NMVOC in the atmosphere see Section 3.6.3 for this source category is calculated by Statistics Norway.

Refining/Storage – 1.B.2.A.iv
The direct emissions of CO_2, CH_4 and NMVOC included in the inventory are reported by the refineries to SFT. There is however one exception and that is CH_4 emissions from the largest refinery. The CH_4 emissions from that refinery are estimated by SFT by multiplying the yearly amount of crude oil throughput by a plant specific emission factor that is based on measurements carried out by Spectracyne in 2002 and 2005. Also the NMVOC emissions are based on measurement carried out by Spectracyne in 2002 and 2005.

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

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

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

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

Gasoline distribution – 1.B.2.a.v
NMVOC emissions from gasoline distribution are calculated from the amount of gasoline sold and emission factors for loading of tankers at gasoline depot, loading of tanks at gasoline stations and loading of cars.

3.4.2.3. Activity data

Loading and storage of crude oil off shore and on shore
The amount of oil buoy loaded and oil loaded from storage tankers is reported by the field operators in an annual report to SFT and Norwegian Petroleum Directorate (NPD). The amount of oil loaded on shuttle tankers with or without VRU is separated in the report.

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

The amount of oil loaded at on shore oil terminals is also reported to SFT and NPD.

Refining – 1.B.2.a.iv
The crude oil throughput is annually reported by the plant to SFT.

Gasoline distribution – 1.B.2.a.v
Gasoline sold is annually collected in Statistics Norway's sale statistics for petroleum products.

3.4.2.4. Emission factors

Loading and storage of crude oil off shore and on shore
For the years before 2003, emission factors used in the calculation of CH_4 and NMVOC emissions offshore are field specific and were reported to SFT and NPD in an annual report. SFT forwarded the emission factors to Statistics Norway. From 2003 the emission figures reported by the field operators are used in the inventory.

The evaporation rate varies from field to field and over time, and the emission factors are dependent on the composition of the crude oil as indicated by density and Reid vapour

pressure (RVP). The VOC evaporation emission factors are obtained from measurements, which include emissions from loading and washing of shuttle tankers. For some fields the emission factors are not measured, only estimated. The CH_4 content of the VOC evaporated is also measured so that total emissions of VOC are split between CH_4 and NMVOC.

The emission factors that the field operator use in their calculations is reported to SFT and NPD. They report emissions factor with and without VRU and the split between CH_4 and NMVOC.

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

Refining/Storage – 1.B.2.A.iv
The emission factor used in the calculation of methane emissions from the largest refinery is based upon measurements performed by Spectracyne in 2002 and 2005. The EF is deduced from the measured methane emissions and the crude oil throughput in 2005.

Gasoline distribution – 1.B.2.a.v
Emission factor for NMVOC from filling gasoline to cars used in the calculations are from (EEA 2001) and is 1.48 kg NMVOC/tonne gasoline.

3.4.2.5. Uncertainties

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

3.4.2.6. Source-specific QA/QC and verification

Statistics Norway gathers data for the amount of crude oil loaded off and on shore from the NPD. This data is reported monthly by the field operators to NPD. The activity data are quality controlled by comparing them with the figures reported in the field operator's annual report to SFT and NPD.

Statistics Norway's calculated emissions for 1990-02 are compared with the emission data that the field operators report to SFT and NPD. From 2003 Statistics Norway estimate emission based on activity data that the filed operators monthly report to NPD and reported emission factors. When discrepancies are found between the two sets of data they are 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.

3.4.2.7. Recalculations

1B 2a iv Refining and storage

- Revised data. Minor reduction in indirect CO_2 emissions from one plant 2005-2006 because of lower NMVOC emissions, due to revised reporting from this plant.

1B 2a v Distribution of oil products

- Revised data. Minor changes in indirect CO_2 emissions, due to new calculations of NMVOC from petrol distribution, based on updated information on time for installation of vapour recovery units. Revised figures for 1991-1992 and 1994-2006. The figures have been reduced for 1992 and 1997 and increased for other years.

3.4.2.8. Planned improvements

There is for the moment no planned activity that will improve the data quality for NIR 2010.

3.4.3. Fugitive Emissions from Natural Gas – CH_4 - 1.B.2.b (Key Category)

3.4.3.1. Description

Sector 1.B.2.b covers fugitive emissions of CH_4 and NMVOC and indirect emissions of CO_2 from the two gas terminals.

CO_2 and CH_4 from natural gas is *key category* with respect to total trend. Their contribution to total uncertainty in level and trend is shown in Annex II.

3.4.3.2. Methodological issues

Fugitive emissions of CH_4 and NMVOC from gas terminals are annually reported from the terminals to SFT.

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

3.4.3.3. Activity data

Activity data is sampled through the terminals measuring and maintenance program which aim is to reduce leakage.

3.4.3.4. Source-specific QA/QC and verification

Reported emissions are compared with previous years' emissions.

3.4.3.5. Recalculations

1B 2b5 Natural gas, other leakage

- Revised data. Somewhat higher indirect CO_2 emissions in 2006, because of revised emission figure for NMVOC from one plant.

3.4.3.6. Planned improvements

There is for the moment no planned activity that will improve the data quality for NIR 2010.

3.4.4. Fugitive Emissions from Venting and Flaring – CO_2, CH_4 - 1.B.2.c – (Key Category)

3.4.4.1. Description

Included in sector 1.B.2.c Flaring are emissions from flaring of gas off shore, at gas terminals and at refineries and the emissions is reported in sector 1.B.2.c.ii. Emission from flaring of oil by well testing is reported in sector 1.B.2.c.i.

Sector 1.B.2.c *Venting* includes emissions of CO_2, CH_4 and NMVOC from exploration and production drilling of gas and oil and reinjection of CO_2 at the Sleipner oil field. The major source is cold vent and leakage of CH_4 and NMVOC from production drilling.

The sector 1.B.2.c *Venting* includes emissions of CH_4 and NMVOC and hence indirect CO_2 emissions from cold venting and diffuse emissions from extraction and exploration of oil and gas. CO_2 emissions vented to the atmosphere when the injection of CO_2 has to stop for maintenance etcetera is reported in this sector. See Section 3.5 CO_2 capture and storage at the oil and gas production field Sleipner Vest for further description of this source.

Most of the emissions in sector *1.B.2.c Flaring* come from flaring of natural gas offshore (during both well testing, extraction and pipeline transport) and at gas terminals and flaring of refinery gas at the refineries. There is some flaring of oil in connection with well testing - amounts flared and emissions are reported to NPD and SFT.

CO_2 and CH_4 from venting and flaring is *key category* with respect to the level and total trend due to change in trend. Their contribution to total uncertainty in level and trend is shown in Annex II.

3.4.4.2. Methodological issues

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

The vented CO_2 at Sleipner Vest is measured.

Flaring
The CO_2, CH_4 and N_2O emissions from flaring of gas off shore is for the period 1990-2002 calculated by Statistics Norway on the basis of field specific gas consumption data and country specific average emission factor, see Table 3.21. From 2003, emissions of CO_2 and CH_4 from flaring offshore reported by the oil companies to NPD and SFT are used in the inventory. The same method is used in the calculation of emission from flaring by well testing. We consider that the method is consistent for all year.

Emissions of CO_2 from flaring at the two gas terminals that is included in the inventory are reported from the plant.

The refineries reports annually CO_2 emissions from flaring to SFT. The emissions are calculated by multiplying the amount of gas flared with plant specific emission factors.

3.4.4.3. Activity data

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

Flaring
Amounts of gas flared at offshore oil and gas installations are monthly reported by the operators to the NPD. Amounts flared at the two gas terminals are reported to NPD and SFT. Amounts of refinery gas flared are found by distributing the total amounts between different combustion technologies by using an old distribution key, based on data collected from the refineries in the early 1990s. This distribution is confirmed in 2003.

3.4.4.4. Emission factors

Venting
The emission factors used in the calculation of vented emissions is the default emission factors listed in Table 3.20 or field specific factors. The reference for the default factors is Aker Engineering (1992). During the expert review of the NIR 2005 it was a subject whether the EF we used were default factors or field specific.

Table 3.20 Default emission factors for cold vents and leakage at gas fields off shore

	NMVOC	**CH_4**	
	Emission factor	**Emission factor**	**Calculation method**
Emission source	[g/Sm3]	[g/Sm3]	
Glycol regeneration	0.065	0.27	
Gas dissolved in liquid from K.O. Drum	0.004	0.00	
Gas from produced water system	0.03	0.03	
Seal oil systems	0.015	0.01	
Leaks through dry compressor gaskets	0.0014	0.00	
Start gas for turbines [4]	0.4	0.36	Tonne per start up
Depressurisation of equipment	0.005	0.02	
Instrument flushing and sampling	0.00021	0.00	
Purge and blanket gas [1]	0.032	0.02	
Extinguished flare	0.014	0.02	
Leaks in process	0.007	0.02	
Depressurisation of annulus	0.0000005	0.00	
Drilling	0.55	0.25	Tonne per well

Flaring
From 2003, CO_2 emission figures reported by the oil companies to the SFT and NPD are used in the inventory. For the years 1990-02, average emission factors, based on field specific factors, are used, except for one field, for which a field specific factor is used for all years. In Table 3.21, the CO_2 emission factors for flaring off shore and at one gas terminals are shown. The other gas terminal uses in 2007 2.67 tonne CO_2/tonne gas.

[4] The gas source is standard fuel gas.

Emission factors used in the calculations for well testing are shown in Table 3.22. During the review of the 2008 inventory submission the expert review team raised question to that CH_4 and N_2O from well testing off shore were not included in the inventory. Norway then estimated the emissions of CH_4 and N_2O and presented the result for the expert review team. Our intention was to include emission estimates in this years submission. But due to an omission this has not been done.

Table 3.21 Emission factors for flaring of natural gas at off shore oil fields and one gas terminal on shore.

	Average emission factor for flaring at one gas terminal t CO_2/t gas	**Average emission factor for flaring off shore kg CO_2/ Sm^3 gas**
2007	2.67	2.42
2006	2.69	2.43
2005	2.70	2.43
2004	2.70	2.44
2003	2.70	2.41
2002	2.70	2.47
2001	2.70	2.42
2000	2.70	2.52
1999	2.70	2.48
1998	2.70	2.34
1997	2.70	2.34
1996	2.70	2.34
1995	2.70	2.42
1994	2.70	2.34
1993	2.70	2.34
1992	2.70	2.34
1991	2.70	2.34
1990	2.70	2.34

Source: SFT/NPD

Table 3.22 Emission factors for flaring in connection with well testing.

Compounds (unit)	**unit/tonne flared oil**	**Source**	**unit/kSm^3 flared natural gas**	**Source**
CO_2 (tonnes)	3.2	SFT (1990)	2.34	SFT (1990)
CH_4 (tonnes)	NE		0.00024	IPCC (1997b)
N_2O (tonnes)	NE		0.00002	OLF (2004)
NMVOC (tonnes)	0.0033	OLF (1994)	0.00006	OLF (2004)
CO (tonnes)	0.18	OLF (2004)	0.015	OLF (2004)

[1]The Norwegian Oil Industry Association (OLF)

3.4.4.5. Uncertainties

The uncertainty in the amount of gas flared is in (Statistics Norway 2000) regarded as being low, ±4 per cent, due to that there is a tax on gas flared and there is requirement by law that the gas volume flared is measured (NPD 2001). The uncertainty in the CO_2 emission factor for flaring is ±10 (Statistics Norway 2000).

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

All uncertainty estimates for this source are given in Annex II.

3.4.4.6. Source-specific QA/QC and verification

Statistics Norway collects the activity data used in the calculation from the NPD. The figures are quality controlled by comparing them with the figures reported in the field operators annually report to SFT and NPD and time series are checked.

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

Statistics Norway 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.

3.4.4.7. Recalculations

1B 2c2.2 Venting and flaring; flaring gas

- Revised data. Changes in figures for energy use in 2004-2006, due to the inclusion of a plant for which data previously were lacking, have caused a minor increase in the emissions.

3.4.4.8. Planned improvements

There is for the moment no planned activity that will improve the data quality for NIR 2010.

3.5. CO_2 capture and storage at the oil and gas production field Sleipner Vest (Key Category)

3.5.1. Description

The natural gas in the Sleipner Vest offshore gas-condensate field contains about 9 per cent CO_2. The CO_2 content has to be reduced to about 2.5 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. The selection of an appropriate reservoir is essential for the success of geological storage of CO_2. In their search for a suitable reservoir the companies were looking for a saline aquifer with reasonable high porosity and a capture rock above to prevent leakage. Furthermore the CO_2 should be stored under high pressure - preferably more than 800 meters below the surface. Under these conditions CO_2 is buoyant and less likely to move upwards than CO_2 in gaseous form.

The Utsira Formation aquifer, which is located above the producing reservoirs at a depth of 800 – 1000 meters below sea level, was chosen for CO_2 storage because of its shallow depth, its large extension (which guarantees sufficient volume), and its excellent porosity and permeability (which is well suited for high injectivity). The formation is overlain by a thick, widespread sequence of Hordaland Group shales, which should act as an effective barrier to vertical CO_2 leakage, see figure 3.1 below:

Figure 3.1 CO_2 capture from Sleipner Vest well stream and storage at Sleipner Øst
Source: Statoil

The reservoir was characterised by reservoir information such as seismic surveys and information from core drillings.

In the Sleipner case it has been very important to locate the injection well and the storage site such that the injected CO_2 could not migrate back to the Sleipner A platform (SLA) and the production wells. This will both prevent corrosion problems in the production wells and minimise the risk of CO_2 leakage through production wells. The injection point is located 2.5 km east of the Sleipner A platform. Migration evaluations have been based on the Top Utsira map (see figure 2 in Annex V) with the CO_2 expected to migrate vertically to the sealing shales and horizontally along the saddle point of the structure. This will take the CO_2 away from other wells drilled from the Sleipner platform. A more detailed description of the reservoirs suitability for long term CO_2 storage is given inn Annex V.

The field and the injection program have been in operation since 1996. Statoil monitors the injected CO_2 with respect to leakages.

Investigations carried out so far show that the injected CO_2 has been kept in place without leaking out. In case unexpected CO_2 movements take place beyond the capture rock in the future it can be registered by the monitoring techniques. Table 3.23 below gives the amount of CO_2 injected since the project started in 1996.

Table 3.23 CO_2 from the Sleipner field injected in the Utsira-formation, 1000 tonnes.

	1996	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
CO_2 (ktonnes)	70	665	842	971	933	1 009	955	914	750	858	820	921

Source: SFT

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 reported under 1B2c - see 3.4.4. In 2006 this emission amounted to 6413 tonnes CO_2. The figures for the other years are given in Table 3.24.

Table 3.24 Emissions of CO_2 from the Sleipner CO_2-injection plant due to inaccessibility of the injection facilities, tonnes.

	1996	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
CO_2 (tonnes)	81 000	29 000	4 195	9 105	8 318	3 050	7 567	23 910	21 377	6 191	2 471	6 413

Source: SFT

The status by 1.1.2008 is that 9.7 million tonnes CO_2 has been injected into the Utsira Formation and 0.2 million tonnes CO_2 has been vented. The following figure 3.2 shows the yearly injected and vented volumes for the entire injection period on Sleipner.

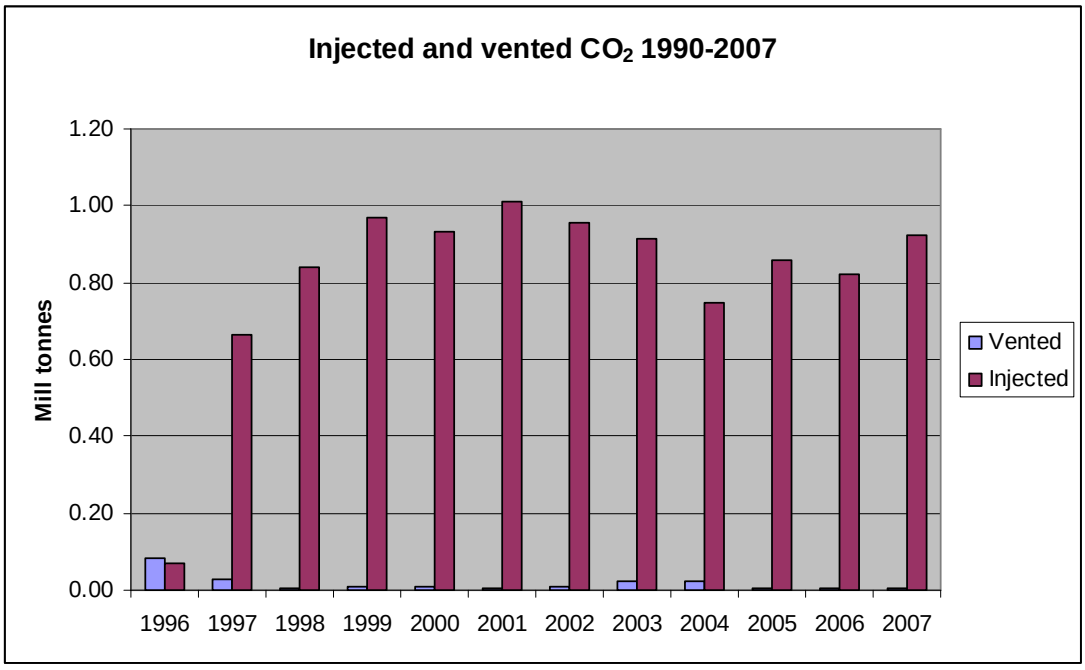


Figure 3.2 Injected and vented CO_2 at Sleipner Vest Source: SFT

3.5.2. Methodological issues

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

The Sleipner CO_2-injection project is considered as the first industrial-scale, environmentally driven CO_2-injection project in the world. In order to document what happens with the CO_2 a European research project initially called SACS ("The saline aquifer carbon dioxide storage project") was organized around it. The SACS project ended in 2002 and was succeeded by the ongoing the EU-cofunded CO2STORE. The projects have run parallel to the development of Sleipner Vest and have special focus on monitoring and simulation. Research institutes and energy companies from several countries participate in the projects. The core of the projects has been to arrive at a reasoned view of whether carbon dioxide remains in the Utsira sand and whether developments in this formation can be monitored. The spread of carbon dioxide through the aquifer is recorded by seismic surveys. Base line 3D seismic data were acquired in 1994, prior to injection, and the first repeat survey was acquired in 1999, when some 2.28 mill tonnes of CO_2 had been injected into the reservoir. This was followed by seismic surveys in 1999, 2001, 2002, 2004 and 2006. The monitoring methodology and the results of the monitoring are described in Annex V written by Statoil.

The stored CO_2 has been monitored using time lapse seismic to confirm its behaviour and evaluate

- whether any of it has leaked into the overburden seal, the ocean or the atmosphere, or
- whether any of it has migrated towards the Sleipner installations, potentially leading to corrosion problems for well casing

The results show that neither of these eventualities has occurred. So far there are no signs of CO_2 above the top of Utsira Formation.

Results from the projects are also given in several reports and articles such as: "Final Tecnical Report of the SACS2 project – EU project NNE-1999-00521, issued 30.07.2002", "Recent time-lapse seismic data show no indication of leakage at the Sleipner CO_2-injection site" published at 7th Greenhouse Gas Control Technologies Conference (GHGT7),Vancouver 2004 and "4D seismic imaging of an injected CO_2 plume at the Sleipner field, central North Sea" (under publishing in the Geological Society of London Memoir). A more detailed list of publications and presentations is given in Annex V. 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 (see figure 5 in Annex V). It is held under the layer of shale cap rock, 80 metres thick, which covers the whole formation. This extends for several hundred kilometres in length and about 150 kilometres in width.

The time-lapse seismic data clearly image the CO_2 within the reservoir, both as high amplitude reflections and as a pronounced velocity pushdown (see figure 4 in Annex V). The data also resolve a vertical CO_2 chimney, which is regarded the primary feeder of CO_2 in the upper part of the bubble.

Flow simulation models, which match the 4D seismic data reasonably well, have been used to predict the CO_2 behaviour, see figure 3.3.

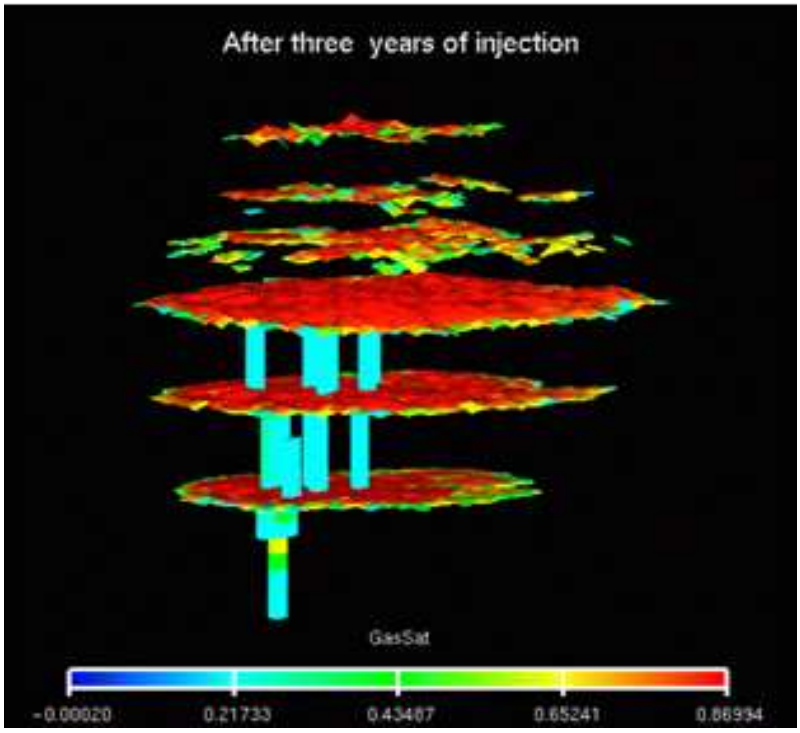


Figure 3.3 Flow simulation of CO_2 Source: Statoil

The results from the simulations indicate that cap rock shales provide a capillary seal for the CO_2 phase.

There are no seismic indications of faults within the upper part of the reservoir, and no indications of leakage into the capture rock.

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

Other monitoring methods Statoil is running are monitoring the injected CO_2, gravimetric monitoring, pressure measurements and well monitoring. For more details see Annex V.

3.5.3. Uncertainties

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

3.5.4. Source specific QA/QC and verification

The results are promising and so far the injected gas remains in place. In Norway storage projects like Sleipner have to apply for a permit after the Pollution control Act. The storage of CO_2 is included in the emission licence for the Sleipner Vest field. According to the license Statoil is obliged to monitor the CO_2-storage. Furthermore Statoil reports the amount of CO_2

emitted and the amount injected every year to The Norwegian Pollution Control Authority. The monitoring gives a system for QA. So far the monitoring is included in the SACS/CO2STORE projects and when these projects are finalized a decision will be taken about a further monitoring program for the Sleipner injection project. The injected CO_2 is so far proven to be removed from the atmosphere and hence it is not reported as in the emission inventory. When the injection have to stop for maintenance etc Statoil have to pay a CO_2-tax for the emissions. These emissions are reported to the Norwegian Petroleum directorate. In this national emissions inventory these fugitive emissions are reported under 1B2c.

3.5.4.1. Planned improvements

Further results from monitoring may improve the data quality for NIR 2010

3.6. Cross-cutting issues

3.6.1. Sectoral versus reference approach

As in previous submissions, there are large deviations in the output from the Reference Approach (RA) and Sectoral Approach (SA), both for the energy consumption data and the CO_2 emissions throughout the years. Possible explanations to the differences are given below. The results for all years in the period 1990-2007 are displayed in Table 3.25. In the RA, both fuel consumption and CO_2 emissions are higher that those of the SA for most years.

The differences that arise between the SA and RA for Norway have still not been possible to fully explain. Some revisions of figures for oil and gas production and export, particularly for 2004-2006, have, however, led to reduced differences. Above all, the extreme 2005 figures in the 2008 submission have now been reduced considerably. However, there is still no explanation why the largest negative difference in the whole period is in 2006.

For some years, there have been very large statistical differences in the Norwegian energy balance, i.e., an incongruity between figures on energy supply and energy use. It is reason to believe that the statistical differences explain at least some of the SA/RA differences. The end-user statistics used in the SA are considered to be reliable.

Generally, the main reason for the deviation between the SA and RA is probably inaccuracies in the oil and gas production or export statistics. Due to the large production and export, small errors can amount to large discrepancies in the national total emissions. According to the Norwegian Petroleum Directorate, the uncertainties for production figures are 1 and 0.3 per cent for natural gas and crude oil, respectively. Norway has also a large non-energy use of coal, coke, natural gas and liquefied petroleum gas (LPG), large oil and gas production and exports (domestic supply is the difference between the two large numbers in each case), and relatively large statistical errors. These factors make the use of the RA inappropriate for Norway. There is also some uncertainty connected to the carbon emission factors used in the RA; changes in the factors, particularly for crude oil, can cause great changes in the figures for actual CO_2 emissions e.g. the use of the IPCC default factor 20.0 instead of 20.33, which is used now, would reduce the emissions by 700,000 tonnes.

There are, as before, intensions to investigate these problems further. Hopefully, these investigations will enable the presentation of less diverging figures in future SA/RA comparisons.

Table 3.25 Comparison of fuel consumption and CO_2 emission data between the Reference Approach (RA) and the Sectoral Approach (SA), 1990-2007.

	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Fuel Consumption											
Reference approach: Apparent consumption (PJ)	403.0	425.9	435.7	476.0	452.9	435.2	428.5	467.2	480.1	516.7	501.3
Sectoral approach (PJ)	375.0	367.9	377.1	392.6	413.1	410.7	446.8	450.5	449.7	452.8	441.2
Difference (RA-SA) (%)	**7.5**	**15.8**	**15.5**	**21.2**	**9.6**	**6.0**	**-4.1**	**3.7**	**6.8**	**14.1**	**13.6**
CO_2 Emissions											
Reference approach (Gg)	29372	30929	31122	33925	32217	30877	30767	33629	34760	37540	36418
Sectoral approach (Gg)	25939	25567	26077	27143	28610	28364	31034	31190	31124	31449	30423
Difference (RA-SA) (%)	**13.2**	**21.0**	**19.3**	**25.0**	**12.6**	**8.9**	**-0.9**	**7.8**	**11.7**	**19.4**	**19.7**
	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**				
Fuel Consumption											
Reference approach: Apparent consumption (PJ)	543.9	430.9	529.3	527.8	456.5	411.2	530.5				
Sectoral approach (PJ)	465.0	467.8	487.8	488.3	479.1	499.9	505.0				
Difference (RA-SA) (%)	**17.0**	**-7.9**	**8.5**	**8.1**	**-4.7**	**-17.8**	**5.1**				
CO_2 Emissions											
Reference approach (Gg)	39441	31304	38099	37977	32739	29729	37637				
Sectoral approach (Gg)	32501	32628	33924	34068	33597	34533	34778				
Difference (RA-SA) (%)	**21.4**	**-4.1**	**12.3**	**11.5**	**-2.6**	**-13.9**	**8.2**				

Source: Statistics Norway/SFT

3.6.2. 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.

Carbon storage factors are based on national conditions for LPG, natural gas, coal, coke oven coke and petroleum coke. For the rest of the feedstocks, the factors used are those of countries that are regarded of having the same production profile and technology as Norway. It should be noted that fuels oxidized during industrial processes are assumed "stored".

3.6.3. Indirect CO_2 emissions from CH_4 and NMVOC

According to the reporting guidelines to the Climate Convention all emissions of carbon from fossil compounds are to be included in the national 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 therefore be included. Indirect CO_2 emissions originating from the fossil part of CH_4 and NMVOC during fuel combustion are automatically included in the emission inventory. The corresponding emissions from non-combustion sources are accounted for in the inventory under the following source categories:

- 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
- Silicon carbide - 2B4.1
- Calcium carbide - 2B4.2
- Methanol - 2B5.5
- Plastic - 2B.5
- Ferroalloys - 2C.2
- Solvent and other product use - 3

The indirect CO_2 emissions from oxidised CH_4 and NMVOC are calculated from the content of fossil carbon in the compounds. The average amount of carbon is estimated to be 75 per cent in methane and 82 per cent in NMVOC. This leads to the emission factors 2.74 kg CO_2/kg CH_4 and 3 kg CO_2/kg NMVOC.

3.7. Memo items

3.7.1. International bunkers

3.7.1.1. Description

Emissions from international marine and aviation bunker fuels are excluded from the national totals, as required by the IPCC Guidelines. The estimated emission figures are reported separately and are presented in Table 3.26.

In 2007 CO_2 emissions from ships and aircraft in international traffic bunkered in Norway amounted to a total of 3.3 million tonnes, which corresponds to about 6 per cent of the total Norwegian CO_2 emissions.

During the period 1990-2007, emissions of CO_2 from marine bunkers increased by 37 per cent, primarily due to activity growth. However, emissions varied greatly in this period and reached a peak in 1997.

Due to variations in the activity level, CO_2 emissions from international air traffic varied during the period 1990-2007, as well. These emissions reached their peak in 2006 and 2007 at a level that was double as high that of 1990. However, as aircraft engines are more fuel-efficient now than they were some years ago, it follows that the increase in international air traffic has in fact been higher than that of the emissions. After a general increase in the 1990s, emissions declined somewhat from 2000 to 2004, followed by a substantial increase in 2005-2007.

Table 3.26. 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, 1990-2007. Unit: 1000 tonnes, CO_2 in Mtonnes.

Marine	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
CO_2	1.5	1.3	1.6	1.7	1.8	2.3	2.5	3.0	2.9	2.7
CH_4	0.1	0.1	0.1	0.1	0.1	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
NOx	28.6	24.2	30.3	32.5	35.8	43.8	48.2	58.4	55.9	52.0
CO	1.4	1.2	1.5	1.6	1.8	2.2	2.4	2.9	2.6	2.4
NMVOC	1.1	0.9	1.2	1.3	1.4	1.7	1.9	2.3	2.2	2.0
SO_2	9.9	9.7	12.3	13.5	14.0	13.7	15.4	18.8	14.5	12.4

Marine	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
CO_2	2.6	2.6	2.1	2.1	2.0	2.3	2.3	2.0
CH_4	0.2	0.2	0.1	0.1	0.1	0.2	0.2	0.1
N_2O	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1
NOx	50.4	50.1	39.8	39.4	37.6	43.2	43.2	38.6
CO	2.4	2.4	1.9	1.9	1.8	2.1	2.1	1.8
NMVOC	2.0	2.0	1.6	1.6	1.5	1.7	1.7	1.5
SO_2	10.6	12.8	7.0	8.0	7.8	8.6	5.1	6.1

Aviation	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
CO_2	0.6	0.6	0.6	0.6	0.6	0.6	0.7	0.8	0.8	0.9
CH_4	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
NOx	2.1	1.9	2.1	2.3	2.2	2.2	2.5	2.8	3.0	3.4
CO	0.9	0.9	1.0	1.2	1.2	1.3	1.3	1.3	1.2	1.2
NMVOC	0.3	0.3	0.4	0.5	0.6	0.6	0.6	0.5	0.5	0.4
SO_2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Aviation	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
CO_2	0.9	0.8	0.7	0.7	0.8	1.1	1.2	1.2
CH_4	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
NOx	3.3	3.0	2.7	2.7	3.1	3.9	4.5	4.5
CO	0.9	0.8	0.8	0.8	0.9	1.1	1.3	1.3
NMVOC	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3
SO_2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Source: Statistics Norway/SFT

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

3.7.1.2. Shipping

Methodological issues

Emissions are calculated by multiplying activity data with emission factors. The sales statistics for petroleum products, which is based on reports from the oil companies to Statistics Norway, has figures on sales for bunkers of marine gas oil, heavy distillates and heavy fuel oil. The same emission factors as in the Norwegian national calculations are used.

Activity data

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

Emission factors

Emission factors used for shipping are described under *Navigation* in Section 3.2.7.

3.7.1.3. Aviation

Methodological issues

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

Activity data

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

Emission factors

Emission factors used for *Aviation* are described under *Aviation* in Section 3.2.4.

3.7.1.4. Precursors

Emissions of NO_x from international sea traffic in 2007 were about 39 ktonnes, which equals 20 per cent of the national Norwegian NO_x emissions. During the period from 1990 to 2007, NO_x emissions from international shipping bunkered in Norway increased by 35 per cent.

NO_x emissions from international aviation amounted to 4.5 ktonnes in 2007. Although the emissions have varied during the period 1990-2006, the 2006 and 2007 emissions were the highest in the period, 114 per cent higher than in 1990.

Apart from NO_x from marine bunkers, emissions of precursors from international aviation and sea transport are small compared to the total national emissions of these gases.

3.7.2. CO_2 emissions from biomass

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

4. Industrial Processes

4.1. Overview

The chapter provides descriptions of the methodologies employed to calculate emissions of greenhouse gases from industrial processes. Only non-combustion emissions are included in this chapter. Emissions from fuel combustion in Industry are reported in Chapter 3 Energy. Nearly all of the GHG emission from industrial processes included in the Norwegian GHG Inventory is from annually reports sent by each plant to the Norwegian Pollution Control Authority (SFT). The rest of the emissions included in the inventory are calculated by Statistics Norway. The calculations are based on emission factors and activity data. The emission factors are collected from different sources, while the activity data used in calculations carried out by Statistics Norway is from official statistics collected by Statistics Norway.

A specific QA/QC was carried out in 2006 for the whole time series for the industrial processes sector as recommended by the expert review team. The QA/QC covered the GHG emissions from the largest industrial plants to be included in the inventory. The methodology for the performances of the QA/QC is presented in Annex III. The changes in the emissions resulting from the QA/QC were described in the recalculation section for each source category in NIR 2006.

The GHG emissions from Industrial processes in 2007 were 16.7 per cent of the total GHG emissions in Norway. The corresponding percentage in 1990 and 2006 were 27.6 and 17.3 per cent respectively. The emissions from this source category decreased by 32.9 per cent from 1990 to 2007 and by 0.7 per cent from 2006 to 2007. The decrease from 1990 to 2007 is mainly due to reduced PFC emissions from production of aluminium and SF_6 from production of magnesium. There was a reduction in the PFC emissions by almost 76 per cent even if the production of aluminium in the period 1990-2007 has increased by 57 per cent. The reduction in the SF_6 emissions is due to the closing down of production of cast magnesium in 2002, improvements in the GIS-sector and an almost end in the use of SF_6 as tracer gas. In June 2006 also the magnesium recycling foundry was closed down.

Metal production contributed to about 61 per cent of the total GHG emissions from Industrial Processes in 2007, mainly from production of ferro alloys and aluminium, and in 1990 the contribution from metal production was about 72 per cent. Chemical Industry and Mineral Product are the two other main contributing sectors in 2007 with 19.5 and 10.9 per cent, respectively, of the total GHG emissions in this sector.

The Tier 2 key category analysis performed for 1990 and 2007 has revealed the key categories in terms of level and/or trend uncertainty in the sector Industrial Processes as shown in Table 4.1. However, source category 2A1, 2B1, 2C1 and 2C4 are key categories from Tier 1 key category analysis.

Table 4.1 Key categories in the sector Industrial Processes.

IPCC	Source category	Gas	Key category according to tier	Method
2A1	**Cement Production**	**CO_2**	**Tier 1**	**Tier 2**
2B1	**Ammonia Production**	**CO_2**	**Tier 1**	**Tier 2**
2B2	**Nitric Acid Production**	**N_2O**	**Tier 2**	**Tier 2**
2B4	**Silicon carbide**	**CO_2**	**Tier 2**	**Tier 2**
2C1	**Iron and Steel Produsction**	**CO_2**	**Tier 1**	**Tier 2**
2C2	**Ferroalloys Production**	**CO_2**	**Tier 2**	**Tier 2**
2C3	**Aluminum Production**	**CO_2**	**Tier 2**	**Tier 2**
2C3	**Aluminum Production**	**PFC**	**Tier 2**	**Tier 2**
2C4	**SF_6 Used in Aluminum and Magnesium Foundries**	**SF_6**	**Tier 1**	**Tier 2**
2F	**Consumption of Halocarbons and Sulphur Hexafluoride**	**HFCs**	**Tier 2**	**Tier 2**

4.2. Mineral Products – 2A

The sector category Mineral products include CO_2 emissions from production of cement, lime and limestone and dolomite use. Table 4.2 shows that the CO_2 emission from the sector category are based on figures reported by the plants to SFT, that it is used a Tier 2 methodology for all sources and if the sources are key category or not.

Production of Mineral Products contributed in 1990 by 1.5 percent of the total GHG emissions in Norway and this share has increased to 1.8 per cent in 2007. The emissions from the sector increased with 39 per cent from 1990-2007 and 7.3 per cent from 2006-2007 mainly due to increased production of clinker.

Table 4.2. Mineral products. Component emitted and included in the Norwegian GHG inventory, tier of method and key category.

Mineral products	**CO_2**	**Tier**	**Key category**
-- Cement production	R	Tier 2	Yes
-- Lime production	R	Tier 2	No
-- Limestone and dolomite use	R	Tier 2	No

[1] R = Figures reported by the plant to SFT

4.2.1. Cement Production – CO_2 - 2A1 (Key Category)

4.2.1.1. Description

Two plants in Norway produce cement. Production of cement gives rise to both non-combustion and combustion emissions of CO_2. The emission from combustion is reported in Chapter 3 Energy. The non-combustion emissions originate from the raw material calcium carbonate ($CaCO_3$). The resulting calcium oxide is heated to form clinker and then crushed to form cement

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

In 2007, the CO_2 emissions from clinker production accounted for 1.6 per cent of the total national GHG emissions and 9.5 per cent of the GHG emissions in the sector Industrial processes.

From 1990-2007 the CO_2 emissions from clinker production increased by 34.8 per cent and from 2006 to 2007 the CO_2 emission increased by 8.7.

CO_2 from clinker production is according to a Tier 1 key category analysis defined as key category due to contribution in level to total GHG emission.

4.2.1.2. Methodological issues

The emissions of CO_2 from clinker production included in the GHG inventory are reported by the two producers in an annually report to SFT. Emissions are estimated by multiplying the annually clinker production, included the Cement Kiln Dust (CKD), at the plant with plant specific emission factors. This is regarded as a Tier 2 methodology.

4.2.1.3. Activity data

The amount of clinker and CKD the plant use in their calculation is reported each year from the plants to SFT.

4.2.1.4. Emission factors

CO_2
The emission factors used are plant specific. The factors are dependent on the chemical composition of the clinker i.e. the content of Ca and Mg. The fraction of CaO from non-carbonate sources like ashes is subtracted. The emission factors are calculated particularly for the two Norwegian factories. One plant uses the factor 0.530 tonne CO_2 per tonne clinker (Norcem 2006). The other producers use the emission factor 0.541 tonne CO_2 per tonne clinker as recommended by (SINTEF 1998a). The IPCC default emission factor is 0.5071 tonne CO_2/tonne clinker. The same emission factors are used for CKD as for clinker production.

4.2.1.5. Uncertainties

Uncertainty estimates for greenhouse gases are given in Annex II.

4.2.1.6. Source specific QA/QC and verification

The general QA/QC methodology is given in Section 1.6 and the specific QA/QC carried out for Industrial processes is described in Annex III.

Statistics Norway occasionally calculate alternative emission figures for CO_2 and compare them with the emission figures reported by the plants to the Norwegian Pollution Control Authority to check if they are reasonable. The calculations are based on the clinker production (reported annually from the plants to the Statistic Norway). The emission factors used are recommended by SINTEF (1998a) and based on the actual composition of the raw materials used. These emission factors are calculated particularly for the two Norwegian plants and are 0.520 and 0.541 tonne CO_2 per tonne clinker respectively. The IPCC default emission factor is 0.5071 tonne CO_2/tonne clinker. The calculated emission figures agree quite well with emissions figures reported by the plants.

4.2.1.7. Recalculations

There has been no recalculation since NIR 2008.

4.2.1.8. Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2010.

4.2.2. Lime Production – 2A2

4.2.2.1. Description

Three plants that produce lime in Norway reported CO_2 emissions from processes to SFT. The GHG emissions from lime production represent 1.1 per cent of the total emission from Industrial processes in 2007.

4.2.2.2. Methodological issues

All three plants calculate the emissions of CO_2 based on actual production volumes of lime and plant specific emission factors for CO_2 from limestone and dolomite respectively. The emissions are reported to the SFT. For one of the plants, SFT has estimated the emissions for 2002-2004 based on activity data and plant specific emission factors. SFT has also interpolated the emissions for the years 1991-1997 for the same plant. .

4.2.2.3. Uncertainties

Uncertainty estimates for greenhouse gases are given in Annex II.

4.2.2.4. Source specific QA/QC and verification

The general QA/QC methodology is given in Section 1.6 and the specific QA/QC carried out for Industrial processes is described in Annex III.

4.2.2.5. Recalculations

There has been no recalculation since NIR 2008.

4.2.2.6. Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2010.

4.2.3. Limestone and Dolomite Use - 2A3

4.2.3.1. Description

Two plants report emissions from limestone and dolomite use to SFT. One plant neutralizes sulphuric acid waste with limestone and fly ash. This produces CO_2. The use of fly ash decrease the CO_2 emissions compared with when limestone is used. The second plant is a brick producer and uses limestone in its production. The GHG emissions from this source category in 2007 were 0.3 per cent of the total emission from Industrial processes.

4.2.3.2. Methodological issues

The plants report emission figures of CO_2 to SFT. The emissions are calculated by multiplying the amount of sulphuric acid and limestone with emission factors.

4.2.3.3. Emission factors

An emission factor of 0.45 tonnes CO_2 per tonne sulphuric acid is used by the plant, calculated from the reaction equation. The brick producing plant uses an emission factor of 0.440 tonnes CO_2 per tonne $CaCO_3$.

4.2.3.4. Uncertainties

Uncertainty estimates for greenhouse gases are given in Annex II. .

4.2.3.5. Source specific QA/QC and verification

The general QA/QC methodology is given in Section 1.6 and the specific QA/QC carried out for Industrial processes is described in Annex III.

4.2.3.6. Recalculations

The minor emissions of CO_2 from a brick producing plant, previously not estimated, have been included for the whole period 1990-2006.

4.2.3.7. Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2010.

4.3. Chemical Industry – 2B

In the Norwegian inventory, there are 14 different activities included under chemical industry. Nearly all emissions figures from this industry included in the inventory are reported figures from the plants to the SFT. Table 4.3 shows what GHGs that is emitted from which industry, tier of methodology and if the source category is key category or not.

Table 4.3. Chemical industry. Components emitted and included in the Norwegian inventory.

	CO_2	**CH_4**	**N_2O**	**NMVOC**	**Tier**	**Key category**
Ammonia	R	NA	NA	NA	Tier 2	Yes
Nitric acid	NA	NA	R	NA	Tier 2	Yes
Silicon carbide	R+E	R/E	NA	NA	Tier 2	Yes
Calcium carbide	R	NA	NA	R	Tier 1	No
Methanol	E	R	NA	R	Tier 2	No
Plastic	R+E	R	NA	R	Tier 2	No

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

4.3.1. Ammonia Production – CO_2 - 2B1 (Key category)

4.3.1.1. Description

In Norway ammonia is produced by catalytic steam reforming of wet fuel gas (containing ethane, propane and some buthane). This is one of the steps during fertilizer production. Hydrogen is needed to produce ammonia, and wet fuel gas is the basis for the production of hydrogen. A substantial amount of CO_2 is recovered from the production process.

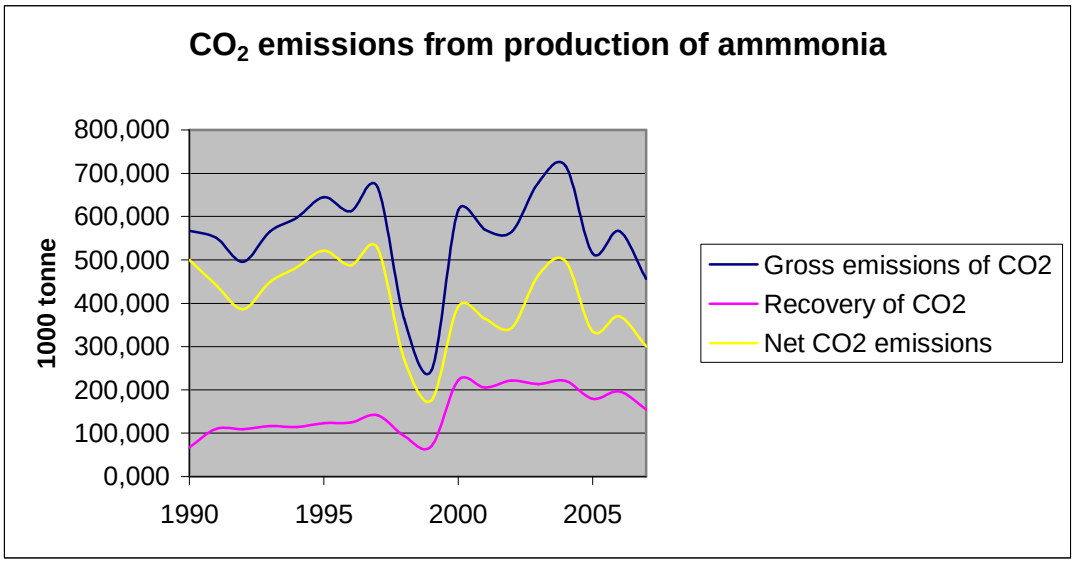
The net CO_2 emissions from production of ammonia represented 3.6 per cent of the GHG emissions from Industrial processes and 0.6 per cent of the Norwegian emissions in 2007.

The gross CO_2 emissions from the production process were about 20 per cent lower in 2007 compared to 1990 while the net emissions decreased with 40 per cent in the period. The reduction in the net emissions is due to that the amount of recovered CO_2 increased by about 130 per cent. From 2006 to 2007 the gross, net and recovered CO_2 all decreasd by about 20 per cent.

In 2007, 155 kilo tonnes CO_2 were captured and sold, see Figure 4.1. The variation in the amount of CO_2 captured is from about 70 k tonnes, in 1990 and 1999, to about 200 kilo tonnes in the years 2000-2006.

According to the Tier 1 key category analysis ammonia production is defined as key category due to contribution in level and trend.

Figure 4.1 CO_2 emissions from production of ammonia.



Source: SFT

4.3.1.2. Methodological issues

The CO_2 emission figures in the Norwegian emission inventory model are based on annually reports from the plant. The plant calculates the emissions by multiplying the amount of each gas used with gas specific emission factor.

The plant has reported consistent figures back to 1990. A part of the CO_2, which is generated during the production process, is captured and sold to other objectives et cetera soft drinks, and therefore deducted from the emission figures for this source and reported in *2D2 Food and Drink*. Some of the captured CO_2 is exported to other countries but is nevertheless included in the Norwegian GHG Inventory.

4.3.1.3. Activity data

The total amount of gas consumed is annually reported by the plant to SFT. As a part of the official Industrial statistics gas consumed is also reported to Statistics Norway who use these figures for the QA/QC calculations by alternative method.

4.3.1.4. Emission factors

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

4.3.1.5. Uncertainties

The amount of gas is measured by using turbine meters and the meters are controlled by the Norwegian Metrology Service. The uncertainty in the measurement of propane and butanes is calculated to ± 0.2 and ethane ± 0.13 per cent. The mix of propane/butanes is as average 60 per cent propane and 60% butanes.

4.3.1.6. Source specific QA/QC and verification

The general QA/QC methodology is given in Section 1.6 and the specific QA/QC carried out for Industrial processes is described in Annex III.

The figures reported from the plant are compared to calculations done by Statistics Norway based on total amount of gas consumed and an emission factor on 3 tonnes CO_2/tonne LPG recommended by IPCC (1997b). The calculated emissions figures agree quite well with emissions figures reported by the enterprises.

4.3.1.7. Recalculations

There has been no recalculation since NIR 2008.

4.3.1.8. Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2010.

4.3.2. Production of Nitric Acid –N_2O - 2B2 (Key Category)

4.3.2.1. Description

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

The two plants have together five production lines. One production line was rebuilt in 1991 and in 2006 two lines were equipped with the technology - N_2O decomposition by extension of the reactor chamber. Full effect of implementing the latter technology will be reached in 2007. Figure 4.3 shows that the production specific N_2O emissions were reduced substantially

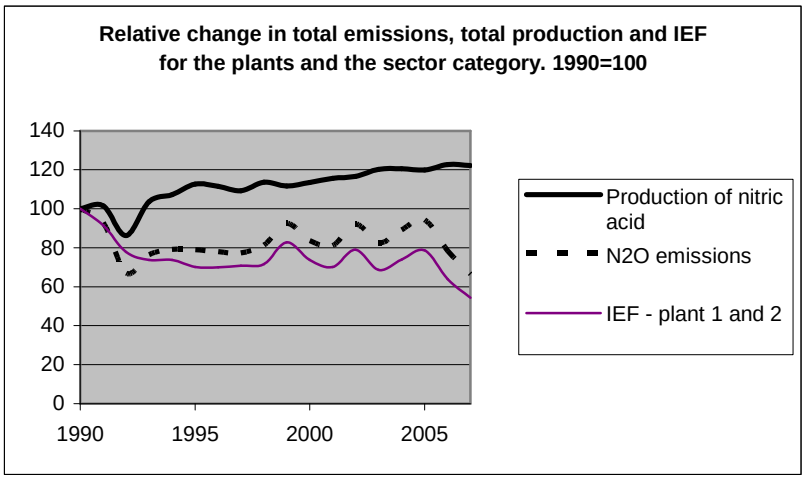
in the early 90ties. The reduced emissions were due to rebuilding of one production line in 1991 and that a larger part of the production became from that line. From 1992 approximately 50 per cent of the total production of nitric acid is from that production line.

The N_2O emissions are based on continuous measurement at two of the production lines that represent about 60 per cent of the production. At three other lines the emissions are based on monthly measurements, two of the lines, and weekly measurements at the last production line. The fluctuation in IEFs is assumed to explain by how the emissions are measured.

The N_2O emissions from production of nitric acid accounted for 2.5 per cent of the total GHG emissions in 2007, and 15.0 per cent of the GHG emissions in sector Industrial processes. The N_2O emissions have decreased with 34 percent from 1990 to 2007 while the production of nitric acid increased by 22 percent. Corresponding changes from 2006 to 2007 was 15 per cent decrease in N_2O emissions and 0.4 percent reduction in production.

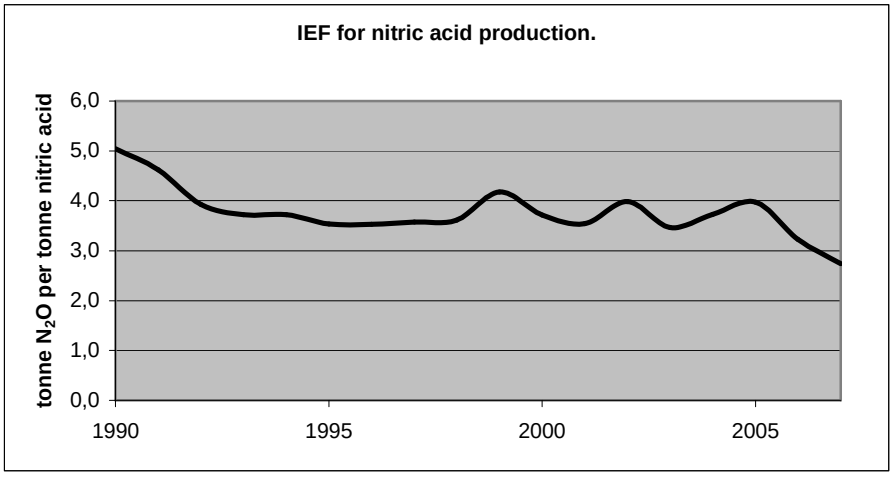
Production of nitric acid is defined as key category both in level and trend according to the Tier 2 key category analysis.

Figure 4.2 Relative change in total emissions, total production and IEF for nitric acid production. 1990=100



Source: SFT

Figure 4.3 IEF for nitric acid production. Tonne N_2O per tonne nitric acid. 1990=100



Source: SFT

4.3.2.2. Methodological issues

NO_2

The two plants report the emissions of N_2O to SFT. The N_2O emissions have been continuously measured since 1991 at one production line and from 2000 at another. The emissions at the three other production lines are based on monthly and weekly measurements.

4.3.2.3. Activity data

The plants report the production of HNO_3 to SFT.

4.3.2.4. Uncertainties

Uncertainty estimates for greenhouse gases are given in Annex II. The uncertainty in the measurements is estimated by the plant to ±7 (SFT 2000). However, in the 2006 report to SFT one plant reports that the uncertainty in measurement of N_2O is calculated to ±1-3 per cent.

4.3.2.5. Source specific QA/QC and verification

The general QA/QC methodology is given in Section 1.6 and the specific QA/QC carried out for Industrial processes is described in Annex III.

The plants report the production of HNO_3 to SFT. They compare trends in the production data with the trend in N_2O emission and use this as a quality check.

4.3.2.6. Recalculations

The reported figure on N_2O emissions from one plant in 2006 has been altered.

4.3.2.7. Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2010.

4.3.3. Silicon Carbide – 2B4 (Key Category)

4.3.3.1. Description

Silicon carbide has been produced at three plants until 2006 when one plant was closed down.

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

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

$$CO \xrightarrow{O_2} CO_2$$

In the production of silicon carbide, CO_2 and CO is released as a by-product from the reaction between quartz and carbon. Methane (CH_4) may be emitted from petrol coke during parts of the process and sulphur origin from the petrol coke.

The GHG emissions from production of silicon carbide accounted for 0.1 per cent of the total GHG emissions in 2007, and 0.8 per cent of the GHG emissions in sector Industrial processes. The emissions were reduced by 67.3 per cent in the years 1990- 2007 and increased by 3.2 per cent from 2006 to 2007. The large decrease from 1990 to 2007 is due to reduced production and that one plant was closed down in 2006. The fluctuation in emissions over the years is due to variation in production of crude silicon carbide.

According to the Tier 2 key category analysis carbide production is defined as key category due to change in trend.

4.3.3.2. Methodological issues

Norway changed in NIR 2006 the method for calculating CO_2 from silicon carbide production from the mass balance method described in the Revised 1996 IPCC Guidelines (using input of reducing agents) to an EF-based method (using crude silicon carbide production as activity data). Both methods are regarded as being Tier 2 methods in IPCC 2006. During the review of the initial report in 2007 the reviewer raised question to the change of method but concluded after consideration that the two methods provide very similar results, except for 1990, and that the use of the present method is justified.

CO_2
Emission figures are reported annually by the three plants to the SFT.

CO_2 from process is calculated based on the following equation:

(4.3) $CO_2 = \Sigma$ *Activity data * Emission factor*

The three production sites have used amount of produced crude silicon carbide as activity data in the calculation of CO_2 emissions.

NMVOC
Emission figures are reported to the Norwegian Pollution Control by the plants. The emissions are calculated by multiplying annual production of silicon carbide by an emission factor.

Indirect emission of CO_2 is calculated by Statistics Norway based on the emission of CH_4.

CH_4
The emission of CH_4 from production of silicon carbide is calculated based on the following equation:

(4.4) $CO_2 = \sum Activity\ data_i * Emission\ factor_i$

The three production sites has used amount of produced crude silicon carbide as activity data and a plant specific emission factor.

CO
The emissions of CO are calculated by Statistics Norway from the consumption of petrol coke and an emission factor.

4.3.3.3. Activity data

The activity data used by the plants for the calculation of CO_2 and CH_4 are the amount of produced crude silicon carbide. The activity data used by Statistics Norway for the calculation of CO is the consumption of petrol coke as reported to Statistics Norway.

4.3.3.4. Emission factors

CO_2
All three sites have changed their emission factor to the default factor of 2.62 ton CO_2/ton crude silicon carbide (IPPC 2006), see Table 4.4.

CH_4
For calculation of methane emissions the plant specific emission factor 4.2 kg CH_4/tonne crude SiC is used, see Table 4.4.

Documentation of the choice and uncertainties of the emission factor is given in Section 4.3.3.5.

CO
The emission factor is in accordance with the IPCC Guidelines (IPCC 1997b).

Table 4.4. Emission factor for CO_2, CH_4 and CO used for silicon carbide production.

Component	Emission factor	Source
CO_2	2.62 tonnes CO_2/tonnes crude SiC	IPCC 2006
CH_4	4.2 tonnes CH_4 /tonnes crude SiC	PS
CO	0.4 tonnes CO/tonnes petrol coke	Rosland (1987)

NMVOC
From 2007 and onwards the emission factor is based on measurements made once a year. The emission factors for 2007 for are 10.906 t NMVOC/kt Sic for Washington Mills and 10.84 t NMVOC/kt Sic for Saint Gobain. For previous years, the emission factor for Saint Gobain is more or less constant whereas the emission factor for Washington Mills varies.

Uncertainties

CO_2

Activity data: The three productions sites use the amount of produced crude silicon carbide as activity data. The uncertainty of the activity data given as this production figure is calculated to be ± 3 per cent.

Emission factor: When using the standard emission factor of 2.62 tonne CO_2/tonnes SiC, the uncertainty range is estimated to be – 16 % to - +7 %. This can be explained due to variations in raw materials as well as process variations, and is based on previous development of site specific emissions factors (SINTEF 1998 e).

The carbon content in coke is varying, normally from 85 to 92 % carbon. The coke is also varying in the content of volatile components, e.g hydrocarbons. There are also variations in the process itself. The Acheson process is at batch process, and the reactions include many part reactions that differ from batch to batch, because of variations in the mix of quarts and coke, the reactivity of the coke etc. The process variations described above is the reason why the factor presented in tonne CO_2/tonn coke used is not constant. For Washington Mills the factor is in the range 1.07-1.27. For Saint Gobain one has to look at the two plants in Lillesand and Arendal together, because the input and output from them are somewhat mixed together. The factor for them is in the range 0.99-1.24.This implies that the output of SiC will have some variation from batch to batch.

The justification of changing method is that the IEF tonne CO_2 /tonne coke varies over the years due to variation in carbon content in coke and that this variation is larger or in the same order of variation that the production of crude silicon carbide. In addition there is a relatively large difference in the carbon consumption data in the early 1990s due to the use of purchase data as a proxy for carbon consumption. The silicon carbide production data in the early 1990s especially is considered being more accurate than the coke consumption.

Emissions: The total uncertainty of the resulting emissions of CO_2, based on uncertainties in activity data and emissions factor, is calculated to be in the range of – 20 % to + 10 %.

CH_4

Activity data: The three production sites use the amount of produced crude silicon carbide as activity data. The uncertainty of the activity data given as this production figure is calculated to be ± 3%.

Emission factor:

The emission factor of 4.2 kg CH_4/tonne SiC is used, and the uncertainty level is estimated to be ± 30%.

The following explains the calculation of emission factor and the uncertainty level:

The production of SiC is a batch process with duration of about 43 hours. The CH_4-concentration (ppm) is monitored continuously the first 6.5 hours. After this, only control monitoring is carried out. The results show that the concentration of CH_4 is peaking in the first hour of the process, giving a CH_4 concentration 10 – 15 times higher than in the last 36 hours of the process. A typical level of the concentration of CH_4 is given in Figure 4.4 below.

If the CH_4-concentration is averaged over the total batch time of 43 hours, this will give an emissions factor of 4.2 kg CH_4/tonne SiC, i.e. 3.5 kg CH_4/tonne petrol coke.

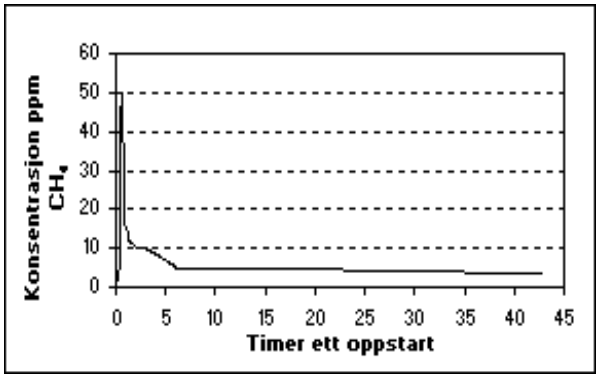


Figure 4.4 Concentration of CH_4 for one batch of SiC.

To establish the uncertainty level, the following assessments was done:

- The uncertainty in monitoring of concentration is normally ± 5 per cent (expert judgment).
- The uncertainty of monitoring of the amount of gas is within ± 15 per cent (type of monitoring equipment).
- The uncertainty of the production of SiC for each batch is stable, and is assessed to be within a level of ± 5 per cent.
- The uncertainties of raw materials and process variation add ± 5 per cent.

If these uncertainties are added, the estimate result of total uncertainties for the resulting emissions of CH_4 is ± 30 per cent.

4.3.3.5. Source spesific QA/QC and verification

The general QA/QC methodology is given in Section 1.6 and the specific QA/QC carried out for Industrial processes is described in Annex III.

4.3.3.6. Recalculations

Emissions of NMVOC from production of crude silicon carbide have been estimated by the plants for the whole period from 1990, and are for the first time included in the emission inventory.

4.3.3.7. Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2010.

4.3.4. Production of Calcium Carbide – 2B4

4.3.4.1. Description

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

The reaction
(4.5) $CaCO_3 \rightarrow CaO + CO_2$
which takes place when limestone (calcium carbonate) is heated.

The reactions
(4.6) $CaO + C \text{ (petrol coke)} \rightarrow CaC_2 + CO$
(4.7) $CO \xrightarrow{O_2} CO_2$
where petrol coke is used as a reducing agent to reduce the CaO to calcium carbide.

4.3.4.2. Methodological issues

The CO_2 figures in the National GHG emission inventory are based on emission figures reported from the plant to SFT. The emission estimates are based on the amount of calcium carbide produced each year and an emission factor estimated by (SINTEF 1998e). Some of the carbon from petrol coke will be sequestered in the product, but not permanently. Thus, this carbon is included in the emission estimate.

4.3.4.3. Activity data

The amount of calcium carbide produced is reported by the plant to SFT.

4.3.4.4. Emission factors

The emission factor used by the plants in the calculation of CO_2 has been estimated by (SINTEF 1998e) to be 1.71 tonne/ tonne included 0.02 t CO_2 /t CaC_2 from fuel. In the CRF the emissions from fuels is reported in the Energy chapter. (SINTEF 1998e) conclude that the one reason for the difference between the factors is that the IPCC assumes that all calcium carbonate is calcinated. However, in the production process at the plant they first produced CaC_2 that gives CO_2 emissions. Some of the CaC_2 was then refined to DICY in a process that consumed CO_2. This CO_2 gas was collected from one of the first steps of the CaC_2 production. The net consumption of CO_2 in production of DICY is according to SINTEF about 1.3 tonne CO_2 per tonne DICY produced. This implies that the specific CO_2 IEF fluctuates.

4.3.4.5. Uncertainties

Uncertainty estimates for greenhouse gases are given in Annex II.

4.3.4.6. Source specific QA/QC and verification

The general QA/QC methodology is given in Section 1.6 and the specific QA/QC carried out for Industrial processes is described in Annex III.

4.3.4.7. Recalculations

There has been no recalculation since NIR 2008.

4.3.4.8. Planned improvements

Since the plant is closed down there is no further planned activity to review historical data.

4.3.5. Production of Methanol - 2B5

4.3.5.1. Description

One plant in Norway produces methanol. Natural gas and oxygen are used in the production of methanol. The conversion from the raw materials to methanol is done in various steps and on different locations at the plant. CH_4 and NMVOC are emitted during the production process. Emissions from flaring of natural gas by production of methanol are now as recommended by IPCC's review team reported under 2B5

Indirect emissions of CO_2 are calculated by Statistics Norway based on the emission of CH_4 and NMVOC, see chapter 1.3.3.

4.3.5.2. Methodological issues

The plant reports emission figures of CH_4 and NMVOC to SFT. The reported emissions are based on measurement.

4.3.5.3. Emission factors

Emission factors for flare of natural gas are for CO_2: 2340 tonnes/Sm^3, for CH_4 0.24 tonnes/Sm^3 and for N_2O: 0.02 tonnes/Sm^3.

4.3.5.4. Uncertainties

Uncertainty estimates for greenhouse gases are given in Annex II.

4.3.5.5. Source specific QA/QC and verification

The general QA/QC methodology is given in Section 1.6 and the specific QA/QC carried out for Industrial processes is described in Annex III.

4.3.5.6. Recalculations

There has been no recalculation since NIR 2008.

4.3.5.7. Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2010.

4.3.6. Production of Plastic 2B5

4.3.6.1. Description

Three plants report emission under this source category. Two of the plants were one plant up to 2001. One of the plants produces ethylene and propylene where the other has vinyl chloride production. Various components are emitted during the production of plastic.

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

During the production process of ethylene and vinyl chloride there is an oxide chloride step for production of ethylene chloride followed by cracking to vinyl chloride monomer and hydrochloric acid.

4.3.6.2. Methodological issues

CO_2, CH_4 and NMVOC

Emission figures are annually reported to SFT. CO_2 from combustion is based on gas specific emissions factors and activity data. CH_4 and NMVOC emissions reported are based on measurements.

Indirect emissions of CO_2 calculated by Statistics Norway are based on the emission of CH_4 and NMVOC.

4.3.6.3. Uncertainties

It is difficult to measure leakages of CH_4 and NMVOC and therefore the uncertainty is regarded as being large. Uncertainty estimates for greenhouse gases are given in Annex II.

4.3.6.4. Source specific QA/QC and verification

The general QA/QC methodology is given in Section 1.6 and the specific QA/QC carried out for Industrial processes is described in Annex III.

4.3.6.5. Recalculations

There has been a minor change in indirect CO_2 emissions from one plant in 2006, due to altered figure for reported NMVOC emissions.

4.3.6.6. Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2010.

4.3.7. Production of Explosives - 2B5

4.3.7.1. Description

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

4.4. Metal Production – 2C

Metal production in Norway includes plants producing iron and steel, ferroalloys, aluminium, nickel zinc and also magnesium until spring 2006. Production of anodes is also included in this chapter. Nearly all emissions figures from the production of metals included in the inventory are figures reported annually from the plants to the SFT.

Approximately 10 per cent of total GHG emissions in Norway were from Metal Production in 2007, and the sector contributed with nearly 61 per cent of the emissions from Industrial Processes. The largest contributor to the GHG emissions from Metal Production in 2007 is Aluminum production and ferro alloys.

The emissions from Metal Production decreased by 43.3 per cent from 1990-2007 and increased by 4.6 per cent from 2006-2007. The reduction from 1990-2007 was due to decreased PFC and SF_6 that again was due to improvement in technology aluminum

production and the close down of a magnesium plant in 2006. The CO_2 emissions from Metal Production increased by 10.4 per cent from 1990-2007 and by 6.9 percent from 2006-2007.

Table 4.5 Metal production. Components emitted and included in the Norwegian inventory.

	CO_2	**CH_4**	**PFCs**	**SF_6**	**Tier**	**Key category**
2C1 Iron and steel	R	NA	NA	NA	Tier 2	Yes
2C2 Ferroalloys	R	R	NA	NA	Tier 2/3	Yes
2C3 Primary aluminium	R	NA	R	R	Tier 2	Yes
2C4 Secondary aluminium	NA	NA	NA	R	Tier 1	No
2C4 Magnesium	E	NA	NA	R	Tier 2	Yes
2C5 Nickel	R	NA	NA	NA	Tier 2	No
2C5 Anodes	R	NA	NA	NA	Tier 2	No

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

4.4.1. Production of Iron and Steel – 2C1

4.4.1.1. Description

Three plants producing iron and steel are included in the Norwegian Inventory. In Norway, iron is produced from ilmenite and coal is used as a reducing agent. Various components are emitted during the production process. Process emissions of CO_2 from an iron/steel production are primary from coal used as a reducing agent.

According to the Tier 1 key category analysis CO_2 emissions from production of iron and steel are key category in level and trend.

4.4.1.2. Methodological issues

In the Norwegian GHG Inventory, emission figures of CO_2, annually reported to the SFT, are used. These emission figures are based on calculations.

4.4.1.3. Uncertainties

Uncertainty estimates for greenhouse gases are given in Annex IV.

4.4.1.4. Source specific QA/QC and verification

The general QA/QC methodology is given in Section 1.6 and the specific QA/QC carried out for Industrial processes is described in Annex III. CO_2 emission figures reported to SFT are compared with calculations at Statistics Norway using the amount of reducing agent and emission factors. This method is recommended by IPCC when data from measurements are not available.

Annually reported emission figures are first controlled by the SFT and then Statistics Norway.

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

4.4.1.5. Recalculations

As stated under 1A2a, CO_2 emissions from one plant, which previously were registered as combustion emissions, have now been split between process and combustion for the whole period 1990-2006, thus causing an increase in process emissions.

4.4.1.6. Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2010.

4.4.2. Production of Ferroalloys - CO_2 - 2C2 (Key Category)

4.4.2.1. Description

There were 12 plants producing ferroalloys in Norway in 2006. One plant closed down in 2001, two plants were closed down during 2003 and two in 2006. The plant that was out of production in 2006 started up again in 2007. Ferrosilicon, silicon metal, ferromanganese and silicon manganese are now produced in Norway. Ferrochromium was produced until the summer in 2001. Ferro silicon with 65 to 96 percent Si and silicon metal with 98-99 percent Si is produced. The raw material for silicon is quarts (SiO_2). SiO_2 is reduced to Si and CO using reducing agents like coal, coke and charcoal.

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

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

In ferroalloy production, raw ore, carbon materials and slag forming materials are mixed and heated to high temperatures for reduction and smelting. The carbon materials used are coal, coke and some bio carbon (charcoal and wood). Electric submerged arc furnaces with graphite electrodes or consumable Soederberg electrodes are used. The heat is produced by the electric arcs and by the resistance in the charge materials. The furnaces used in Norway are open, semi-covered or covered.

Several components are emitted from production of ferroalloys. Emission of CO_2 is a result of the oxidation of the reducing agent used in the production of ferroalloys. In the production of FeSi and silicon metal NMVOC and CH_4 emissions originates from the use of coal and coke in the production processes. From the production of ferro manganes (FeMn), silicon manganes (SiMn) and ferrochromium (FeCr) there is only CO_2 emissions.

Measurements performed at Norwegian plants producing ferro alloys indicates that in addition to emissions of CO_2 and CH_4 also N_2O is emitted. The emissions of CH_4 and N_2O are influenced by the following parameters:

- The silicon level of the alloy (65, 75, 90 or 98 % Si) and the silicon yield
- The method used for charging the furnace (batch or continuously)
- The amount of air used to burn the gases at the top controlling the temperature in off gases.

The GHG emissions (CO_2, CH_4 and N_2O) from ferroalloy production accounted for 5.2 per cent of the national total GHG emissions in 1990 and 3.9 per cent in 2007. The GHG (CO_2, CH_4 and N_2O) emissions from production of ferroalloy decreased by 16.7 per cent from 1990 to 2007. From 2006 to 2007 the GHG emissions from ferroalloy production increased by 17.2 per cent.

According to the Tier 2 key category analysis CO_2 emissions from production of ferroalloys are key category in level due to uncertainty in emission factors and the large share of total emissions.

4.4.2.2. Methodological issues

CO_2
The methods used in the calculation of CO_2 emissions form production of ferroalloy is in accordance with the method recommended by the IPCC (IPCC 1997b), GPG (IPCC 2001) and the 2006 Guidelines adopted by IPCC in April this year. Emissions are reported by each plant in an annual report to the SFT.

The plants have used two different methods for calculating CO_2-emissions:

1. Mass balance; the emissions for CO_2 is calculated by adding the total input of C in raw materials before subtracting the total amount of C in products, wastes and sold gases (Tier 3)
2. Calculate emission by multiplying the amount of reducing agents in dry weight with country specific emission factors for coal, coke, petrol coke, electrodes, anthracite, limestone and dolomite. (Tier 2)

The two methods are regarded as being consistent and each plant have used the same method for the entire time series.

Indirect emissions of CO_2 are calculated based on the emission of CH_4 and NMVOC.

CH_4 and N_2O
The emissions of CH_4 and N_2O are calculated by multiplying the amount of ferroalloy produced with an emission factor. Emissions are reported by each plant in an annual report to the SFT.

Plants producing ferro manganes, silicon manganes and ferrochromium do not emit emissions of CH_4 and N_2O.

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

4.4.2.3. Activity data

CO_2
Calculation of emissions is based on the consumption of gross reducing agents and electrodes in the production of ferroalloys.

CH_4 and N_2O

The gross production of different ferroalloys is used in the calculation.

NMVOC
The gross amount of reducing agents that are used for the calculation of NMVOC emissions are annually reported to Statistics Norway from each plant.

4.4.2.4. Emission factors

CO_2
The carbon content of each raw materials used in the Tier 3 calculation is from carbon certificates from the suppliers. The carbon in each product, CO gas sold et cetera is calculated from the mass of product and carbon content.

In the Tier 2 calculation the emission factors are from SINTEF (1998b, 1998c and 998d) and the factors are listed in Table 4.6.

Table 4.6. Emission factors from production of ferroalloys. Tonnes CO_2/tonne reducing agent or electrode.

	Coal	**Coke**	**Electrodes**	**Petrol coke**	**Carbonate ore**	**Dolomite Limestone**
Ferro silicon	3.08	3.36	3.36	--	--	--
Silicon metal	3.12	3.36	3.54	--	--	--
Ferro chromium	--	3.22	3.51	--	--	--
Silicon manganese	--	3.24	3.51	3.59	0.16- 0.35	0.43-0.47
Ferro manganese	--	3.24	3.51	3.59	0.16- 0.35	0.43-0.47

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

CH_4 and N_2O
Measurements performed at Norwegian plants producing ferro alloys indicate emissions of N_2O in addition to CH_4. The emissions of CH_4 and N_2O are influenced by the following parameters:

- The silicon level of the alloy (65, 75, 90 or 98 % Si) and the silicon yield
- The method used for charging the furnace (batch or continuously)
- The amount of air used to burn the gases at the top controlling the temperature in off gases.

Measurements campaigns at silicon alloy furnaces have been performed since 1995, and these measurements is the base for the values in the BREF document for silicon alloys. The results of the measurements, that the emissions factors in the Norwegian CH_4 and N_2O are based upon, are presented in SINTEF (2004a). A summary of the report is given in the publication Reduction of emissions from ferroalloy furnaces SINTEF (2004b). Main focus for the studies has been NO_x emissions. However, the emissions of CH_4 and N_2O have also been measured.

Full scale measurements have been performed at different industrial FeSi/Si furnaces. The average CH_4 and N_2O concentrations in the ferroalloy process are with some exceptions a few ppm. For N_2O and CH_4 the exception is during spontaneous avalanches in the charge (i.e. collapse of large quantities of colder materials falling into the crater or create cavities) occur from time to time, see Figure 7 in SINTEF (2004b). In the avalanches the N_2O emissions goes from around zero to more that 35 ppm. The avalanches are always short in duration. There are also increased N_2O emissions during blowing phenomenon.

The EF used in the inventory represents the longer-term average N_2O and CH_4 concentration measurements outside the peaks in concentrations. The peaks in concentration occur due to avalanches (sudden fall of large amount of colder charge into the furnace) that occur from time to time is not fully reflected in the EFs. The EFs used we regard as conservative particular for the early 1990s when the avalanches were more frequent than the latest years.

All companies apply sector specific emission factors in the emission calculation, see Table 4.7. The factors are developed by the Norwegian Ferroalloy Producers Research Organisation (FFF) and standardized in meeting with The Federation of Norwegian Process Industries (PIL) (today named Federation of Norwegian Industries) in February 2007.

Table 4.7. Emission factors for CH_4 and N_2O from production of ferroalloys. Emission factors in kg per tonne produced ferroalloy.

Alloy, charging routines and temperature	Si-met			FeSi-75%			FeSi-65%		
	Batch-charging	Sprinkle-charging [1]	Sprinkle-charging and >750℃ [2]	Batch-charging	Sprinkle-charging[1]	Sprinkle-charging and >750℃ [2]	Batch-charging	Sprinkle-charging[1]	Sprinkle-charging and >750℃ [2]
kg CH_4 per tonne metal	0.1187 M	0.0881 M	0.1000 E	0.0890 E	0.0661 E	0.0750 E	0.0772 E	0.0573 E	0.0650 E
kg N_2O per tonne metal	0.0433 E	0.0214 E	0.0252 E	0.0297 E	0.0136 E	0.0161 E	0.0117 E	0.0078 E	0.0097 E

1 Sprinkle-charging is charging intermittently every minute.
2 Temperature in off-gas channel measured where the thermocouple cannot 'see' the combustion in the furnace hood.
M=measurements and E= estimates based un measurements

NMVOC
Statistics Norway uses an emission factor of 1.7 kg NMVOC/tonne coal or coke (EPA 1986) in the calculations.

4.4.2.5. Uncertainties

The uncertainty in activity data and emission factors have been calculated to ±5 per cent and ±7 per cent respectively, see Annex II.

4.4.2.6. Source specific QA/QC and verification

The general QA/QC methodology is given in Section 1.6 and the specific QA/QC carried out for Industrial processes is described in Annex III. The reported emissions from the plants were compared with emissions data given in the white book and other relevant data available. In some cases, the emission data were verified by making control calculation based on emission factors and activity data. In all cases, the construction of charts and figures of emissions and activity data helped identifying missing data and possible errors.

All the main producers of ferroalloys in Norway were contacted and asked to supply missing emissions data and activity, and to explain any possible errors identified. The feedback from the companies made it possible to make corrections and filling of gaps in the series of data.

A complete time series from 1990 to 2004 could be established for all three relevant greenhouse gas parameters for most companies. Data from the white book and the reported company data corresponded well.

During the review of the initial report in the 2007 activity data like coal, coke, electrodes, petrol coke and bio carbon were collected from each plant once again and so was emissions of CH_4 and N_2O based on EFs shown in Table 4.7. With very few exceptions the AD reported in the CRF is data that the plants have reported to SFT. The IEF for the sector and also for each plant is fluctuating from year to year mainly due to variation in sold CO and in production of ferro alloy products.

Statistics Norway makes in addition 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.

4.4.2.7. Recalculations

CO_2 emissions from some plants have been adjusted slightly downwards for 2006, as the previous figures also included combustion emissions. As combustion emissions also were calculated separately in the 2008 submission, a double counting has accordingly been corrected.

4.4.2.8. Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2010.

4.4.3. Production of Primary Aluminium –CO_2 and PFC - 2C3 (Key Category)

4.4.3.1. Description

There are seven plants in Norway producing aluminium. Both prebaked anode and the Soederberg production methods are used. In the Soederberg technology, the anodes are baked in the electrolysis oven, while in the prebaked technology the anodes are baked in a separate plant. In general the emissions are larger from the Soederberg technology than from the prebaked technology.

Production of aluminium leads to emission of various components as CO_2, SO_2, NO_x, perfluorocarbons (PFCs), heavy metals and persistent organic pollutants. The emission of CO_2 is due to the electrolysis process during the production of aluminium, while the SO_2 emissions are from the sulphur in the reducing agents used. NO_X is primary produced by the high temperature oxidation of nitrogen in the air. All plants also report emissions of particles, heavy metals and PAH. Emissions of heavy metals are due to the metal content in the raw materials used and the reducing agents.

There has been a substantial reduction in the total PFC emissions from the seven Norwegian aluminium plants in the period from 1990 to 2007. This is a result of the sustained work and the strong focus on reduction of the anode effect frequency in all these pot lines and that there

has been a shift from Soederberg to prebaked technology. The focus on reducing anode effect frequency started to produce results from 1992 for both technologies. For prebaked technology the PFC emissions per tonne aluminium were reduced from 2.57 in 1990 to 1.98 in 1991 and 0.96 in 1992 and respective values fro Soederberg were 5.61, 5.29 and 5.03. In 2007 the specific PFC emissions were for prebaked and Soederberg 0.40 and 1.57 kg CO_2-equivalent, see Figure 4.5. In 1990 57 per cent of the aluminium production in Norway was produced with prebaked technology and the share of aluminium production from prebaked was increased to 83 per cent in 2007. Two new plants with prebaked technology were established in 2002 and two plants using Soederberg technology were closed down in 2001 and 2003.

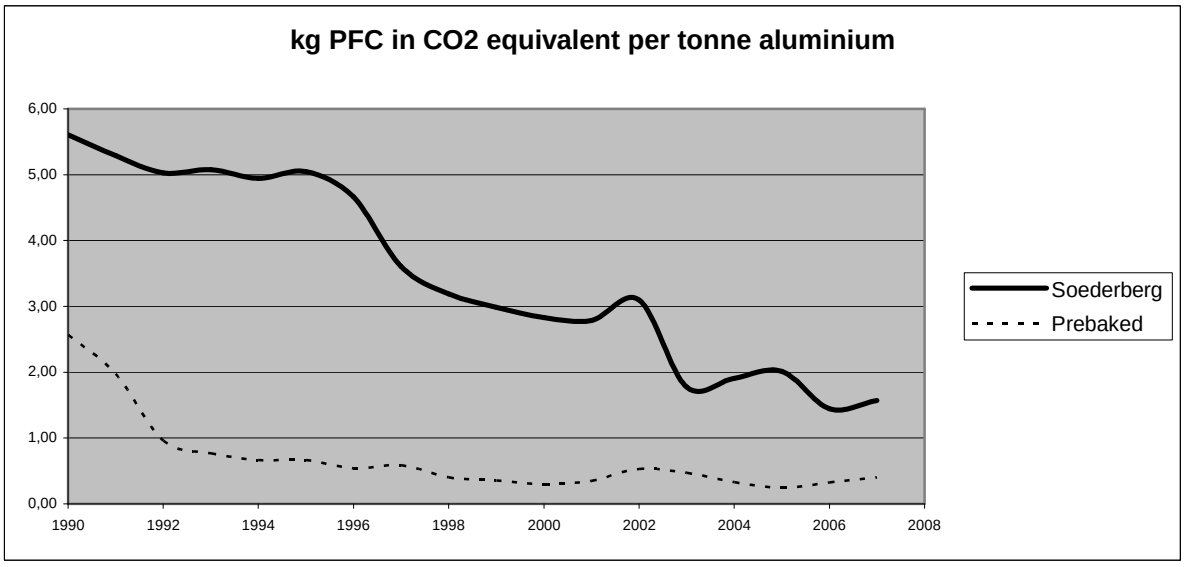
PFCs emissions from production of aluminium contribute in 1990 to 6.8 per cent of the total GHG emissions in Norway. The share of the totals in 2007 is reduced to 1.5 per cent. Emissions of PFCs are decreased with 76.2 per cent from 1990 to 2007. However, between 2006 and 2007 the emissions have increased by 7.9 per cent.

The PFC emissions per tonne aluminium produced in Norway was 3.88 kg CO_2-equivalent in 1990 and 0.60 kg CO_2-equivalent in 2007. This is a reduction of 84 per cent from 1990 to 2007. However, there was an increase of 12 per cent from 2006 to 2007. The increase in specific emissions in 2007 was due to plant specific conditions..

An increase in production capacity is also included in the modernisation, leading to higher emissions of CO_2.

PFCs and CO_2 emissions from aluminium production are both key category in level, PFC also in trend both according to the Tier 2 key category analysis.

Figure 4.5 kg PFC in CO2 equivalent per tonne aluminium



4.4.3.2. Methodological issues

CO_2

The inventory uses the emission figures reported to SFT, calculated by each plant 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.

Previously, Statistics Norway estimated the CO_2-emissions from consumption data provided by the enterprises but now figures reported by the plants to SFT are used. Reported figures are available since 1992. For 1990 and 1991 there were no data, hence recalculation was made using production data and reported emissions data for 1992.

The aluminium industry calculates the CO_2 emissions separate for each technology. The following methods are used:

CO_2 from Prebake Cells

(4.9) Q = A*C*3.67

- Where
- Q is the total yearly emissions of CO_2
- A is the yearly net consumption of anodes
- C is per cent carbon in the anodes
- 3,67 is the mol-factor CO_2/C

CO_2 from Soederberg Cells
*(4.10) Q = S*3.67*(K*C1+P*C2)*
- Where
- Q is the total yearly emissions of CO_2
- S is the yearly consumption of Soederberg paste
- K is the share of coke in the Soederberg paste
- P is the share of patch in the Soederberg paste
- K+P=1
- C1 is the fraction of carbon in the coke. Fraction is per cent Carbon/100
- C2 is the fraction of carbon in the peach. Fraction is per cent Carbon/100

PFCs
Perfluorinated hydrocarbons (PFCs), e.g. tetrafluoromethane (CF_4) and hexafluoroethane (C_2F_6), are produced during anode effects (AE) in the Prebake and Soederberg cells, when the voltage of the cells increases from the normal 4-5V to 25-40V. During normal operating condition, PFCs are not produced. The fluorine in the PFCs produced during anode effects originates from cryolite. Molten cryolite is necessary as a solvent for alumina in the production process.

Emissions of PFCs from a pot line (or from smelters) are dependent on the number of anode effects and their intensity and duration. Anode effect characteristics will be different from plant to plant and also depend on the technology used (Prebake or Soederberg).

During electrolysis two per fluorocarbon gases (PFCs), tetrafluormethane (CF_4) and heksafluorethane (C_2F_6), may be produced in the following reaction:

Reaction 1

$$4Na_3AlF_6 + 3C \rightarrow 4Al + 12NaF + 3CF_4$$

Reaction 2

$$4Na_3AlF_6 + 4C \rightarrow 4Al + 12NaF + 2C_2F_6$$

The national data are based on calculated plant specific figures from each of the seven Norwegian plants. We have used the Tier 2 method in our calculations, which are based on a technology specific relationship between anode effect performance and PFCs emissions. The PFCs emissions are then calculated by the so-called slope method, where a constant slope coefficient, see Table 4.8, given as kg CF_4/tonne Al/anode effect minutes per cellday, is multiplied by the product of anode effect frequency and anode effect duration (in other words, by the number of anode effect minutes per cell day), and this product is finally multiplied by the annual aluminum production figure (tonnes of Al/year). The formula for calculating the PFCs is:

$$\text{kg } CF_4 \text{ per year} = S_{CF4} \bullet AEM \bullet MP$$

and

$$\text{kg } C_2F_6 \text{ per year} = \text{kg } CF_4 \text{ per year} \bullet F_{C2F6/CF4}$$

Where :

S_{CF4} = "Slope coefficient" for CF_4, (kg $_{PFC}/t_{Al}$/anode effect minutes/cell day

AEM = anode effect minutes per cell day

MP = aluminium production, tonnes Al per year

$F_{C2F6/CF4}$ = weight fraction of C_2F_6/CF_4

Table 4.8. Technology specific slope and overvoltage coefficients for the calculation of PFCs emissions from aluminium production.

Technology [a]	"Slope coefficient" [b, c] (kg $_{PFC}/t_{Al}$)/ (anode effect/cellday)		Weight fraction C_2F_6/CF_4	
	S_{CF4}	Uncertainty **(±%)**	$F_{C2F6/CF4}$	**Uncertainty (±%)**
CWPB	**0.143**	**6**	**0.121**	**11**
SWPB	**0.272**	**15**	**0.252**	**23**
VSS	**0.092**	**17**	**0.053**	**15**
HSS	**0.099**	**44**	**0.085**	**48**

a. Centre Worked Prebake (CWPB), Side Worked Prebake (SWPB), Vertical Stud Søderberg (VSS), Horizontal Stud Søderberg (HSS).

b. Source: Measurements reported to IAI, US EPA sponsored measurements and multiple site measurements.

c. Embedded in each slope coefficient is an assumed emission collection efficiency as follows: CWPB 98%, SWPB 90%, VSS 85%, HSS 90%. These collection efficiencies have been assumed based on measured PFC collection fractions, measured fluoride collection efficiencies and expert opinion.

Slope coefficient": The connection between the anode parameters and emissions of PFC.

Measurements of PFCs at several aluminium plants have established a connection between anode parameters and emissions of CF_4 and C_2F_6. The mechanisms for producing emissions of PFC are the same as for producing CF_4 and C_2F_6. The two PFC gases are therefore

considered together when PFC emissions are calculated. The C_2F_6 emissions are calculated as a fraction of the CF_4 emissions.

The Tier 2 coefficients for Centre Worked Prebaked cells (CWPB) are average values from about 70 international measurement campaigns made during the last decade, while there are fewer data (less than 20) for Vertical Stud Soederberg cells (VSS). The main reason for the choice of the Tier 2 method is that the uncertainties in the facility specific slope coefficients is lower than the facility specific based slope coefficients in Tier 3. This means that there is nothing to gain in accuracy of the data by doing measurements with higher uncertainties.

"Slope coefficient" is the number of kg CF_4 per tonne aluminium produced divided by the number of anode effects per cell day. The parameter cell day is the average number of cells producing on a yearly basis multiplied with the number of days in a year that the cells have been producing.

Sulphur hexafluoride (SF_6)
SF_6 used as cover gas in the aluminium industry is assumed to be inert, and SF_6 emissions are therefore assumed to be equal to consumption. At one plant SF_6 was used as cover gas in the production of a specific quality of aluminium from 1992 to 1996. The aluminium plant no longer produces this quality, which means that SF_6 emissions have stopped.

4.4.3.3. Emission factors

In the present calculations we have calculated the PFC emissions using the newest Tier 2 recommended values by IAI for CF_4 (the slope coefficients of 0.143 kg CF_4/tonne Al/anode effect minutes per cell day for CWPB and 0.092 for VSS). The amount of C_2F_6 is calculated from the Tier 2 values for CF_4, where the weight fraction of C_2F_6 to CF_4 is set equal to 0.121 for CWPB and 0.053 for VSS. This change alone increases the calculated CO_2-equivalent emissions by 10% for our prebake cells, because of the high global warming potential for C_2F_6.

Thus, all the values we have used in our present calculations are technology specific data, recommended by IAI. Our facility specific measured data that we have used until today are all in agreement with these data, within the uncertainty range of the measurement method employed.

4.4.3.4. Activity data

Both production data and consumption of reducing agents and electrodes is reported annually to SFT.

PFCs
The basis for the calculations of PFCs is the amount of primary aluminium produced in the pot lines and sent to the cast house. Thus, any remelted metal is not included here.

4.4.3.5. Uncertainties

Uncertainty estimates for greenhouse gases are given in Annex II.

PFCs
The uncertainties in the so-called Tier 2 slope coefficients from IAI is lower (6% and 17% for CWPB and VSS cells, respectively), compared to the measured facility specific based slope coefficients, where the uncertainties are around 20%, even when the most modern measuring equipment is used (the continuous extractive-type Fourier Transform Infrared (FTIR) spectroscopic system). Control measurements in two Hydro Aluminium plants (Karmøy and Sunndal) done by Jerry Marks in November 2004, showed that the measured values for CWPB and VSS cells were well within the uncertainty range of the Tier 2 slope coefficients.

4.4.3.6. Source specific QA/QC and verification

The general QA/QC methodology is given in Section 1.6 and the specific QA/QC carried out for Industrial processes is described in Annex III.

CO_2
It was possible to establish data series of CO_2 from 1990 to 2004 for all plants. There are still some discrepancies between reports of process related CO_2 and energy related CO_2, especially in the beginning of the 1990s. This is because it was difficult to provide sufficient energy data to calculate the energy related combustions.

The emission figures reported by the plants are also controlled by Statistics Norway. Statistics Norway make their own estimates based on the consumption of reducing agents and production data collected in an annual survey and average emission factors.

Percflourocarbons (PFCs)
The emission figures from the aluminium plants are reported to SFT annually. As a quality control, it is checked that the reports are complete. Each figure is compared with similar reports from previous years and also analysed taking technical changes and utilisation of production capacity during the year into account. If errors are found the SFT contacts the plant to discuss the reported data and changes are made if necessary.

SFT has regular meetings with the aluminium industry where all plants are represented. This forum is used for discussion of uncertainties and improvement possibilities.

SFT's auditing department are regularly auditing the aluminium plants. As part of the audits, their system for monitoring, calculation and reporting of emissions are controlled.

4.4.3.7. Recalculations

There has been no recalculation since NIR 2008.

4.4.3.8. Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2010.

4.4.4. Production of Secondary Aluminium – 2C4

4.4.4.1. Description

One open mill in Norway is handling secondary aluminium production. For earlier years there have been some emissions of SF_6.

4.4.5. Production of magnesium –SF_6 - 2C4 (Key Category)

4.4.5.1. Description

There is one plant in Norway producing magnesium. The plant closed down the production of primary magnesium in 2002 but the production of cast magnesium is continuing. From the mid-1970s, both the magnesium chloride brine process and the chlorination process were used for magnesium production. Since 1991, only the chlorination process was in use.

Production of magnesium leads to process related CO_2 and CO emissions. During the calcinations of Dolomite ($MgCa(CO_3)_2$) to magnesium oxide, CO_2 is emitted. During the next step, magnesium oxide is chlorinated to magnesium chloride and coke is added to bind the oxygen as CO and CO_2. SO_2 is emitted due to the sulphur in the reducing agent used.

In the foundry, producing cast magnesium, SF_6 is used as a cover gas to prevent oxidation of magnesium. The Norwegian producers of cast magnesium has assessed whether SF_6 used a cover gas reacts with other components in the furnace. The results indicate that it is relatively inert, and it is therefore assumed that all SF_6 used as cover gas is emitted to airs.

SF_6 from magnesium foundries accounted in 1990 for 4.3 per cent of the national total GHG emissions. The emissions have decreased and this is due to improvements in technology and in process management. The primary magnesium production stopped in 2002 and only secondary production is retained and this production has no CO_2 emissions from processes. During 2006 also the production of remelting Mg stopped and there were no emissions from this source in 2007.

SF_6 emissions from magnesium foundries are, according to the Tier 1 key category analysis, defined as key category in level and trend.

4.4.5.2. Methodological issues

CO_2
The IPCC (1997b) recommends using the consumption of reducing agent as the activity data for estimating emissions. (SINTEF 1998f), on the other hand, recommends using production volume in the calculations. The Norwegian emission inventory use production data as activity data. The CO_2 emissions are therefore calculated by using annually production volume and the emission factor recommended by (SINTEF 1998f).

SF_6
The consumption figures of the cover gas (SF_6) are used as the emission estimates in accordance with the IPCC Guidelines (IPCC 1997a, 1997b). The SF_6 emissions are reported annually to SFT.

Studies performed by the Norwegian producer have assessed that SF_6 used as cover gas is inert. Therefore the consumption of SF_6 is uses as the emission estimate in accordance with the IPCC Inventory Guidelines and Good Practice Guidance.
The plant reports the emissions each year to SFT.

4.4.5.3. Activity data

The GHG emission inventory we use production volumes as activity data in the calculation of CO_2. This method is recommended by (SINTEF 1998f). The plant reports the consumption of SF_6 to SFT.

4.4.5.4. Emission factor

An emission factor of 4.07 tonnes CO_2/tonnes produced magnesium is used to calculated the annually emissions of CO_2 (SINTEF 1998f).

4.4.5.5. Uncertainties

The uncertainty in the emissions is assumed to be ± 5 per cent, see Annex II.

4.4.5.6. Source specific QA/QC and verification

The general QA/QC methodology is given in Section 1.6.

Last years reported emission data from the plant is compared with previously reported data and the emissions are compared with the production.

4.4.5.7. Recalculations

There has been no recalculation since NIR 2008.

4.4.5.8. Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2010.

4.4.6. Production of Nickel - 2C5

4.4.6.1. Description

One plant in Norway produces nickel. During the production of nickel CO_2 are emitted. CO_2 is emitted in the production of nickel due to the soda from the production of nickel carbonate and use of coke as a reducing agent.

4.4.6.2. Methodological issues

CO_2
Emission figures are annually reported from the plant to the SFT and based on calculation of material balance.

4.4.6.3. Uncertainties

Uncertainty estimates for greenhouse gases are given in Annex II.

4.4.6.4. Source specific QA/QC and verification

The general QA/QC methodology is given in Section 1.6 and the specific QA/QC carried out for Industrial processes is described in Annex III. There is no source specific QA/QC procedure for this sector. See section 1.6 for the description of the general QA/QC procedure.

4.4.6.5. Recalculations

There has been no recalculation since NIR 2008.

4.4.6.6. Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2010.

4.4.7. Manufacture of Anodes - 2C5

4.4.7.1. Description

Three plants in Norway produce anodes (Årdal, Sunndal and Mosjøen). Prebaked anodes and coal electrodes are alternatives to the use of coal and coke as reducing agents in the production process for aluminium and ferroalloys. The anodes and coal electrodes are produced from coal and coke. The production of anodes and coal electrodes leads to emissions of CO_2.

4.4.7.2. Methodological issues

The emissions of CO_2 are calculated by each plant and the method is based on the Aluminium Sector Greenhouse Gas Protocol by the International Aluminium Institute (IAI, 2005a).

4.4.7.3. Uncertainties

Uncertainty estimates for greenhouse gases are given in Annex II.

4.4.7.4. Source specific QA/QC and verification

The general QA/QC methodology is given in Section 1.6 and the specific QA/QC carried out for Industrial processes is described in Annex III.

4.4.7.5. Recalculations

The CO_2 figures for 2005-2006 from one anode producing plant have been somewhat reduced.

4.4.7.6. Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2010.

4.5. Other Production – 2D

4.5.1. Pulp and paper - 2D1

4.5.1.1. Description

There are CO_2 emissions from non-combustion from one plant in this sector. The emissions originate from the limestone. Emissions from combustion is included in Chapter 3.

4.5.1.2. Methodological issues

The CO_2 emissions are calculated by multiplying the amount of limestone by an emission factor. For the years 1990-97 the emissions are calculated by SFT based upon activity data reported to SFT by the plant and emission factor. The emissions in the period 1998-2004 are reported in the plant's application for CO_2-permits within the Norwegian emissions trading scheme. From 2005 and onwards, the plant reports the emissions through the annual reporting under the emissions trading scheme.

4.5.1.3. Activity data

Activity data is reported by the plant to SFT. The amount of limestone is calculated from purchased amount.

4.5.1.4. Emission factors

The emission factor used in the calculation is 0.44 CO_2 per tonne limestone.

4.5.1.5. Uncertainties

No source specific uncertainty is known.

4.5.1.6. Source specific QA/QC and verification

The general QA/QC methodology is given in Section 1.6 and the specific QA/QC carried out for Industrial processes is described in Annex III.

4.5.1.7. Recalculations

There has been no recalculation since NIR 2008.

4.5.1.8. Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2010.

4.5.2. Food and drink - CO_2 - 2D2

4.5.2.1. Description

This source category includes NMVOC emissions from production of bread and beer, CO_2 from carbonic acid mainly used in breweries, export of captured CO_2 and CO_2 from production of bio protein.

As mentioned in Section 4.3.1 Ammonia Production, some CO_2 from this production is captured and in Norway mainly used as carbonic acid in carbonated beverages but most of the captured CO_2 is exported. The whole tonnage, inland use and exported volume, is reported under this category, 2D2. The largest part of the emissions takes place after the bottles is opened and not in the breweries. In 2007, about 155 ktonnes CO_2 were sold for national use and export.

4.5.2.2. Methodological issues

CO_2
The figures are based on the sale statistics from the ammonia producing plant.

NMVOC
Production of bread and beer (and other similar yeast products) involves fermentation processes that lead to emission of NMVOC (ethanol). Emissions are calculated based on production volumes and emission factors.

Production of Bio Protein CO_2
CO_2 emissions from production of bio protein from natural gas are included from the year 2001 when this production started. The bio protein is being used as animal fodder. Emission data reported from the plant to the SFT are included in the national inventory.

4.5.2.3. Activity data

NMVOC
Production volumes of bread and beverage are annually reported to Statistics Norway.

4.5.2.4. Emission factors

- *NMVOC*
- The emission factors in Table 4.10 are taken from (EEA 1996).

Table 4.9. NMVOC emission factors from production of bread and beverage.

	Emission factor	Unit
Production of bread	0.003	tonnes/tonnes produced
Production of beverage	0.2	kg/1000 litre

Source: EEA (1996)

4.5.2.5. Uncertainties

NMVOC
The emission factors used is recommended by EEA (1996) and not specific for Norwegian conditions.

4.5.2.6. Source specific QA/QC and verification

NMVOC
The general QA/QC methodology is given in Section 1.6 and the specific QA/QC carried out for Industrial processes is described in Annex III.

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

4.5.2.7. Recalculations

There has been no recalculation since NIR 2008.

4.5.2.8. Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2010.

4.6. Consumption of Halocarbons and SF_6

4.6.1. HFCs and PFCs from Products and Processes – HFC - 2F (Key Category)

4.6.1.1. Description

HFCs and PFCs can be used as substitutes for ozone depleting substances (CFCs and HCFCs) that are being phased out according to the Montreal Protocol. They are used in varied applications, including refrigeration and air conditioning equipment, as well as in foam blowing, fire extinguishers, aerosol propellants and analysing purposes. There are no production of HFCs and PFCs in Norway. However, PFCs are emitted as a by-product during the production of aluminium, see chapter 4.4.3.5. The most significant gases, measured in CO_2 equivalents are HFC-134a, HFC-143a and HFC-125. Measured in metric tonnes emissions of the low-GWP HFC-152a are also significant. The use of PFCs in product-applications is very low e.g. due to high taxation.

In January 2003 a tax on import and production of HFC and PFC was introduced. In July 2004 this tax was supplemented with a refund for the destruction of used gas. In 2007 the tax and refund were both 193.98 NOK (approximately 22Euro) per tonnes of CO_2-equivalents. Based on these new realities a project was established to review the emission calculations of HFC and PFC. This work (Statistics Norway (2007/8)) was completed in mars 2007 and is reflected in this report.

HFC emissions increased from 0,52 Mtonnes CO2-equivalents in 2006 to 0,57 Mtonnes CO2-equivalents in 2007, and constitute 1 % of total emissions in Norway.

This sector (2F) is according to the Tier 2 key category analysis defined as key category due to uncertainty in trend.

4.6.1.2. Method

Actual emissions of HFCs and PFCs are calculated using the Tier 2 methodology. This methodology takes into account the time lag in emissions from long lived sources, such as refrigerators and air-conditioning equipment. The chemicals slowly leak out from seams and ruptures during the lifetime of the equipment. The leakage rate, or emission factor, varies considerably depending on type of equipment.

Potential emissions are calculated employing the Tier 1b methodology, which only considers the import, export and destruction of chemicals in bulk and in products without time lag. It

was found that the ratio between potential (Tier 1b) and actual emissions (Tier 2) was about 2:1 in 2007.

4.6.1.3. Activity data

There is no production of HFC or PFC in Norway. Hence all emissions of these chemicals originate from imported chemicals. Imported and exported amounts of chemicals in bulk are collected annually by the Norwegian Pollution Control Authority. Imported and exported amounts of chemicals in products for the years 1995-1997 were collected through a survey in 1999 (SFT 1999a), and this information was used to estimate imports and exports the years prior to and after the survey. For the source category refrigeration, data on imports from customs statistics were used to update the estimated amounts for 1998-2006.

4.6.1.4. Emission factors

Leakage rates and product lifetimes used in the calculations are shown in Table 4.10.

Table 4.10. Emission factors for HFCs from products and lifetime of products

Application category	Annual emissions during lifetime (per cent of initial charge) 1990-2006	Lifetime of pro-ducts (years)
Refrigeration and air conditioning		
Household refrigerators and freezers		1
Commercial and industrial applications, imported	3	1
Refrigerated transport, imported	2	1
Air conditioning aggregates and heat pumps, imported		1
Water/liquid refrigerating aggregates, water-based heat pumps, imported		1
Stationary equipment produced in Norway	1	1
Mobile air conditioners	1	1
Foam		
Polyurethane with diffusion barrier		4
Polyurethane without diffusion barrier		2
Extruded polystyrene		3
Fire extinguishers		1
Solvents	5	
Aerosol propellants	5	

Source: Hansen (2007)

4.6.1.5. Uncertainties

The uncertainties of the different components of the national greenhouse gas inventory have been evaluated in detail in 2006 by Statistics Norway (See annex II). Both the leakage rate (emission factor) and the stored amount of chemicals (activity data) are considered quite

uncertain. The total uncertainties for the emission estimates by the consumption of halocarbons are estimated to be ±50 per cent for both HFC and PFC.

4.6.1.6. 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.

4.6.1.7. Recalculations

Revisions of activity data for 2005 and 2006 for several gases contributed to minor changes (< 1 per cent) in estimated emissions. Activity data on imports of PFC-218 and HFC-134 for earlier years were also revised, but had insignificant effect on the estimated emissions from HFCs and PFCs.

In the previous inventory the data for import of HFCs (mainly HFC-134a) in mobile air conditioning for 2005 and 2006 was set equal to the estimated imports in 2004. In the present inventory the import was calculated based on the average annual increase for previous years.

4.6.1.8. Planned improvements

The methodology will progressively be improved as new import statistics and information from users and sectors become available.

4.6.2. Emissions of SF_6 from Products and Processes – 2F

4.6.2.1. Description

In mars 2002 a voluntary agreement was signed between the Ministry of Environment and the most important users and producers of GIS. According to this agreement emission from this sector should be reduced by 13 per cent in 2005 and 30 per cent in 2010 with 2000 as base year. For the following up of this agreement, the users (electricity plants and -distributors) and producers (one factory) report yearly to the government.

4.6.2.2. Methodological issues

The general methodology for estimating SF_6 emissions was revised in 1999 (SFT 1999d), while the sector-specific methodology for GIS has been revised in this years reporting based on new information from the agreement. The current method for GIS is largely in accordance with the Tier 3a methodology in the IPPC Good Practice Guidance (IPCC 2000). The method for other sources is largely in accordance with the Tier 2 methodology in the IPPC guidelines for emission inventories (IPCC 1997a,b). The calculations take into account imports, exports, recycling, accumulation in bank, technical lifetimes of products, and different rates of leakage from processes, products and production processes. From 2003 and onwards emission estimates reported directly from users and producers, according to the voluntary agreement, are important input.

Emissions from production of GIS (one factory) were included for the first time in 2003. The company has, as part of the voluntary agreement with the Ministry of the Environment, made detailed emission estimates back to 1985. These emissions constitute a significant part of national emissions of SF_6. In recent years emissions rates have been considerably reduced due

to new investments and better routines. The company now performs detailed emission calculations based on accounting of the SF_6 use throughout the whole production chain.

Emissions from a small number of GIS users that are not part of the agreement are calculated with emission factors from Table 4.13. They account for 1-2 per cent of total emissions from GIS use.

4.6.2.3. Activity data

Data is collected from direct consultations with importers and exporters of bulk chemicals and products containing SF_6, and from companies that use SF_6 in various processes.

4.6.2.4. Emission factors

Leakage rates and product lifetimes used in the calculations are shown in Table 4.11 and 4.12.

Table 4.11. Yearly rate of leakage of SF_6 from different processes

Emission source	**Leakage rate (per cent of input of SF_6)**
Secondary magnesium foundries	100
Tracer gas in the offshore sector	0
Tracer gas in scientific experiments	100
Production of semiconductors	50
Medical use (retinal surgery)	100
Production of sound-insulating windows	2
Other minor sources	100

Source: SFT (1999d).

Table 4.12 Product lifetimes and leakage rates from products containing SF_6

Product emission source	**Yearly rate of leakage**	**Product lifetime (years)**
Sealed medium voltage switchgear	0.1	30
Electrical transformers for measurements	1	30
Sound-insulating windows	1	30
Footwear (trainers)	25	9
Other minor sources	..	..

Source: SFT (1999d).

4.6.2.5. Source specific QA/QC and verification

During the work on the new methodology for 2005 emissions, historical data were recalculated, emission factors from different sources were established and the bank of SF_6 in existing installations was estimated. For GIS, information from the industry, attained through the voluntary agreement with the Ministry of Environment, was important input in this recalculation.

4.6.2.6. Recalculations

There has been no recalculation since NIR 2008.

4.6.2.7. Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2010.

4.6.3. Paraffin wax use – 2G

4.6.3.1. Description

Paraffin waxes are produced from crude oil and used in a number of different applications, including candles, tapers and the like. Combustion of such products results in emissions of fossil CO_2.

Emissions from the incineration of products containing paraffin wax, such as wax coated boxes, are covered by emissions estimates from waste incineration.

4.6.3.2. Methodological issues

Emissions of CO_2 from the burning of candles, tapers and the like are calculated using a modified version of equation 5.4 for Waxes – Tier 1 Method of the 2006 IPCC Guidelines:

(4.11) $Emissions = PC * PF * \cdot CC_{Wax} * \cdot 44/12$

Where:

- Emissions = CO_2 emissions from waxes, tonne CO_2
- PC = total candle consumption, TJ
- PF = fraction of candles made of paraffin waxes
- CC_{Wax} = carbon content of paraffin wax (default), tonne C/TJ (Lower Heating Value basis)
- 44/12 = mass ratio of CO_2/C

Consumption figures on paraffin waxes are multiplied by the default net calorific values (NCV). Net consumption in calorific value is then converted to carbon amount, using the value for carbon content (Lower Heating Value basis) and finally to CO_2 emissions, using the mass ratio of CO_2/C.

4.6.3.3. Activity data

Statistics Norway collects data on import, export and sold produce of “Candles, tapers and the like (including night lights fitted with a float)”. Using theses data, net consumption of paraffin waxes and other candle waxes (including stearin) can be calculated.

4.6.3.4. Emission factors

Parameter values used in the emissions calculations are given in Table 4.13.

Table 4.13 Parameters employed when calculating emission

Parameters	Factor	Unit	References
Net calorific value (NCV)	40.20	TJ/Gg	2006 IPCC
Carbon content (CC_{Wax}, Lower Heating Value basis)	20.00	tonnes C/TJ = kg C/GJ	2006 IPCC
Mass ratio of CO_2/C	3.67	-	
Fraction of paraffin wax (PF)	0.66	-	

The assumption of 0.66 as the fraction of all candles being made of paraffin waxes is based on estimates obtained from one major candle and wax importer (estimating ca. 0.5) and one Norwegian candle manufacturer (estimating ca 0.8). The importer estimated the fraction to be ca. 5 per cent higher in 1990. However, since this possible change is considerably smaller than the difference between the two fraction estimates, we have chosen to set this factor constant for the whole time series. The fraction of paraffin waxes has probably varied during this period, as it, according to the importer, strongly depends on the price relation between paraffin wax and other, non-fossil waxes. However, at present we do not have any basis for incorporating such factor changes.

Furthermore, we assume that practically all of the candle wax is burned during use, so that emissions due to incineration of candle waste are negligible.

4.6.3.5. Uncertainties

According to the 2006 IPCC Guidelines, the default emission factors are highly uncertain. However, the default factor with the highest uncertainty is made redundant in our calculations, due to the level of detail of our activity data.

4.6.3.6. Source specific QA/QC and verification

There is no specific QA/QC procedure for this sector. See section 1.5 for the description of the general QA/QC procedure.

4.6.3.7. Recalculations

There has been no recalculation since NIR 2008.

4.6.3.8. Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2010.

5. Solvent and other product use

5.1. Overview

This chapter describes emissions from solvents and other products. Use of solvents and products containing solvents result in emissions of non-methane volatile organic compounds (NMVOC), which is regarded as an indirect greenhouse gas. The NMVOC emissions will over a period of time in the atmosphere oxidise to CO_2.

In addition to solvents emitting NMVOC, there are other products that emit other volatile components. Emissions of N_2O from anaesthesia procedures and spray cans are included in the Norwegian inventory.

In 2007, the total emissions from solvents and other product use totalled 0,187 million tonnes of CO_2-equivalents. This represented approximately 0.3 per cent of the total GHG emissions in 2007. The emissions have decreased by 1.7 % compared to 1990 and increased by 3.0 % from 2006.

5.2. Solvent losses (NMVOC)

5.2.1. 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, which is included in the total greenhouse gas emissions reported to UNFCCC.

Solvents and other product use are non-key categories.

5.2.2. Method

Our general model is a simplified version of the detailed methodology described in chapter 6 of the EMEP/CORINAIR Guidebook 2007 (EEA 2007). It represents a mass balance *per substance*, where emissions are calculated by multiplying relevant activity data with an emission factor. For better coverage, point sources reported from industries to the Norwegian Pollution Control Authority and calculated emissions from a side model for cosmetics are added to the estimates. For a detailed description of method and activity data, see Holmengen and Kittilsen (2009).

It is assumed that all products are used the same year as they are registered, and substances are not assumed to accumulate in long-lived products. In other words, it is assumed that all emissions generated by the use of a given product during its lifetime take place in the same year as the product is declared to our data source, the Norwegian Product Register. In sum, this leads to emission estimates that do not fully reflect the actual emissions taking place in a given year. Emissions that in real life are spread out over several years all appear in the emission estimate for the year of registration. However, this systematic overestimation for a given year probably more or less compensates for emissions due to previously accumulated amounts not being included in the estimate figures.

No official definition of solvents exists, and a list of substances to be included in the inventory on NMVOC emissions was thus created. The substance list used in the Swedish NMVOC inventory (Skårman et al. 2006) was used as a basis. This substance list is based on the definition stated in the UNECE Guidelines[5]. The list is supplemented by NMVOC reported in the UK's National Atmospheric Emissions Inventory (NAEI) (AEA Energy and Environment 2007). The resulting list was comprised by 678 substances. Of these, 355 were found in the Norwegian Product Register for one or more years in the period 2005-2007.

Cosmetics

Cosmetics are not subject to the duty of declaration. The side model is based on a study in 2004, when the Norwegian Pollution Control Authority calculated the consumption of pharmaceuticals and cosmetics (SFT 2005a). The consumption was calculated for product groups such as shaving products, hair dye, body lotions and antiperspirants. The consumption in tonnes each year is calculated by using the relationship between consumption in Norwegian kroner and in tonnes in 2004. Figures on VOC content and emission factors for each product group were taken for the most part from a study in the Netherlands (IVAM 2005), with some supplements from the previous Norwegian solvent balance (the previous NMVOC emission model).

NMVOC and CO_2

The use of solvents leads to emissions of non-methane volatile organic compounds (NMVOC) which is regarded as an indirect greenhouse gas. The NMVOC emissions will over a period of time in the atmosphere oxidise to CO_2, which is included in the total greenhouse gas emissions reported to UNFCCC (see chapter 1.9.).

5.2.3. Activity data

The data source is the Norwegian Product Register. Any person placing dangerous chemicals on the Norwegian market for professional or private use has a duty of declaration to the Product Register, and import, export and manufacturing is reported annually. The only exception is when the amount of a given product placed on the market by a given importer/producer is less than 100 kg per year.

The information pertained in the data from the Product Register makes it possible to analyse the activity data on a substance level, distributed over product types (given in UCN codes; Product Register 2007), industrial sectors (following standard industrial classification (NACE; Statistics Norway 2003), including private households (no NACE), or a combination of both. As a consequence, the identification of specific substances, products or industrial sectors that have a major influence on the emissions is greatly facilitated.

Cosmetics

The side model for cosmetics is updated each year with data on from the Norwegian Association of Cosmetics, Toiletries and Fragrance Suppliers (KLF).

Point sources

Data from nine point sources provided by the Norwegian Pollution Control Authority is added to the emissions estimates. The point sources are reported from the industrial sector "Manufacture of chemicals and chemical products" (NACE 24). In order to avoid double counting, NMVOC used as raw materials in this sector are excluded from the emission estimates from the Product Register data.

[5] "Volatile compound (VOC) shall mean any organic compound having at 293.15 degrees K a vapor pressure of 0.01 kPa or more, or having a corresponding volatility under the particular conditions of use."

5.2.4. Emission factors

Emission factors are specific for combinations of product type and industrial sector. Emission factors are gathered from the Swedish model for estimating NMVOC emissions from solvent and other product use (Skårman et al. 2006). The emission factors take into account different application techniques, abating measures and alternative pathways of release (e.g. waste or water). These country-specific emission factors apply to 12 different industries or activities that correspond to sub-divisions of the four major emission source categories for solvents used in international reporting of air pollution (European Environment Agency 2007).

It is assumed that the factors developed for Sweden are representative for Norwegian conditions, as we at present have no reasons to believe that product types, patterns of use or abatement measures differ significantly between the two countries. Some adjustments in the Swedish emission factors were made (See Holmengen and Kittilsen (2009)).

In accordance with the Swedish model, emission factors were set to zero for a few products that are assumed to be completely converted through combustion processes, such as EP-additives soldering agents and welding auxiliaries. Quantities that have not been registered to industrial sector or product type are given emission factor 0.95 (maximum). Emission factors may change over time, and such changes may be included in this model. However, all emission factors are at the moment constant for all years.

5.2.5. Uncertainty

Uncertainty in emission factors

The emission factors are more detailed in the new NMVOC model than in the previous model, as this model can take into account that emissions are different in different sectors and products, even when the substance is the same. However, for this to be correct, a thorough evaluation of each area of use is desirable, but not possible within a limited time frame. Thus, the emission factor is set with general evaluations, which leads to uncertainty.

The emission factors are gathered from several different sources, with different level of accuracy. The uncertainties in emission factors depend on how detailed assessment has been undertaken when the emission factor was established. Some emission factors are assumed to be unbiased, while others are set close to the expected maximum of the range of probable emission factors. This, together with the fact that the parameter range is limited, gives us a non-symmetrical confidence interval around some of the emission factors. For each emission factor we thus have two uncertainties; one negative (n) and one positive (p). These are aggregated separately, and the aggregated uncertainty is thus not necessarily symmetrical.

Uncertainty in activity data

For the activity data, the simplified declarations and the negative figures due to exports lead to known overestimations, for which the uncertainty to a large extent is known. A more elaborate problem in calculations of uncertainty is estimating the level of omissions in declaration for products where the duty of declaration does apply. In addition, while declarations with large, incorrect consumption figures are routinely identified during the QA/QC procedure, faulty declarations with small consumption figures will only occasionally be discovered. There is however no reason to believe that the Product Register data are more uncertain than the data source used in the previous model (statistics on production and external trade), as similar QA/QC routines are used for these statistics.
The errors in activity data are not directly quantifiable. Any under-coverage in the Product Register is not taken into account. Skårman et al. (2006) found that the activity data from the Swedish Product register had an uncertainty of about 15 per cent. The Norwegian Product

Register is assumed to be comparable to the Swedish, and thus the uncertainty in the activity data is assumed to be 15 per cent. For some products, simplified declarations give an indication of maximum and minimum possible amounts. In these cases, the maximum amount is used, and the positive uncertainty is set to 15 per cent as for other activity data, while the negative uncertainty is assumed to be the interval between maximum and minimum amount. All activity data are set to zero if negative.

For a detailed description of the uncertainty analysis, see Holmengen and Kittilsen (2009). The variance of total emission was estimated from the variance estimates obtained for emission factors and activity data, using standard formulas for the variance of a sum and the variance of a product of independent random variables. The aggregated uncertainties in level and trend are given in table 5.1 and 5.2.

Table 5.1 Uncertainty estimates for level in NMVOC emissions, 2005-2007. Tonnes and per cent

Uncertainty in level	Negative (n)	Negative (n) (per cent of total emissions)	Positive (p)	Positive (p) (per cent of total emissions)
2005	2 288	4.58	1 437	2.88
2006	1 651	3.70	1 103	2.47
2007	1 299	2.79	1 168	2.51

Table 5.2 Uncertainty estimates for trend in NMVOC emissions, 2005-2007. Tonnes

Uncertainty in trend	**Negative (n)**	**Positive (p)**	**95% confidence interval for change**
2005-2006	2 135	1 067	(-7 366 , -4 164)
2006-2007	1 420	947	(407 , 2 774)
2005-2007	1 882	1 076	(-5 286 , -2 328)

5.2.6. Completeness
No major missing emission sources are likely.

5.2.7. Source specific QA/QC and verification
Internal checks of the time-series of calculated emissions data and input activity data have been conducted by Statistics Norway and corrections are made when errors are found.

5.2.8. Planned improvements
There is no planned activity this year that will improve the data quality for NIR 2010.

5.2.9. Recalculations
The whole time series 1990-2006 has been recalculated. The indirect CO_2 emissions from solvents have risen by 10-25 ktonnes, due to the implementation of a new estimation method for NMVOC emissions from solvents.

5.3. Other product use -3D

5.3.1. Use of N_2O in anaesthesia – 3D

5.3.1.1. Method

N_2O is used in anaesthesia procedures and will lead to emissions of N_20. The figures are based on N_2O data from the two major producers and importers in 2000. These figures are related to the number of births and number of bednights in hospitals for each year to estimate consumption.

5.3.1.2. Activity data

For this source actual sale of N_2O is used for the year 2000. Number of births and bednigths in hospitals is gathered from the Statistical yearbook of Norway each year.

5.3.1.3. Emission factors

As mentioned, no emission factors are used since the figures are based on sales of N_2O.

5.3.1.4. Uncertainty

The figures are uncertain. There may be small importers not included in Statistics Norway's telephone survey with 2000 data, but the emissions are small, so it is believed that the uncertainty is at an acceptable level.

5.3.1.5. Completeness

A minor consumption from small importers may be missing, but these will probably account for an insignificant fraction of the total N_2O emissions.

5.3.1.6. Source specific QA/QC and verification

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

5.3.1.7. Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2010.

5.3.1.8. Recalculations

No recalculations are carried out since last year.

5.3.2. Use of N_2O as propellant – 3D

N_2O is used as a propellant in spray boxes and this use will lead to emissions of N_2O. It is also used in research work, for instance in the food industry and at universities. Small amounts are used at engineering workshops among others for drag-racing. There is no production of N_2O for these purposes in Norway.

5.3.2.1. Methodological issues

Information on sale volumes is given from the plants to Statistics Norway. Statistics Norway assumes that all propellant is released to air.

5.3.2.2. Uncertainty

The figures for 2000 are used for all years. It is believed that all figures from all major importers are included in the inventory.

5.3.2.3. Completeness

No major missing emission components are likely.

5.3.2.4. Source specific QA/QC

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

5.3.2.5. Planned improvements

There is no planned activity this year that will improve the data quality for NIR 2010..

5.3.2.6. Recalculations

No recalculations are carried out since last year.

6. Agriculture

6.1. Overview

About 8 per cent of the total Norwegian emissions of greenhouse gases (GHG) originated from agriculture, in 2007. This corresponds to 4.3 million tonnes CO_2-eqv. The emissions from agriculture are quite stable, with emissions in 2007 about 3 percent lower than in 1990, but about 2 percent higher than in 2006.

The sectors clearly biggest sources of GHG's are "enteric fermentation" (CH_4) from domestic animals, contributing with 44 per cent and "agricultural soils" (N_2O) contributing with 46 percent of the sectors emissions.. Manure management contributes with more than 10 percent. These three are also key categories

Agriculture contributes particularly to CH_4, N_2O and NH_3 emissions. Domestic animals are the major source of CH_4 emissions from agriculture. Both enteric fermentation and manure management contribute to process emissions of methane. Manure management also generates emissions of N_2O.

Microbiological processes in soil lead to emissions of N_2O. Three sources of N_2O are distinguished in the IPCC methodology:

1. direct emissions from agricultural soils (from use of synthetic fertilisers, animal excreta nitrogen used as fertiliser, biological nitrogen fixation, crop residues, industrial and urban wastes and cultivation of soils with a high organic content)
2. direct soil emissions from animal production (emissions from droppings on pastures)
3. N_2O emissions indirectly induced by agricultural activities (N losses by volatilisation, leaching and runoff).

There are also some emissions of the greenhouse gases N_2O and CH_4 and of the precursor NO_X arising from the burning of crop residues on the fields.

Animal manure and the use of fertiliser also generate emissions of ammonia (NH_3). Another source of ammonia is treatment of straw using ammonia as a chemical.

As indicated in Table A1-3 in Annex I of this report, the key category analysis performed in 2009 for the years 1990 and 2007 has revealed that in terms of total level and trend uncertainty the *key categories* in the Agricultural sector are the following:

- Enteric fermentation - CH_4 (4A)
- Direct soil emissions - N_2O (4D1)
- Animal production - N_2O (4D2)
- Indirect emissions - N_2O (4D3)
- Manure management – [6]CH_4 and N_2O (4B)

[6] Key category only in Tier 1 key category analysis.

6.2. Emissions from enteric fermentation in domestic livestock 4A– CH_4 (Key Category)

6.2.1. Description

An important end product from the ruminal fermentation is methane (CH_4). The amount of CH_4 produced from enteric fermentation is dependent on several factors, like animal species, production level, quantity and quality of feed ingested and environmental conditions. According to IPCC (IPCC, 2001) the method for estimating CH_4 emission from enteric fermentation requires three basic items:

· No. 1 The livestock population must be divided into animal subgroups, which describe animal type and production level.
· No 2. Estimate the emission factors for each subgroup in terms of kilograms of CH_4 per animal per year.
· No 3. Multiply the subgroup emission factors by the subgroup populations to estimate subgroup emission, and sum across the subgroups to estimate total emission.

Enteric fermentation is a key category because of uncertainty in level and trend.
Its contribution to uncertainty in the national inventory is 4.30 % to uncertainty in level and 1.88 % to uncertainty in trend.

Enteric fermentation contributed with 89 ktonnes of CH_4 emissions in 2007, corresponding to 1.871 Mtonnes CO_2 equivalents, which is 3.3 per cent of the national GHG emissions. Enteric fermentation constitutes 85 per cent of the overall CH_4 emissions from agriculture and 44 percent of this sectors GHG emissions. Emissions have been rather stable with minor fluctuations. Emissions decreased by 3.9 percent in the period 1990-2007 but increased by 1.7 percent in 2006-2007.

6.2.2. Methodological issues

The methodology for calculating CH_4 from enteric fermentation for the main emission sources cattle and sheep was in 2006 updated to the Tier 2 approach for all years, as recommended by the UNFCCC review team.
The methodology for calculating CH_4 from enteric fermentation for the other animal categories is in accordance with IPCC's Good Practice Guidance Tier 1 method (IPCC 1997a, 1997b). The numbers of animals of each kind and average emission factors for each kind of animals are used to calculate the emissions.

6.2.3. Activity data

The Tier 2 method of calculation requires subdividing the cattle and sheep populations by animal type, physiological status (dry, lactating or pregnant) live weight and age. Table 6.1 describes the animal categories used for cattle and sheep in the calculations.
For dairy cows additional information from the Cow Recording System, concerning annual milk production and proportion of concentrate in the diet has been used. The Cow Recording System also supplies information about slaughter age, slaughter weight and average daily weight gain (ADG) for growing cattle, which are utilized in the calculations for growing cattle

Table 6.1 Categories of cattle and sheep used in the Norwegian calculations of methane emission from enteric fermentation.

Categories of cattle and sheep
Dairy cows
Beef cows
Replacement heifers, < one year
Replacement heifers, > one year
Finisher heifers, < one year
Finisher heifers, > one year
Finisher bulls, < one year
Finisher bulls, > one year
Breeding sheep, > one year
Breeding sheep, < one year
Slaughter lamb, < one year. Jan- May
Slaughter lamb, < one year. Jun- Sept

The main source of the livestock statistics is the register of production subsidies. The register covers 90-100 per cent of the animal populations, except for horses and reindeer. The register is used in order to get consistent time series of data. Animals are counted twice a year and the register is updated with these counts. The average number of the two counts is used. In addition to the animals included in the register of production subsidies, an estimate of the number of horses that are not used in farming is obtained from the Norwegian Agricultural Economics Research Institute (NILF). The number of reindeer is obtained from the Norwegian Reindeer Husbandry Administration.

For some categories of animals not living a whole year, for instance lambs, lifetime is taken into account to get a yearly average for the number of animals. An expert judgment suggests an average lifetime of 143 days for lambs (UMB 2001). The formula for calculating the average figure for lambs will then be:

(6.1) $$Lambs * \frac{143}{365}$$

There exist some differences between these numbers and the FAO statistics. The explanation is, that the figures to the FAO are supplied by the Norwegian Agricultural Economics Research Institute (NILF). NILF elaborates an overall calculation for the agricultural sector, which is the basis for the annual negotiations for the economic compensation to the sector. The overall calculation includes a grouping of all agricultural activities, comprising area, number of animals and production data. This method is a little different from the one used by Statistics Norway. Differences include

- Different emphasis on the dates for counting, 31.07 and 31.12
- NILF does not register pigs under 8 weeks, whilst Statistics Norway does.

6.2.4. Emission factors

For cattle and sheep the following basic equation are used to calculate the CH_4 emission factor for the subgroups (Tier 2):

(6.2) $EF = (GE \cdot Ym \cdot 365 \text{ days/yr}) / 55.65 \text{ MJ/kg } CH_4$

Where:
EF = emission factor, kg CH_4/head/yr
GE = gross energy intake, MJ/head/day
Ym = CH_4 conversion rate, which is the fraction of gross energy in feed converted to CH_4.

This equation assumes an emission factor for an entire year (365 days). In some circumstances the animal category may be alive for a shorter period or a period longer than one year and in this case the emission factor will be estimated for the specific period (e.g., lambs living for only 143 days and for beef cattle which are slaughtered after 540 days).

For the animal categories others than cattle and sheep, the Tier 1 default emission factors for each kind of animal (IPPC 1997a, 1997b) is used. The emissions from domestic reindeer, deer, ostrich and fur-bearing animals are included in the Norwegian calculations. Emission factors for these animals are developed by scaling emission factors for other animals that are assumed most similar with regard to digestive system and feeding. The scaling is done by comparing average weights for the actual animal groups. The emission factor used for reindeer is 11 kg/animal/yr, and has been estimated by scaling the emission factors for goats and sheep according to carcase weight. The emission factor for deer of 52.64 kg/animal/yr has been estimated by scaling the emission factor for dairy cattle, and the emission factor 4.97 kg/animal/yr for ostrich by scaling the emission factor for horses. The emission factor for fur-bearing animals is set to 0.10 kg/animal/yr, and has been estimated by scaling the emission factor for swine.

Table 6.2 Emission factors for CH_4 from enteric fermentation and different animal types estimated with the Tier 1 method

Animal	Emission factor (Tonnes/animal/year)
Horses	0.018
Goats	0.005
Pigs	0.0015
Hens	0.00002
Turkeys	0.00002
Reindeer	0.011
Deer	0.053
Ostrich	0.0050
Fur-bearing animals	0.0001

Source: IPCC (1997a, 1997b) and Agricultural Statistics from Statistics Norway.

6.2.5. Uncertainties

Activity data
The data are considered to be known within ±5 per cent.

Emission factors
Although the emissions depend on several factors and therefore vary between different individuals of one kind of animal, average emission factors for each kind are used in the tier 1 methodology for all animal categories except cattle and sheep, where a tier 2 methodology is used . The standard deviation of the emission factors is considered to be ±25 per cent, which is the estimate from IPCC (IPCC 1997 [Greenhouse Gas Inventory. Reference Manual…]). This uncertainty estimate is also used for the emission factors for cattle and sheep in the tier 2 methodology. Even if the calculations, due to considerations of a number of nutrition related factors have become more accurate, the standard deviation can still be the same, according to expert judgement (UMB 2006 [Email from Harald Volden, the Norwegian University of Life Sciences, January 27 2006]).
..

6.2.6. Completeness

Major missing emission sources are not likely.

6.2.7. 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. The revised data on animal populations form the basis for the emission calculations for all years. In 2005-2006, Statistics Norway and the Norwegian Pollution Control Authority carried out a project in cooperation with the Norwegian University of Life Sciences, which resulted in an update of the emission estimations for cattle and sheep using a tier 2 method.

6.2.8. Recalculations

No new recalculations since the last NIR

6.2.9. Planned improvements

No new improvements are planned for NIR 2010

6.3. Emissions from manure management - 4B - CH_4 , N_2O /Key categories)

6.3.1. Description

The relevant pollutants emitted from this source category are CH_4 (IPCC 4B(a)), N_2O (IPCC 4B(b)) and NH_3 (NFR 4B).

N_2O is key category according to Tier 2 key category analysis because of its contributions to level uncertainty, 0.84 percent. CH_4 is key category only in the Tier 1 key category analysis.

CH_4-emissions due to manure management amounted to 14.95 ktonnes in 2007, corresponding to 0.31 Mtonnes CO_2 equivalents. N_2O-emissions due to manure management amounted to 0.40 ktonnes in 2007 corresponding to 0.12 Mtonnes CO_2 equivalents.

Manure management emitted in 2007 0.45 Mtonnes of CO_2 equivalents, which is 10 per cent of the GHG's from agriculture and 0.8 per cent of the Norwegian emissions of GHGs.

Emissions of GHGs from manure management increased by 1 % in the period 1990-2007 and by 2.6 % from 2005 to 2006.

Organic material in manure is transformed to CH_4 in an anaerobic environment by microbiological processes. Emissions from cattle(manure) 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).

During storage and handling of manure (i.e. before the manure is added to soils), some nitrogen is converted to N_2O. The amount released depends on the system and duration of manure management. Solid storage and dry lot of manure is the most important source.

Emissions of NH_3 from manure depend on several factors, e.g. type of animal, nitrogen content in fodder, manure management, climate, time of spreading of manure, cultivation practices and characteristics of the soil. In the IPCC default method a NH_3 volatilisation fraction of 20 per cent is used for the total N excretion by animals in the country. But in the Norwegian emission inventory, ammonia volatilisation values from Statistics Norway's ammonia model are used, which are expected to give more correct values for Norway. The estimated national volatilisation fractions have differed between 17-20 per cent since 1990, and are now close to the IPCC default value of 20 per cent.

6.3.2. Methodological issues

CH_4

Emissions of methane from manure are estimated using the following equation, in accordance with the IPCC Tier 2 method (IPCC 1997a, 1997b):

$$(6.3) \quad E_i = \frac{N_i \cdot M_i \cdot VS_i \cdot B_{0_i} \cdot MCF_i}{1000}$$

E: Emissions of methane
N: Population of animals
M: Production of manure (kg/animal/year)
VS: Volatile solids (per cent)[7]
B_0: Maximum methane-producing capacity (m^3/kg-VS)
MCF: Methane conversion factor
$_i$: Species

[7] Volatile solids (VS) are the degradable organic material in livestock manure (IPCC 1997a,b).

Table 6.3 Norwegian factors used to estimate CH_4 from manure management in the IPCC Tier 2 method

	Manure production (kg/animal/day)	VS (per cent)	B_0 (m^3/kg-VS)	MCF (per cent)
Dairy cattle	45	9.2	0.18	8
Bulls > 1 year	35	9.2	0.21	8
Heifers > 1 year	30	9.2	0.21	8
Non-dairy cattle < 1 year	15	9.2	0.21	8
Horses	25.5	16.4	0.21	8
Sheep > 1 year	2	19.5	0.19	5
Sheep < 1 year	1	19.5	0.19	5
Diary goats	1.8	23	0.19	5
Other goats	1	23	0.19	5
Pigs for breeding	9	9.5	0.21	8
Pigs for slaughter	4.5	9.5	0.21	8
Hens	0.16	15.6	0.25	8
Chicks bred for laying hens	0.085	19.4	0.25	8
Chicks for slaughter	0.085	19.4	0.25	8
Ducks for breeding	0.17	16	0.25	8
Ducks for slaughter	0.057	16	0.25	8
Turkey and goose for breeding	0.7	16	0.25	8
Turkey and goose for slaughter	0.29	16	0.25	8
Mink, males	0.35	16	0.25	8
Mink, females	0.7	16	0.25	8
Fox, males	0.56	16	0.25	8
Fox, females	1.12	16	0.25	8
Reindeer	2	19.5	0.19	2
Deer	23.7	9.2	0.18	8
Ostrich	7.05	16.4	0.21	8

Source: Agricultural Statistics from Statistics Norway and Norwegian University of Life Sciences.

The factors M, VS, B_0 and MCF are average factors meant to represent the whole country. The factor B_0 represents the maximum potential production of methane under optimum conditions. MCF is a correction of B_0 according to how the manure is handled reflecting Norwegian manure handling practices for each type of animal waste. The factors are estimated jointly by Statistics Norway and the Norwegian University of Life Sciences (Institute of Chemistry and Biotechnology, Section for Microbiology).

N_2O

In Norway, all animal excreta that are not deposited during grazing are managed as manure. N_2O from manure is estimated in accordance with the IPCC default method (IPCC 1997b), but with Norwegian values for N in excreta from different animals according to Table 6.4.. Norwegian values are also used for the fraction of total excretion per species for each management system (MS) and for pasture. The fractions are updated every year and are given in table 6.5. The distributions between different storage systems and pasture are consistent with the distributions used for calculating NH_3 emissions

Table 6.4 N in excreta from different animals

	kg/animal/year[1]
Dairy cattle	82
Heifer < 1 year	29
Bull < 1 year	24
Heifer > 1 year	35
Bull > 1 year	35
Horses	50
Sheep < 1 year	7.7
Sheep > 1 year	11.6
Goats	15.5
Pigs for breeding	18.3
Pigs for slaughtering[2]	4.4
Hens	0.7
Chicks bred for laying hens[2]	0.147
Chicks for slaughtering[2]	0.053
Ducks, turkeys/ goose for breeding[2]	2
Ducks, turkeys/ goose for slaughtering[2]	0.34
Mink	4.27
Foxes	9
Reindeer	6
Deer	12
Ostrich	12

[1] Includes pasture.

[2] Per stalled animal. Stall we define as the room for one animal. An animal that lives one year needs one stall the whole year. But for example in a stall (or pen) for slaughter swine you breed more than one slaughter swine per year. This means that the N in excreta for dairy cattle is from one cattle per year, but for slaughter swine is "per stalled animal" equal to 2.5 slaughter swine per stall (or pen) per year.

Source: Sundstøl and Mroz (1988) and estimations by Statistics Norway.

Table 6.5 Fraction of total excretion per specie for each management system and for pasture 2005

	Anaerobic Lagoon	Liquid system	Solid storage and drylot	Pasture range and paddock	Other manure management systems
Dairy cattle	0	0.67	0.05	0.28	0
Non-dairy cattle	0	0.64	0.05	0.31	0
Poultry	0	0.27	0.73	0	0
Sheep	0	0.26	0.30	0.44	0
Swine	0	0.88	0.12	0	0
Other animals	0	0.26	0.28	0.46	0

Source: : Data for storage systems from Statistics Norway (2004) and Gundersen and Rognstad (2001) (poultry) and data for pasture times from Tine BA (2003) (Dairy cattle, goat), Statistics Norway's Sample Survey 2001 (Statistics Norway 2002) (non-dairy cattle, sheep) and expert judgements

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

$$(6.4) \quad E = \sum_s \left\{ \left[\sum_i \left(N_i \cdot Nex_i \cdot MS_{i,s} \right) \right] \cdot EF_s \right\}$$

E: Emissions of N_2O-N (kg N_2O-N/year, N_2O-N is the amount of nitrogen in the nitrous oxide compound)
N: Population of animals
Nex: Annual average N excretion (kg N/animal/year)
MS: Fraction of total excretion per specie for each management system
EF: N_2O emission factor (kg N_2O-N/kg N)
$_S$: Manure management system
$_i$: Species

NH_3

Statistics Norway's NH_3 model is used for calculating the emissions of ammonia from manure management. The principle of the model is illustrated in figure 6.1.

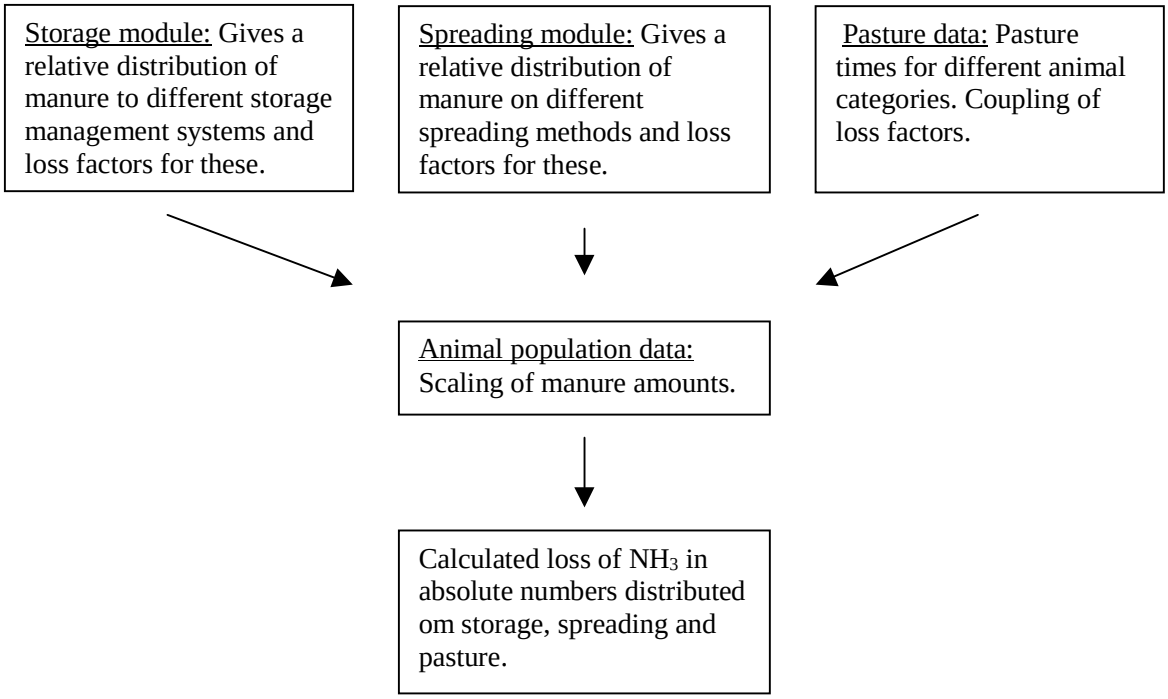


Figure 6.1 The principle of the NH_3 model

The storage module in the NH_3 model gives the relative distribution of manure to the different storage management systems. Total emissions from storage are estimated by multiplying the different emission factors for the storage systems by the amount of manure for each storage system and summarizing the results. The amount of manure is estimated by the number of animals and manure production factors for each type of animal.

6.3.3. Activity data

CH_4 and N_2O
Emissions are estimated from the animal population. How the animal population is estimated is described in Section 6.2.3.

NH_3
Activity data on storage systems are rare, and the only source practically available is the Sample survey of agriculture and forestry 2003 (Statistics Norway 2004) and Statistics Norway survey of different storage systems in 2000 (Gundersen and Rognstad 2001). Data for storage systems are unavailable for other years. Analyses and estimations of the effects on emissions of the assumed changes in storage systems since 1990, show that the assumed change is of little significance to the emissions. In addition, data on animal populations are used to estimate the amounts of manure. How the animal population is estimated is described in Section 6.2.3.

The manure is distributed to the following storage systems categories:

- Manure cellar for slurry
- Manure pit for slurry
- Indoor built up/deep litter
- Outdoor built up/enclosure
- Storage for solid dung and urine

Each of these categories are given for all combinations of the following productions and regions:
Regions:

- South-Eastern Norway
- Hedmark and Oppland
- Rogaland
- Western Norway
- Trøndelag
- Northern Norway

Production:

- Cattle
- Pork
- Sheep and goat
- Poultry
- Horse, farm raised fur-bearing animals and rabbit

6.3.4. Emission factors

CH_4
The calculated average emission factors for different animal types are shown in table 6.6. They are country specific factors which may deviate from the IPCC default values.

Table 6.6 Average CH_4 emission factors for manure management in the Norwegian method. Tier 2

	Emission factor (kg/animal/day)
Dairy cattle	14.41
Bulls > 1 year	13.07
Heifers > 1 year	11.20
Non-dairy cattle < 1 year	5.60
Horses	16.98
Sheep > 1 year	0.90
Sheep < 1 year	0.45
Dairy goats	0.95
Other goats	0.53
Pigs for breeding	3.47
Pigs for slaughter	1.74
Hens	0.12
Chicks bred for laying hens	0.08
Chicks for slaughter	0.08
Ducks for breeding	0.13
Ducks for slaughter	0.04
Turkey and goose for breeding	0.54
Turkey and goose for slaughter	0.23
Mink, males	0.27
Mink, females	0.54
Fox, males	0.43
Fox, females	0.87
Reindeer	0.36
Deer	7.58
Ostrich	4.69

Source: Agricultural Statistics from Statistics Norway.

N_2O

The IPCC default values for N_2O emission factors from manure management are used. These are consistent with the good practice guidance (IPCC 2001).

Table 6.7 N_2O emission factors for manure management per manure management system

Manure management system	Emission factor, kg N_2O-N/kg N
Anaerobic lagoon	0.001
Liquid system	0.001
Daily spread	0
Solid storage and dry lot	0.02
Pasture range and paddock	0.02
Other system	0.005

Source: IPCC (1997b).

NH_3

Emission factors vary with production and storage system; in the model there is no variation between regions. The factors used are shown in Table 6.8.

Table 6.8 NH_3 Emissions factors for various storage systems and productions. Per cent NH_3-N of total N

	Storage system						
	Manure cellar for slurry	Open manure pit for slurry	Manure pit for slurry with lid	Open flagstones	Indoor built up/deep litter	Outdoor built up/enclosure	Storage for solid dung and urine
	Gutter	Gutter		Drainage to gutter			
Cattle, milking cow:							
Loss from animal room	5	5	5	5	8	8	5
Loss from storage room	2	9	2	2	15	15	15
Total loss	7	14	7	7	23	23	20
Pigs:							
Loss from animal room	15	15	15	15	15	15	20
Loss from storage room	4	6	2	2	25	25	30
Total loss	19	21	17	17	40	40	50
Sheep and goats:							
Loss from animal room	15	15	15	15	15	15	15
Loss from storage room	2	6	2	2	10	10	10
Total loss	17	21	17	17	25	25	25
Poultry:							
Loss from animal room	12	10	12	12	25	25	25
Loss from storage room	15	15	15	15	25	25	25
Total loss	27	25	27	27	50	50	50
Other animals:							
Loss from animal room	5	0	0	0	15	15	15
Loss from storage room	10	0	0	0	15	15	15
Total loss	15	0	0	0	30	30	30

Source: Morken (2003a).

The emission factors in Table 6.8 are based on data from Denmark, Germany and Netherlands, since measurements of NH_3-losses in storage rooms have so far not been carried out in Norway.

The emission factors are combined with the activity data in the survey (Gundersen and Rognstad 2001), the Sample survey of agriculture and forestry 2003 and emission factors for NH_3 emissions from storage of manure and stalled animals, calculated for production and region (Table 6.9). To estimate losses, these emission factors are in turn multiplied with the amount of manure (based on number of animals and N-factors per animal). The number of animals is the only activity data that differs from year to year.

Table 6.9 Average emission factors for the manure storage systems used, distributed on type of animal production and region. Per cent of total N

	South-Eastern Norway	Hedmark/Oppland	Rogaland	Western Norway	Trøndelag	Northern Norway
Cattle	10.1	8.4	8.8	8.1	7.7	7.7
Pigs	26.2	22.1	19.8	20.3	21.0	21.2
Sheep and goats	22.5	21.8	18.6	20.9	21.4	21.1
Poultry	47.0	46.4	38.7	37.3	41.7	44.5
Other animals	25.7	24.7	17.1	19.1	23.5	21.6

Source: Statistics Norway, NH_3-model estimations.

6.3.5. Uncertainties

Uncertainties estimates are given in Annex II.

6.3.5.1. Activity data

CH_4

The data for the number of animals are considered to be known within ±5 per cent. Other activity data are the different manure storage systems (which will determine the emission factor), which have been assessed by expert judgements. This will contribute to the uncertainty.

N_2O

Emissions are estimated from the animal population. The data for the number of animals are considered to be known within ±5 per cent.

For the emissions of N_2O from manure management, Norwegian data for N in excreta are used. The nitrogen excretion factors are uncertain, but the range is considered to be within ±15 per cent. (SFT 1999a) The uncertainty is connected to differences in excretion between farms in different parts of the country, that the survey farms may not have been representative, general measurement uncertainty and the fact that fodder and fodder practices have changed since the factors were determined.

There is also an uncertainty connected to the division between different storage systems for manure, which is considered to be within ±10 per cent, and the division between storage and pasture, which is considered to be within ±15 per cent.

6.3.5.2. Emission factors

CH_4

Norway is using the IPCC default factors (Tier 2 methodology) for the emission of CH_4, but with some national data. The emission factors are considered to have the uncertainty range ±25 per cent (Rypdal and Zhang 2000).

N_2O

For the emission of N_2O from different storage systems, IPCC default emission factors are used. They have an uncertainty range of -50 to +100 per cent (IPCC 2001) except for the storage category "daily spread" where it is not applicable.

NH_3

Ammonia emissions from agriculture are estimated based on national conditions. There is not made any uncertainty analysis for the revised NH_3 model, which has been in use since 2003.).

6.3.6. Completeness

Major missing emission sources are not likely.

6.3.7. Source specific QA/QC and verification

In a Nordic project in 2002, the results for emissions of both CH_4 and N_2O from manure management in the national emission inventories have been compared with the results using the IPCC default methodology and the IPCC default factors (Petersen and Olesen 2002). This study contributed to discover differences and gaps in each of the Nordic national methodologies.

Statistics Norway has, in cooperation with the Norwegian University of Life Sciences (UMB), made improvements in the calculation model for ammonia emissions from the agricultural sector. Data sources used for the recalculations in the revised NH_3 model are coefficients from the Norwegian University of Life Sciences, and two surveys from Statistics Norway; a manure survey (Gundersen and Rognstad 2001) and the sample survey of agriculture and forestry (2001).

Statistics Norway's detailed manure survey gives more extended activity data which are better related to emission source categories, for manure management and spreading. New loss factors for different manure management categories are also used in the revised NH_3-model. These factors are closer connected to specific activities.

6.3.8. Recalculations

No recalculations in 2009

6.3.9. Planned improvements

No improvements are planned before NIR 2010.

6.4. Direct and indirect emissions from agricultural soils - 4D - N_2O (Key Category)

6.4.1. Description

The greenhouse gases N_2O and CO_2 are emitted from agricultural soils in Norway. Emissions of CO_2 are discussed section 7.

The emissions of N_2O in Norway from agricultural soils amounted to 6.4 ktonnes in 2007, or 2 Mtonnes calculated in CO_2-equivalents. They accounted for about 47 per cent of the total Norwegian N_2O emissions in 2007 or about 3.6 per cent of the total Norwegian greenhouse gas emissions that year

Emissions of N_2O from agricultural soils are key category because of uncertainty, both in level and trend. Their contribution to uncertainty of the national inventory was 31 % for level in 2007 and 11.5 % for trend (1990-2007)

The emissions had minor fluctuations in the period 1990-2007 with a top in the years 1996-98. During the period 1990-2007 emissions decreased by 2,6 % in spite of a 2 % increase from 2006 to 2007

Three sources of N_2O from agricultural soils are distinguished in the IPCC methodology, namely:

- Direct emissions from agricultural soils (from use of synthetic fertilisers, animal excreta nitrogen used as fertiliser, biological nitrogen fixation, crop residues, industrial and urban wastes and cultivation of soils with a high organic content);
- Direct soil emissions from animal production (emissions from droppings on pastures);
- N_2O emissions indirectly induced by agricultural activities (N losses by volatilisation, leaching and runoff).

The use of synthetic fertilisers, animal excreta nitrogen as fertiliser, and droppings on pastures also results in emissions of NH_3. For the first two sources, the calculated amount of nitrogen that is emitted directly as N_2O has been corrected for the nitrogen emitted as NH_3.

6.4.2. Methodological issues

6.4.2.1. Synthetic fertiliser

N_2O

The direct emissions of N_2O from use of synthetic fertiliser are calculated from data on total annual amount of fertiliser sold in Norway and its nitrogen content, corrected for the amount of synthetic fertilizer applied in forest.(this in accordance with the comments of the review team in the 2005 review) The resulting amount that is applied on agricultural fields is multiplied with the IPCC default emission factor. The emissions are corrected for NH_3 that volatilises during spreading.

NH_3

Statistics Norway's NH_3 model (described section 6.3.2) is used for calculating the emissions of ammonia from the use of synthetic fertiliser. The calculations of NH_3 emissions from the use of synthetic fertiliser are based on the amounts of nitrogen supplied and emission factors for the percentage of nitrogen emitted as NH_3 during spreading.

6.4.2.2. Manure applied to soils

N_2O

In Norway, all animal excreta that are not deposited during grazing are used as manure and applied to soils. Further, it is assumed that animals do not emit N_2O themselves, but emissions of N_2O and NH_3 from manure management before manure application on fields are taken into account (see section 6.3.2).

The emission of N_2O from manure used as fertiliser is calculated by multiplying the total amount of N in manure used as fertiliser with the IPCC default emission factor. The N_2O emissions are corrected for NH_3 that volatilises during spreading.

NH_3

Statistics Norway's NH_3 model(fig 6.1 in section 6.3.2) is used for calculating emissions of ammonia from spreading of manure on cultivated fields and meadow. A spreading module in the NH_3 model gives the relative distribution of manure spread as fertiliser, distributed on different spreading methods. Total emissions from spreading are estimated by emission factors for the different spreading methods multiplied by the amount of manure. The amount of manure is estimated by the number of animals and manure production factors for each type of animal.

6.4.2.3. N_2O from biological nitrogen fixation

Another source of N_2O emissions is biological nitrogen fixation. The most important N-fixing crop in Norway is clover. The amount of nitrogen fixed by a crop is very uncertain, and it is difficult to assign a conversion factor for N_2O emissions derived from nitrogen fixation (IPCC 1997a, 1997b). The amount of nitrogen fixed is multiplied with the IPCC default emission factor.

6.4.2.4. N_2O from crop residues

Concerning re-utilisation of nitrogen from crop residues, there is only limited information. Nitrous oxide emissions associated with crop residue decomposition are calculated by using the Tier 1b method, as described in the IPCC (2001).. Due to lack of national or default factors, factors from the Swedish National Inventory (Swedish Environmental Protection Agency (2005) have been used for the Residue/Crop ratio for grass and green fodder, for $Frac_{DM}$ for rapeseed, potato, roots for feed and green fodder, and for $Frac_N$ for grass, rapeseed and green fodder. Factors from the Austrian National Inventory Report (Umweltbundesamt 2005) have been used for vegetables.

$$(6.5)\ F_{CR} = \sum_i \left[Crop_i * (Res/Crop)_i * Frac_{DMi} * Frac_{Ni} * \left(1 - Frac_{BURNi} - Frac_{REMOVEDi}\right) \right]$$

F_{CR} = N in crop residue returned to soils (tonnes)
$Crop_i$ = Annual crop production of crop i (tonnes)
Res/Crop = The residue to crop product mass ratio (Table 6.10)
$Frac_{DM}$ =Dry matter content (Table 6.10)

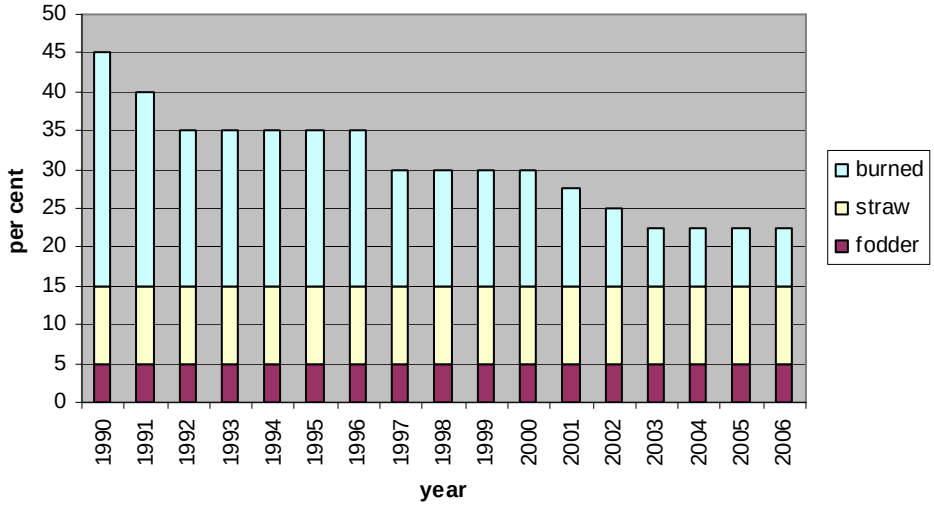
$Frac_N$ = Nitrogen content (Table 6.10)
$Frac_{BURN}$ = Fraction of crop residue burned on field (Figure 6.2)
$Frac_{REMOVED}$ = Fraction of crop residue removed used as fodder and straw in animal rooms (Figure 6.2)

Table 6.10 Factors used for the calculation of the nitrogen content in crop residues returned to soils

	Residue/Crop	$Frac_{DM}$	$Frac_N$
Grass[1]	0.25	0.85	0.014
Wheat	1.3	0.85	0.0028
Rye	1.6	0.85	0.0048
Ryewheat	1.45	0.85	0.0038
Barley	1.2	0.85	0.0043
Oats	1.3	0.85	0.007
Rapeseed	1.8	0.91	0.0107
Potatoes	0.4	0.2	0.011
Roots for feed	0.3	0.2	0.0228
Green fodder	0.25	0.835	0.013
Vegetables	0.8	0.2	0.005
Peas	1.5	0.87	0.0142
Beans	2.1	0.855	0.0142

- [1] Including perennial grasses and grass-clover mixtures
- Source: IPCC (2001), Swedish Environmental Protection Agency (2005), Austrian Umweltbundesamt (2005), Statistics Norway.

Figure 6.2. Fraction of crop residue used as straw and fodder, and fraction burned



6.4.2.5. N_2O from industrial and urban wastes

No data are available for the amount of N in industrial waste applied as fertiliser, but this source is assumed to be very limited in Norway. Data for the N_2O emission arising from sewage sludge applied on fields has been calculated by multiplying the amount of nitrate in the sewage sludge applied with the IPCC default emission factor. Statistics Norway (waste water statistics) annually gives values for the amount of sewage sludge, and the fraction of the

sewage sludge that are applied on fields. The N-content in the sludge is given in Statistics Norway (2001), and the same value of 2.82 per cent is used for all years.

6.4.2.6. N_2O from cultivation of soils with a high organic content

Large N_2O emissions occur as a result of cultivation of organic soils (histosols) due to enhanced mineralization of old, N-rich organic matter (IPCC 1997a, 1997b). The emissions are calculated using the IPCC default emission factor of 8 kg N_2O-N/ha per year, and an approximation of the area of cultivated organic soil in Norway. The same activity data are used for all years, due to lack of annual data. Jordforsk (the Norwegian Centre for Soil and Environmental Research, changed name to ”Bioforsk” in 2006) has estimated that there is 64 438 ha organic agriculture soils based on more than 500 000 soil samples. However, they expect organic soils to be underrepresented in their sampling. Jordforsk expect the real area to be between 70 000 and 100 000 ha (Jordforsk 2004). It is assumed to be 85 000 ha in the calculations. The estimate of organic soils is based on measurements of C in the soil. The area estimate of organic soils is based on measurements of C in soil (Jordforsk 2004).

6.4.2.7. Direct soil emissions from animal production (emissions from droppings on pastures)

N_2O
The fraction of the total amount of animal manure produced that is droppings on pastures is given by national data for the distribution of manure to different storage systems and data for pasture times (Table 6.5). The amount of N deposited during grazing is multiplied with the IPCC default emission factor.

NH_3
Statistics Norway's NH_3 model is used for calculating the emissions of ammonia from pastures. Animal population data, data for pasture times, and factors for the nitrogen amount in excreta for different animal categories give the nitrogen amounts for the animal categories on pastures. Specific emission factors by animal category are used.

6.4.2.8. N losses by volatilisation

Atmospheric deposition of nitrogen compounds fertilises soils and surface waters, and enhances biogenic N_2O formation. Climate and fertiliser type influence the ammonia volatilisation. Deposition of ammonia is assumed to correspond to the amount of NH_3 that volatilises during the spreading of synthetic fertiliser, storage and spreading of manure, and volatilisation from pastures. This amount is obtained from Statistics Norway's ammonia model. The N_2O emissions are calculated by multiplying the amount of N from deposition with the IPCC default emission factor.

6.4.2.9. N_2O from leaching and runoff

A considerable amount of fertiliser nitrogen is lost from agricultural soils through leaching and runoff. Fertiliser nitrogen in ground water and surface waters enhances biogenic production of N_2O as the nitrogen undergoes nitrification and denitrification. The fraction of the fertiliser and manure nitrogen lost to leaching and surface runoff may range from 10 to 80 per cent. The IPCC (1997a, 1997b) proposes a default value of 30 per cent, but in the Norwegian inventory a national factor of 18 per cent (Jordforsk 1998) is used that is believed to give better results under Norwegian conditions. This country specific factor has been calculated based on an estimate of the amount of nitrate leaching for the country on 33 kg

N/hectare (Jordforsk 1998), which comes from a runoff model by Jordforsk (Norwegian Centre for Soil and Environmental Research),. The figure is an estimated average based on measurements of N-leaching in 12 small watershed areas, and expresses the discharge to nearest surface water recipient. Behind this average figure, there is a huge variation in N-leaching, depending on weather conditions, soil types, farm practices, geographical location etc. Climate data, soil data, agricultural practices etc. are monitored closely in these 12 watershed areas. The areas are chosen so that they together make up a representative selection of Norwegian farming with regard to farming practices, geographical localization and climate and soil conditions. The amount of nitrogen lost to leaching is multiplied with the IPCC default emission factor to calculate the emission of N_2O.

6.4.3. Activity data

N_2O

The activity data significant for the estimation of direct and indirect emissions of N_2O from agricultural soils and N_2O emissions from pastures, and the sources for the activity data are listed in Table 6.11.

Table 6.11 Activity data for process emissions of N_2O in the agriculture

	Sources
Consumption of synthetic fertilizer	Norwegian Food Safety Authority (total sale), NIJOS (2005) (fertilizing of forest)
Number of animals	Statistics Norway (applications for productions subsidies)
Distribution between manure storage systems	Sample Survey of agriculture and forestry 2003 (Statistics Norway 2004) and Gundersen and Rognstad (2001)
Pasture times for different animal categories	Tine BA (2003) (Dairy cattle, goat), Statistics Norway's Sample Survey 2001 (Statistics Norway 2002) (non-dairy cattle, sheep), expert judgements.
Biological N-fixation	Aakra and Bleken (1997)
Crop yield	Statistics Norway
Amount of sewage sludge	Statistics Norway, waste water statistics
Fraction sewage sludge applied on fields	Statistics Norway, waste water statistics
Area of cultivated organic soils	Jordforsk (2004)

NH_3

-Synthetic fertiliser
The Norwegian Food Safety Authority calculates a total value for annual consumption of synthetic fertilisers in Norway based on sale figures. These data are corrected for the amount of fertilizer used in forests. For the calculation of the emission of NH_3 we need a specification of the use of different types of synthetic fertiliser. Due to the lack of newer data, we have to assume that the percentual distribution between the usage of different fertiliser types is the same as in 1994, see table 6.13 .

-Animal manure applied to soil and pasture
There are several sources of activity data on spreading of manure in the NH_3-model. The main sources are the manure survey in 2000 by Statistics Norway (Gundersen and Rognstad 2001), various sample surveys of agriculture and forestry 1990-2007 and the annual animal population. Animal population is updated annually. The animal population estimation methodology is described in Section 6.2.3. Data from the manure survey do only exist for 2000, while the data from the sample surveys have been updated for several, but not all, years.

Data for time on pasture and share of animals on pasture are collected from the Sample Survey in Statistics Norway 2000 and from TINE BA (TINE BA is the sales and marketing

organisation for Norway's dairy cooperative and covers most of the milk production). The data from TINE BA comprises pasture data for goats and milking cows and are updated annually. All other pasture data are from the Statistics Norway Sample survey 2000. The parameters used in the calculations and their sources are shown in Table 6.12.

Table 6.12 Parameters included in the estimation of NH_3 emissions from manure

Parameters (input)	**Sources**
Number of animals	Statistics Norway (applications for productions subsidies)
Nitrogen factors for manure	Various sources, compiled by Statistics Norway
Area where manure is spread, split on cultivated field and meadow.	Statistics Norway (Sample Surveys of Agriculture), Gundersen and Rognstad (2001)
Area and amount where manure is spread, split on spring and autumn.	Statistics Norway (Sample Surveys of Agriculture), Gundersen and Rognstad (2001)
Addition of water to manure, , .	Gundersen and Rognstad (2001), expert judgements, Statistics Norway's Sample Survey 2007
Spreading techniques	Gundersen and Rognstad (2001), expert judgements
Usage and time of harrowing and ploughing	Gundersen and Rognstad (2001), expert judgements, Statistics Norway's Sample Surveys of Agriculture
Pasture times for different animal categories	Tine BA (Dairy cattle, goats), Statistics Norway's Sample Survey 2001 (non-dairy cattle, sheep), expert judgements.

6.4.4. Emission factors

N_2O

The IPCC default emission factor of 0,0125 kg N_2O-N/kg N has been used for all sources of direct N_2O emissions from agricultural soils, with the following two exceptions: Emissions of N_2O from animals on pastures are calculated using the IPCC factor of 0.02 kg N_2O-N/kg N, and the emissions that occur as a result of cultivation of organic soils are calculated by using the IPCC default emission factor of 8 kg N_2O-N/ha per year (IPCC 2001).

The IPCC default emission factor of 0.01 kg N_2O-N/kg NH_3-N is used to calculate emissions of N_2O from ammonia volatilised. The IPCC default emission factor of 0.025 kg N_2O-N/kg N lost to leaching/runoff is used.

NH_3

-Synthetic fertiliser

Different types of synthetic fertilisers are being used, resulting in different emissions of NH_3. Their share, based on data from 1994, and their NH_3 emission factors are shown in Table 6.13.

Table 6.13 Emission factors for NH_3-N for different fertilisers and their share of the total use of fertiliser

Fertiliser	Emission factor (per cent of applied N)	Used (per cent)
Urea	15	0.3
Ammonium sulphate and Ammonium nitrate	5	0.02
Calcium nitrate	0	9.7
Calcium ammonium nitrate	1	10.7
NPK	1	77.6
Other	1	1.6

Source: ECETOC (1994) and Norsk Hydro.

-Animal manure applied to soil and pasture

Emission factors for spreading of stored manure vary with spreading method, water contents, type and time of treatment of soil, time of year of spreading, cultivation, and region. The basic factors used are shown in Table 6.14.

Table 6.14 Emissions factors for NH_3-N for various methods of spreading of manure. Per cent of total N

			Western and northern Norway			Southern and eastern Norway		
			Spring	Summer	Autumn	Spring	Summer	Autumn
Meadow								
Surface spreading			0.5	0.6	0.4	0.5	0.6	0.4
Injection			0.1	0.1	0.05	0.1	0.1	0.05
Water mixing			0.3	0.3	0.2	0.3	0.3	0.2
Dry manure			0.04	0.1	0.1	0.04	0.1	0.1
Open fields								
Method	Time before down-moulding	Type of down-moulding						
Surface spreading	0-4 hrs	plow	0.2		0.2	0.15		0.3
Surface spreading	+ 4 hrs	plow	0.5		0.35	0.4		0.4
Surface spreading	0-4 hrs	harrow	0.4		0.35	0.35		0.35
Surface spreading	+ 4 hrs	harrow	0.5		0.45	0.45		0.45
Water mixing	0-4 hrs	plow	0.1		0.1	0.1		0.15
Water mixing	+ 4 hrs	plow	0.25		0.2	0.2		0.25
Water mixing	0-4 hrs	harrow	0.2		0.2	0.2		0.2
Water mixing	+ 4 hrs	harrow	0.3		0.25	0.25		0.25
Dry manure			0.04		0.1	0.04		0.1

Source: Morken and Nesheim (2004):

The factors in table 6.14 are combined with the activity data in the survey (Gundersen and Rognstad 2001) and a time series on mixture of water in manure (latest updated in 2006 based on data from Sample survey of agriculture and forestry 2007), and emission factors for NH_3 emissions from spreading of manure distributed to meadow and cultivated fields, time of season and region are calculated (see table 6.15).. These factors are in turn connected to activity data that are updated in the years since 1990, i.e. number of animals (amount of manure), time of spreading and type of cultivation of the areas where the manure is spread.

Table 6.15 Average NH_3 emission factors for cultivated fields and meadows after time of spreading and region. Per cent, Year 2006

	South-Eastern Norway		Hedmark/ Oppland		Rogaland		Western Norway		Trøndelag		Northern Norway	
	Field	Meadow	Field	Meadow	Field	Meadow	Field	Meadow	Field	Meadow	Field	Meadow
Spring	32.9	44.4	35.3	44.3	23.2	48.2	4.0	40.2	28.4	46.9	5.1	47.6
Autumn	28.5	33.3	28.9	33.2	21.3	34.4	10.0	28.9	30.9	34.4	11.0	33.2

Source: Statistics Norway, NH_3-model estimations.

The emission factors used for the calculation of the NH_3 emissions from grazing animals are shown in Table 6.16. These are the same as the emission factors used in Germany (Dämmgen et al. 2002) and Denmark (Hutchings et al. 2001).

Table 6.16 Ammonia emission factors from droppings from grazing animals on pasture. Per cent

	N-loss/N applied
Cattle	7.5
Sheep and goats	4.1
Reindeer	4.1
Other animals	7.5

Source: Dämmgen et al. (2002), Hutchings et al. (2001).

6.4.5. Uncertainties

6.4.5.1. Activity data

There are several types of activity data entering the calculation scheme:

Sales of nitrogen fertiliser: The data are based on sales figures during one year (The Norwegian Food Safety Authority). The uncertainty in the sales figures is within ±5 per cent (Rypdal and Zhang 2000). Another possible error is that sale does not equal consumption in a particular year due to storage. The distribution between the uses of the various types of nitrogen fertiliser is fixed to an investigation in 1994, and the error connected to this approach will probably increase over the years.

Ammonia losses from fertilizer containing ammonium are related to soil pH. This could probably also lead to uncertainness, but Norwegian soils are very dominated by soils with low pH, which leads to small losses of this type.

Amount of nitrogen in manure: The figures are generated for each animal type, by multiplying the number of animals with a nitrogen excretion factor. The nitrogen excretion factors are uncertain. However, due to research on nitrogen leakage problems in parts of Norway, the certainty has been improved over time (the range is considered to be within ±15 per cent (SFT 1999a)). The uncertainty is connected to differences in excreted N between farms in different parts of the country, that the farms included in the same survey may not have been representative, general measurement uncertainty and the fact that fodder and feeding practices have changed since the factors were determined.

The uncertainty connected to the estimate of the amount of manure is higher than for the amount of synthetic fertiliser used.

Fate of manure: There is significant uncertainty connected to the allocation of manure between what is used as fertiliser and droppings on pastures.

Deposition of other agricultural emissions: The data are based on national NH_3 emission figures. These are within ±30 per cent. (SFT 1999a)

Leakage of nitrogen: The upper limit for the leakage is the applied nitrogen. The uncertainty is roughly about ±70 per cent.(SFT 1999a)

6.4.5.2. Emission factors

N_2O
Uncertainty estimates used for the N_2O emission factors are given in Annex II.

NH_3
The uncertainty in the estimate of emissions of NH_3 from use of fertiliser is assessed to be about ±20 per cent (Rypdal and Zhang 2001). This uncertainty could be lower if better data on fertiliser composition were obtained. The uncertainty is higher for animal manure, ±30 per cent (Rypdal and Zhang 2001). This is due to uncertainties in several parameters including fraction of manure left on pastures, amount of manure, conditions of storage, conditions of spreading and climate conditions. (Rypdal and Zhang 2001). Other factors that could lead to uncertainness are variation in storage periods, variation in house types and climate, variation in manure properties.

6.4.6. Completeness

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

6.4.7. Source specific QA/QC and verification

In a Nordic project in 2002, the estimates for emissions of direct and indirect N_2O from agricultural soils in the national emission inventories have been compared with the results using the IPCC default methodology and the IPCC default factors. The results for the Nordic countries are presented in a report (Petersen and Olesen 2002). The report concludes that there are significant differences between the Nordic countries in the application of the IPCC methodology. It states that there is a clear need to improve this IPCC methodology and to make it more locally adapted, but based on common guidelines. The emission factors for nitrous oxide from both direct and indirect sources, should be differentiated more than what is currently the case. There is a need to re-evaluate the principles of the current IPCC methodology for some of the emissions from manure management.

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

Statistics Norway has, in cooperation with the Norwegian University of Life Sciences (UMB), made improvements in the calculation model for ammonia emissions from the agricultural sector. Data sources used for the recalculations in the revised NH_3 model are coefficients from the Norwegian University of Life Sciences, and two surveys from Statistics Norway; a manure survey (Gundersen and Rognstad 2001) and the sample survey of agriculture and forestry (2001).

Statistics Norway's detailed manure survey gives more extended activity data which are better related to emission source categories, for manure management and spreading. New loss factors for different manure management categories are also used in the revised NH_3-model. These factors are closer connected to specific activities.

In 2006, the methodology used for estimating N_2O from crop residues has been changed to the method Tier 1b (IPCC 2001). The new method is more detailed and is supposed to better reflect the real emissions than the earlier used national method.

6.4.8. Recalculations

No recalculations have been carried out since the 2008-report.

6.4.9. Planned improvements

No new improvements are planned before NIR 2010

6.5. Emissions from agricultural residue burning (agricultural wastes)- 4F - CH_4 , N_2O

Burning of agricultural residues gives emissions of a large range of standard combustion products, ranging from GHGs to heavy metals and POPs.

6.5.1. Methodological issues

CH_4, N_2O and NO_X
The emissions from the burning of crop residues are being calculated according to the guidelines in the IPCC reference manual (IPCC 1997b).
The amount of carbon released is calculated according to equation *6.6* . In the IPCC manual a default value of 0.9 for the fraction oxidised is given, and water content of 15 per cent for wheat and barley, which are the main cereals that gives straw in Norway. To find the C-fraction in Norwegian straw, the default values given for wheat and barley in the IPCC manual are being used, and scaled according to the per cent distribution between the two cereals in Norway in 1999 due to Food and Agriculture Organization of the United Nations (FAO 2002).

(6.6) $CR = CRB * Fdm * Fo * Fc$

CR:	Amount of carbon released (tonnes C/yr)
CRB:	Amount of crop residue burned (tonnes/yr)
Fdm:	Dry matter fraction
Fo:	Fraction oxidised
Fc:	Carbon fraction

To calculate the emissions of CH_4, the amount of carbon released is multiplied with an emission ratio(equitation *6.7*). The emission ratio gives the mass of the actual chemical substance emitted (in C-units) related to the mass of the total carbon emissions by residual burning. To get total amount of emissions of the actual emission component, a molecular weight conversion factor must also be multiplied

(6.7) $E_i = CR * ER * MW_i * (N/C)$

E:	Emissions (tonnes/yr)
CR:	Carbon released (tonnes C/yr)
ER:	Emission ratio
MW:	Molecular weight conversion factor
N/C:	Nitrogen/Carbon-ratio
$_i$:	Emission component

For N_2O and NO_X, the emission ratio gives the ratio of emissions of N_2O relative to the N-content of the crop residuals. This factor also has to be multiplied with the ratio between nitrogen and carbon.

For the emission ratios, the IPCC default values are used. As N/C ratio a value of 0.012 is used, which is the IPCC default value for wheat.

Table 6.17 Factors used for agricultural residue burning in Norway

Factor	Value			Source
Fdm	0.85			IPCC (1997b)
Fo	0.9			IPCC (1997b)
Fc	0.4643			IPCC (1997b), FAO (2002)
	CH_4	*N_2O*	*NO_X*	
ER	0.005	0.007	0.121	IPCC (1997b)
MW	16/12	44/28	46/14	IPCC (1997b9
N/C	-	0.012	0.012	IPCC (1997b)

6.5.2. Activity data

The annual amount of crop residue burned on the fields is calculated based on data from Statistics Norway and the Norwegian Crop Research Institute. (Figure 6.2, chapter 6.4.2.4).

6.5.3. Emission factors

Table 6.18 Emission factors for agricultural residue burning. g emitted/tonnes crop residue burned

Components	Emission factors
Greenhouse gases	
CH_4	2 400
N_2O	46.9
Precursors	
NO_X	1 700

6.5.4. Uncertainties

Uncertainty estimates are given in Annex II.

6.5.5. Completeness

As mentioned, the estimations may not be entirely complete, since the statistics are not of particularly high quality or completeness.

6.5.6. Source specific QA/QC and verification

In 2002, the emissions of CH_4, N_2O, NO_X and dioxin from agricultural residual burning were included in the Norwegian inventory, and in 2003, the emissions of As, Cr and Cu were added. The time series were included but it should be noted that the figures for the earlier years have a higher uncertainty than the more recent years.

6.5.7. Recalculations

No recalculations since the 2008 report.

6.5.8. Planned improvements

No further improvements are planned before NIR 2010

6.6. Other agricultural emission sources – 4G – NH_3

Straw treated with NH_3 to be utilised as fodder is a source for NH_3 emissions in Norway. Agricultural activities are also a source of process emissions of particles. There are also stationary emissions of particles as a result of combustion of different energy commodities in motorized equipment used in the agriculture. These emissions are included in Chapter 3 Energy.

6.6.1. NH_3 emissions from treatment of straw

6.6.1.1. Methodological issues

Emissions of NH_3 from treatment of straw depend only on the amount of NH_3 used. The total amount of NH_3 used for treatment of straw in Norway is multiplied with the share of the NH_3 that is not integrated in the straw.

6.6.1.2. Activity data

The amount of NH_3 used per year is obtained from Norsk Hydro and the Norwegian Agricultural Supply Cooperative. The area of cultivated fields is given from a sample survey of agriculture and forestry made by Statistics Norway 2003.

6.6.1.3. Emission factor

It is estimated that 65 per cent of the NH_3 applied is not integrated with the straw, and is therefore emitted after the treatment (Morken 2003b). The same estimation is being used in Denmark.

6.6.1.4. Uncertainty

Uncertainty in the estimate of emissions from ammonia treatment of straw is rather low (±5 per cent) (Rypdal and Zhang 2001).

6.6.1.5. Completeness

Major missing emission components are not likely.

6.6.1.6. Source specific QA/QC and verification

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

7. Land-Use, Land-Use Change and Forestry (LULUCF)

This chapter provides estimates of emissions and removals from land-use, land-use change and forestry (LULUCF) and documentation of the implementation of guidelines given in "Good Practice Guidance for Land use, Land-use Change and Forestry" (IPCC, 2003). The information is mainly based on the report "Emissions and removals of greenhouse gases from land, use, land use change and forestry in Norway" (NIJOS, 2005).

The NIJOS 2005 report discussed carbon stock changes and each category of emissions and removals of CO_2 and other greenhouse gases the methodological choice, underlying assumptions, availability of data and recommendations for use of data. The NIJOS 2005 report included a chapter entitled "Recommendation for future reporting framework" and a chapter that discussed how data collected for reporting under UNFCCC could be used for Kyoto Protocol reporting. These chapters are now covered in "Framework for reporting under Article 3.3 and 3.4 of the Kyoto Protocol" (Anon, 2006b), "Estimates of emissions and removals resulting from activities under Article 3.3 and 3.4 of the Kyoto Protocol" (Anon, 2006a) and "Electing Cropland Management as an Article 3.4 Activity under the Kyoto Protocol. Considerations for Norway" (Rypdal et al, 2006) and in the "National Greenhouse gas inventory system in Norway" (see Annex VI).

The whole time-series have been recalculated due to revision of the methods used to calculate total biomass of forest trees, land use change and updating of activity data. The method used to recalculate changes of carbon stock in dead organic matter and for soil is the same as reported in 2007, but the activity data has been updated. CRF-tables for LULUCF are updated compared to earlier submitted reports and enclosed in the NIR-submission. The work was carried out by the Norwegian Forest and Landscape Institute and Statistics Norway.

Norway has chosen commitment-period accounting on the activities under Article 3.3 and for the activity "forest management" under Article 3.4.of the Kyoto Protocol, see Annex VIII.

7.1. Overview of sector

7.1.1. Activity data

In light of the importance of the forest sector and the lack of sources of statistical information that can be used to monitor all land-use transitions on an annual basis, data from the National Forest Inventory (NFI) have been used as the most important source of information to establish total area of forest, cropland, wetlands, settlements and other land and land-use transitions between these. The data from NFI have been complemented with other statistical data, in particular for agriculture areas collected by Statistics Norway.

7.1.2. Emissions and removals

The average annual net sequestration from the LULUCF sector was about 16 870 Gg CO_2-equivalents for the period 1990-2007 (Figure 7.1). The average annual net sequestration was 11 358 from 1990 to 1998, and about 22 382 Gg CO_2-equivalents per year from 1999 to 2007. In 2007 the net sequestration was calculated at 25 883 Gg CO_2 -equivalents, which would offset 47 per cent of the total greenhouse gas emissions in Norway that year (55 055 Gg CO_2-equivalents.). In 2007 the land-use category forest land remaining forest land was the major

contributor to the total amount of sequestration with 27 693 Gg CO_2. Land converted to forest land contributed 330 Gg CO_2. All other land-use categories showed net emissions, which totalled 2 128 Gg CO_2. Of these, the most important category was grassland with total emissions of 1 875 Gg CO_2 (Figure 7.2). Farmed organic soils (mostly for grass production) contribute with CO_2 emissions of 1 870 Gg CO_2. The uncertainties are, however, large (more than a factor of 2). The estimate has been kept constant because annual data are missing, but large annual changes are not likely given that very little new organic soils are farmed at present. CO_2 emissions from agricultural mineral soils are small due to small new areas cleared for agriculture. Erosion control (in particular mandatory spring-till) has contributed to a small sequestration.

The emission of CH_4 and N_2O are given in Figure 7.3. The large emissions of CH_4 in 2006 were due to a large number of wildfires that year.

Forest land covers around one fourth of the mainland area of Norway and is the most important land use category considered managed (Figure 7.4). The C sequestered in living biomass was estimated at 5 975 Gg C in 2007 (Figure 7.6). The sequestration in forest soils was found to be 899 Gg C and the carbon stock change in dead organic matter was 679 Gg C.

The carbon stock has increased for living biomass through out the time series (Figure 7.5). The increase in living biomass can be explained by an active forest management policy, but also to some extent by natural factors. There is an annual variation for dead organic matter which is to a large extent influenced of the annual variation in forest harvest (Figure 7.7).

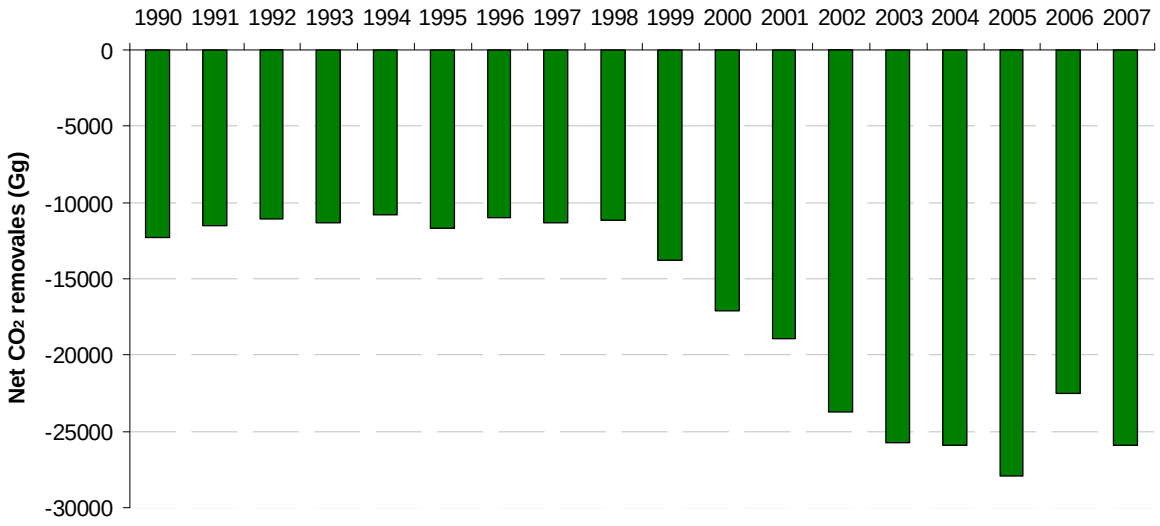


Figure 7.1 Removals in the LULUCF sector from 1990 to 2007. Gg CO2-equivalents.

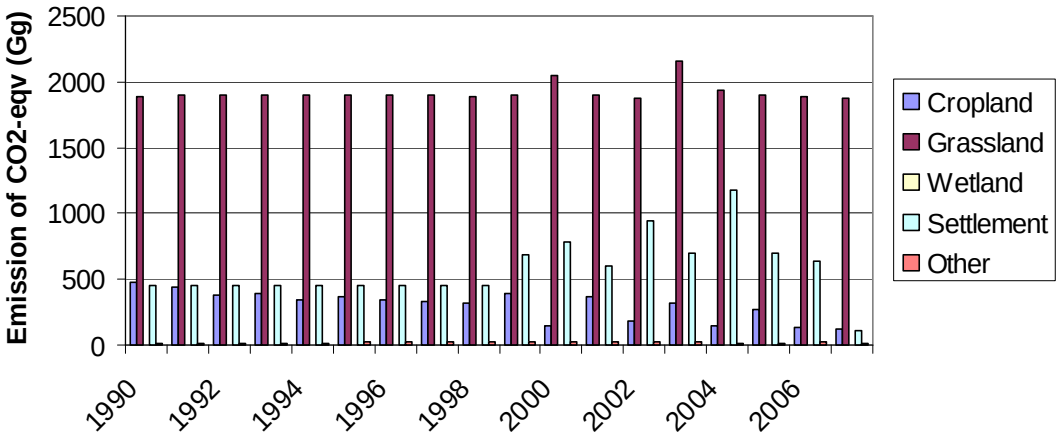


Figure 7.2. Emission form LULUCF sector from 1990 to 2007. Gg CO2-equivalents.

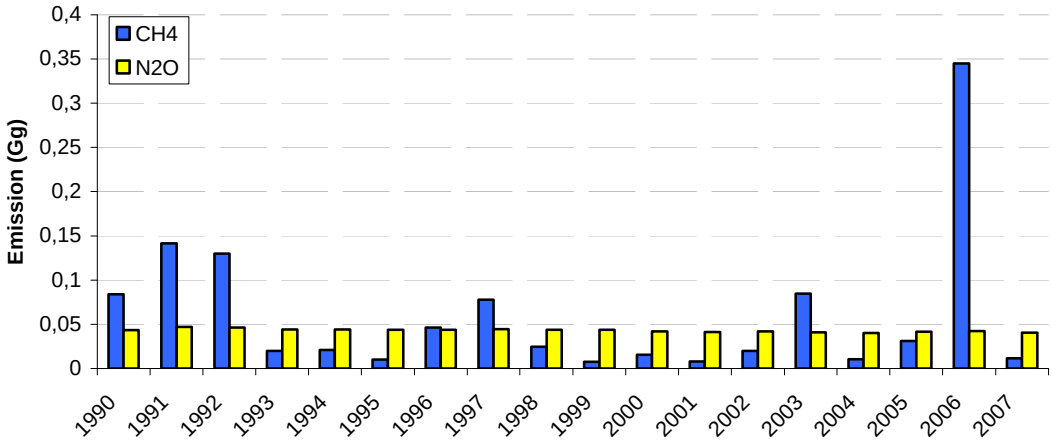


Figure 7.3. Emission of CH_4 and N_2O form LULUCF sector from 1990 to 2007. Gg.

Land use

The calculated land use categories for Norway from 1990 until 2007 are shown in Figure 7.4.

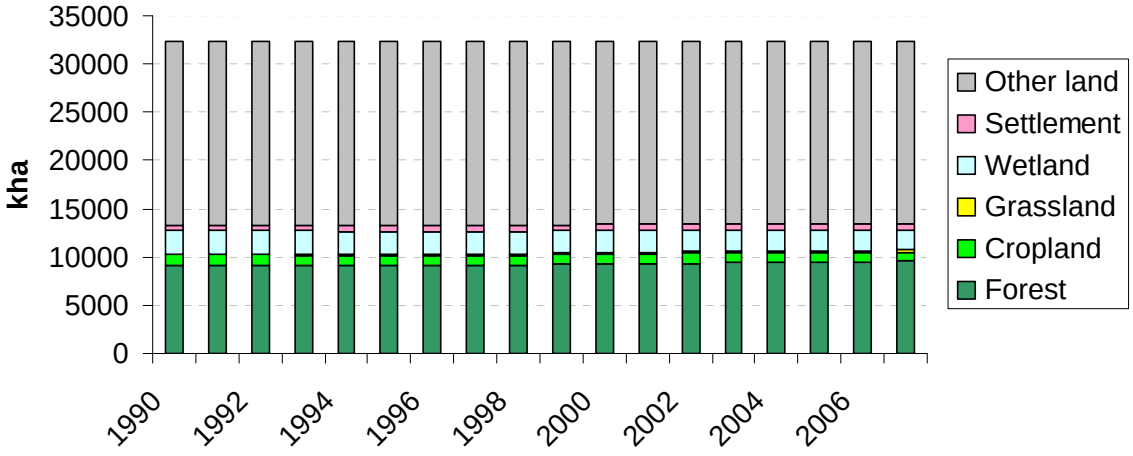


Figure 7.4. Area (k ha) distribution on the IPCC land-use, land-use change and forestry categories, 1990-2007

A key finding from these data is that change in land-use from 1990 to 2007 is quite small; the forest area is slightly increasing and the cropland area is decreasing.

Carbon stock

Figure 7.5 shows the calculated carbon stock changes on forest land from 1990 through 2007. The calculations of carbon stock changes in living biomass are based on data obtained from the National Forest Inventory (NFI). The NFI utilizes a 5-year cycle based on a re-sampling method with permanent plots. Each year 1/5 of the plots are inventoried with the sample plots randomly distributed across the country in order to reduce the periodic variation between years. The same plots are inventoried again after 5 years. The current system with permanent plots was put in place between 1986 and 1993, and fully operational for the cycle covering the years 1994 through 1998. This change of method has implications for how the calculations are performed, and in particular for how the different sampling methods are bridged.

There are no annual biomass data available in the NFI for the years between 1990 and 1998. The annual estimates in Figure 7.5 of carbon stock for the years from 1991 to 1997, inclusive, are based on the values for 1990 and 1998 using linear interpolation between these years. Because of the linear interpolation the calculated annual changes in carbon stock are all constant in this period, see Figure 7.6.

The reported values for 1990 are based on data obtained between 1986 and 1993. The reported values for 1998 are based on data obtained during the 5-year cycle from 1994 through 1998. Values for subsequent years are based on the corresponding 5-year cycle. All calculations are based on data obtained from the same set of permanent plots. This procedure reduces the variation due to changes in the sample, and permits consistent and verifiable estimation of changes over time. By electing to report for the last year in the cycle any land use changes are reported when they are registered, and the reported values for a particular year will not change as additional years are added. This is different from submission earlier than 2008 were mid year in a cycle was used as reference year.

The calculated changes in carbon depend upon several factors such as growing conditions, harvest levels, and land use changes. In particular will variations in annual harvest directly influence the variations in changes in carbon stocks and dead organic matter (Figure 7.7). The steady increase in biomass (carbon stock) is the result of an active forest management policy the last 50 years. The annual harvest levels are much lower than the annual increments thus causing an accumulation of wood and other tree components biomass.

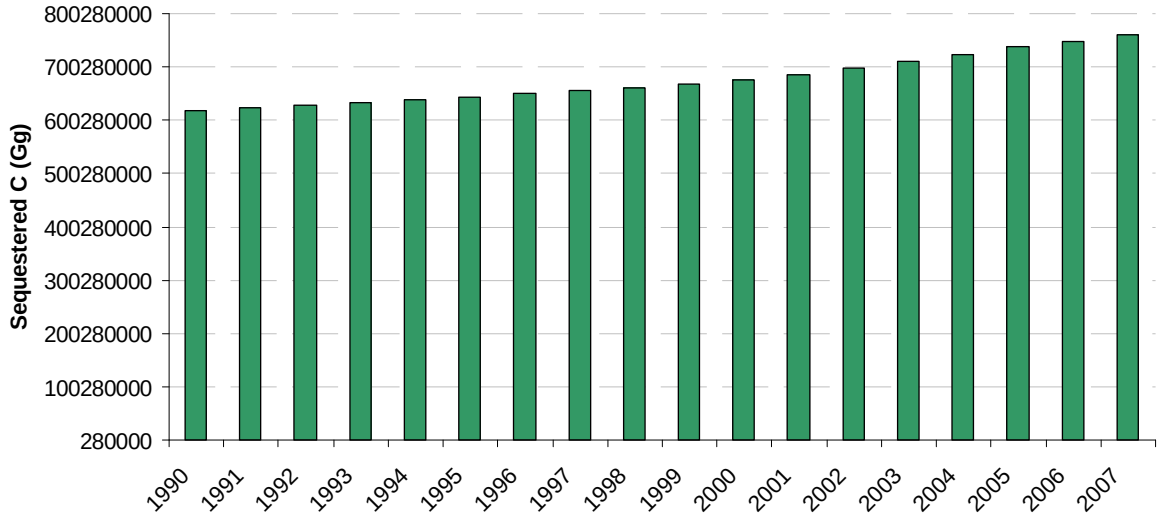


Figure 7.5. Carbon stock in forest living biomass, 1990-2007.

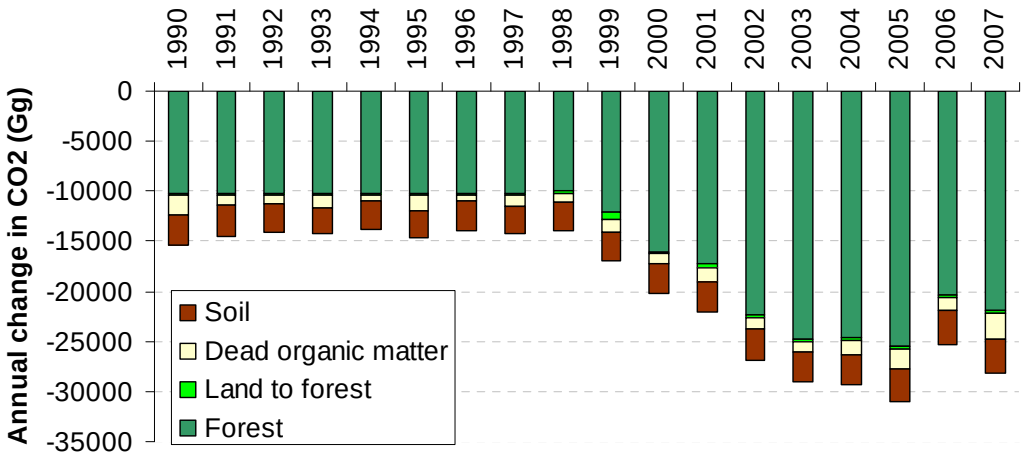


Figure 7.6. Annual changes in carbon stock in forest, land to forest, dead organic matter and soil. 1990-2007.

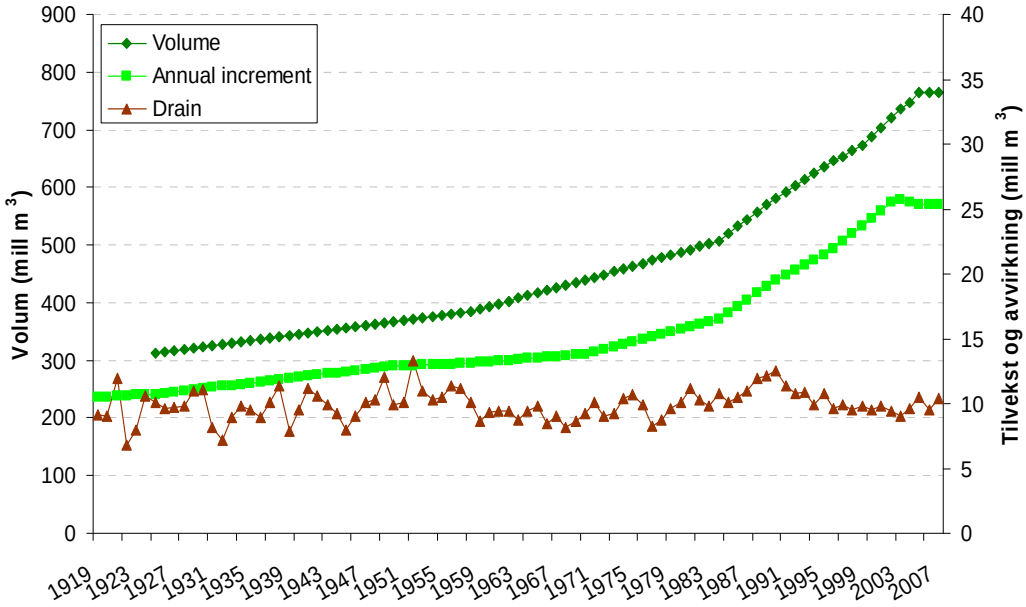


Figure 7.7. Forest harvest (brown), annual increment (green) and volume - 1990-2007 (Statistics Norway, and Norwegian Forest and Landscape Institute) The two last years are extrapolated for annual increment .

7.1.3. Key categories

Table 7.1 shows the results of the key category analysis performed as described in IPCC (2003). There have been several changes due to the changes in methodology. All changes are among categories derived from the forest inventory. 5E1 *Forest land converted to settlements* is a new key category because the biomass loss rate for these conversions was changed from 75 per cent to 100 per cent, leading to higher emissions. 5A2 *Land converted to forest land* is now only a key category according to the Tier 1 analysis and 5B1 *Cropland remaining cropland, liming* is a new Tier 1 key. 5D1 *Wetland remaining wetland* is no longer a key category. Previously, the net biomass gain was calculated as the total increase in forest biomass due to the reclassification of the areas. Thus, all biomass on the areas at the time of reclassification was recorded as a gain. In the revised method, only the biomass change in the inventory year is recorded. The key categories relating to soils remain unchanged.

Uncertainties were not determined by a rigid analysis, see Section 7.11. There are some differences between the two tiers. Tier 1 level analysis does not identify forest drained organic soil, cropland histosols and forest converted for settlements. The reason is that these categories have large uncertainties. For the trend analysis there are small differences between the two tiers with respect to the LULUCF categories identified, and the trend analysis does not identify any additional LULUCF categories to those identified in the level analysis. Including LULUCF also influences other key categories identified. However, according to IPCC (2003) the LULUCF key categories are additional to those identified analyzing the inventory excluding LULUCF. In both analyses, forest remaining forest (all three pools) are among the top key categories.

Table 7.1. Summary of identified LULUCF key categories.

	Source category	Gas	Level assessment Tier 2 1990	Level assessment Tier 2 2007	Trend assessment Tier 2 1990-2007	Method (Tier) 2007
Tier 2 key categories (large contribution to the total inventory uncertainty)						
5A1	Forest Land remaining Forest Land, Forest inventory area, Living Biomass	CO_2	**9.15**	**16.76**	**26.19**	Tier 3
5C1	Grassland remaining Grassland, Histosols, Soils	CO_2	**13.29**	**11.12**	**6.09**	Tier 2*
5A1	Forest Land remaining Forest Land, Forest inventory area, Dead Biomass	CO_2	**6.22**	**6.35**	**5.61**	Tier 3
5A1	Forest Land remaining Forest Land, Forest inventory area, Soils, Mineral	CO_2	**4.66**	**4.39**	**3.32**	Tier 3
5A1	Forest Land remaining Forest Land, Forest inventory area, Soils, Organic	CO_2	**2.34**	**2.07**	**1.35**	Tier 1
5B1	Cropland remaining Cropland, Histosols, Soils	CO_2	**1.48**	**1.24**	0.68	Tier 2
5E2	Forest Land converted to Settlements, Living biomass	CO_2	**1.40**	0.30	**1.47**	Tier 3
Tier 1 key categories (large contribution to the total emissions)						
5A2	Land converted to Forest Land, Living biomass	CO2	0.27	0.42	0.59	Tier 3
5B1	Cropland remaining Cropland, Liming	CO2	0.48	0.13	0.45	Tier 1

7.2. Source category description

7.2.1. Land use categories, CRF 5A, 5B, 5C, 5D, 5E and 5F

In light of the importance of the forest sector data from the National Forest Inventory are used to establish total area of forest, cropland, wetlands, settlements and other land and land-use transitions between these. The land use categories are in accordance given in IPCC Good practice Guidance (IPCC, 2003).

Forest land is defined according to the Global Forest Resources Assessment (FRA) 2004 (FAO, 2004). Forest land is *land with tree crown cover of more than 10 per cent and area of more than 0.5 ha*. The trees should be able to reach a minimum height of 5 m at maturity *in situ*. No minimum width for Forest land is considered in the Norwegian inventory causing a small discrepancy according to the definition in FRA 2004. Young natural stands and all plantations established for forestry purposes, as well as forest land which are temporarily unstocked as a result of human intervention are included under Forest land. All Forest land is considered managed which includes also recreation areas, protected areas and nature reserves. All forests in Norway are used either for wood harvesting, hunting, picking berries, hiking etc.

Cropland is defined for lands where the *soils are regularly cultivated, and where annual or perennial crops are grown.* This category includes temporarily grazed lands that regularly are being cultivated. Cropland also includes areas for meadows and pastures close to the farm.

Grassland is identified as *areas utilized for grazing on an annual basis, but which are not mechanically harvested*. More than 50 per cent of the area should be covered with grasses. The soil is not cultivated, and may partly be covered with trees, bushes, stumps, rocks etc. Land with tree cover may be classified as grassland if grazing is considered more important than forestry. Meadows and pasture within the farm area are included under cropland, which is consistent with the agricultural statistics. All grassland is considered managed, because grassland left unmanaged will over time be converted to forest or vegetated "other land".

Wetlands are assumed unmanaged and are defined as mires and areas regularly covered or saturated by water for at least some time of the year. A wetland area of about 338 ha is used for peat extraction and assumed managed. Land used for reservoirs (dams) used to hydroelectric power productions are also considered managed wetlands, but is not reported since it is not mandatory (IPCC, 2003).

Settlements include all types of built-up land; houses, gardens, villages, towns, cities, parks, golf courses, sport recreation areas, power lines within forests, and cabins areas, industrial areas, gravel pits, mines. All settlements are considered managed.

Other lands is defined as impediments (waste land), areas with bare rocks, shallow soil or particularly unfavourable climatic conditions and Calluna heath which is potential forest land but currently unused land without tree cover in western Norway. Also the group "other wooded land" (land with sparse tree cover) on mineral soil is assigned to Other lands. The areas above the coniferous limit and the northernmost county of Finnmark which is not yet included in the database, is assigned to Other land to ensures that the total area identified equals the total area of the country.

Management status of the reported land use categories are summarised in Table 7.2, and the National Land cover and Land use categories surveyed by the National Forest Inventory, their correspondence to the UNFCCC/KP Land use categories is given in table 7.3.

Table 7.2. Management status of different land use categories. An area is only classified as belonged to one land use category. The predominant national land cover and land use decides to which category.

Land use category	Abbreviation	Management status
Forest land	F	Managed
Cropland	C	Managed
Grassland,	G	Managed
Settlements	W	Unmanaged or Managed (small area)
Other land	O	Unmanaged

Table 7.3. National Land cover and Land use categories, their correspondence to the UNFCCC/KP Land use categories.

Land cover	Land use								
	Forestry (no other use or restrictions) (1)	City urban area Settlements of different kinds (2)	Cabin area (3)	Recreation area (9)	Military training field (4)	Protected Area, Nature Reserve (5)	Roads/Railroad Airport (6)	Power line (7)	Other (8)
Productive forest land (1)	Forest	Settlements	Settlements	Forest	Forest	Forest	Settlements	Settlements	Settlements
Non-productive forest land (12)	Forest	Settlements	Settlements	Forest	Forest	Forest		Settlements	Settlements
Other wooded land, Crown cower 5-10% (13)	Other		Settlements	Other	Other	Other		Other	
Wooded mire, Crown cover 5-10% (13)	Wetland		Wetland		Wetland	Wetland		Wetland	Wetland
Calluna heath (2)	Other								
Bare rocks, shallow soil (22)	Other		Other	Other	Other	Other		Other	Other
Mire without tree cover (22)	Wetland					Wetland		Wetland	Wetland
Lakes and rivers (not sea) (30)	Wetland				Wetland	Wetland			Wetland
Grazing land, not regularly cultivated (40)									Grassland
Arable land, regularly cultivated (41)					Cropland	Cropland			Cropland
Other areas, gravel pits, mines, gardens, halting places, skiing slopes (50), forest roads etc.	Settlements	Settlements	Settlements	Settlements	Settlements		Settlements	Settlements	Settlements

- (1) Productive forest land is defined as forest with crown cover that exceeds 10 percent and that hosts a potential yield of stem-wood, inclusive bark, exceeding one cubic meter inclusive bark per hectare and year.
- (12) Non-productive forest land is defined as forest with crown cover that exceeds 10 percent and that hosts a potential yield of stem-wood less then one cubic meter, inclusive bark, per hectare and year.
- (13) Other wooded land is defined as land with sparse tree cower with crown cover lager then 5 percent but less then 10 percent and hosts trees that have the potential to reach a height of 5 meter, or with a combined cover of shrubs, bushes and trees above 10 percent. It is classified as other wood land if the soil is classified as mineral soil and wooded mire if the organic soil is more than 40 cm.

7.2.2. Consistency in reporting Land use categories

7.2.2.1. Land use categories inventoried by National forest inventory

National forest inventory (NFI) is a sample plot inventory with the aim of providing data about natural resources and environment for forest land in Norway. The NFI is the only system that can present area changes and current area distribution based on a georeferenced sample of field plots (NIJOS 2005). The Norwegian Forest and Landscape Institute is responsible for the NFI. Inventory work was started in 1919 with regular inventory cycles. The 9th inventory cycle started in 2005 and will be completed in 2009. Until 2004 the inventory comprised all types of land below the coniferous forest limit, but a more comprehensive description was made only for forest land. Until 2004 the mountain birch areas above the coniferous limit and Finnmark County was not included in the NFI. During the 9th inventory cycle the mountain birch areas and part of Finnmark County will be assessed in the same way as the rest of the country. The plan is that the land use and biomass for the mountainous area and the rest of Finnmark are completed in 2013.

The sampling design is based on a systematic grid of georeferenced sample plots with 3 x 3 km spacing. Approximately 17 000 permanent sample plots have been established in total. The NFI utilizes a 5-year cycle based on a re-sampling method with permanent plots. The re-measuring is carried out in such a way that 20 per cent of the plots are surveyed every year with the sample plots randomly distributed across the country in order to reduce the periodic variation between years. The same plots are inventoried again after 5 years. The current system with permanent plots was put in place between 1986 and 1993, and was fully operational for the cycle covering the years 1994 through 1998. This change of method has implications for how the calculations are performed, and in particular for how the different sampling methods are bridged.

NFI provides national as well as regional statistics of forest resources and environment, and gives in addition the possibilities to assess land use and detect changes both in land-use and forest situation. To obtain reliable data for individual counties, data from permanent plots are supplemented with data from temporary plots, which will not be described in further detail here. The data collection makes it possible to compute volume and biomass for different tree species and size classes as well as the numbers of trees and annual increment.

The classifications for land area of Norway are given in Table 7.4. The figures are based on data from NFI and Statistics Norway which provided the figures for the total land area for Norway. Areas above the coniferous forest limit and Finnmark County are classified as "Other land". The category "Other land" ensures that the total land area identified equals the total area of the country.

Table 7.4. Land-use classification in 1990, 1996 and 2002, representing respectively the 6th, 7th and the 8th NFI

Classes	**Land-use in 1990** *The 6th NFI*		**Land-use in 1996** *The 7th NFI*		**Land-use in 2002** *The 8th NFI*	
	Area (ha)	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**
Forest	8 897.49	27.5	8 824.46	27.3	9 364.39	28.9
Cropland	1 079.76	3.3	1 054.52	3.3	1 017.01	3.1
Grassland	154.98	0.5	154.98	0.5	172.94	0.5
Wetlands	2 188.51	6.8	2 219.17	6.9	2 087.36	6.4
Settlements	636.48	2.0	649.10	2.0	676.74	2.1
Other	19 422.98	60.0	19 477.97	60.2	19 061.78	58.9
Sum	**32 380.20**	**100.0**	**32 380.20**	**100.0**	**32 380.20**	**100.0**

** The figures in this table are calculated for each inventory cycle with the mid year as the reference year.*

A key finding from these data is that the change in land-use from 1990 to 2002 is quite small; the forest area is increasing and the agriculture area is decreasing.

The six land-use categories are consistent with the national definitions applied in 7th (1994-1998) and 8th NFI (2000-2004). However, in the 6th NFI (1983-1993) the crown cover percentage was not recorded, and also the category "Grassland" had not been defined in the land-use classification. Due to the missing assessments of the crown cover parameter and the area of "Grassland", the values from the 7th NFI were used as estimates of crown cover and grassland in the 6th NFI. Areas classified as grassland in the 7th inventory were assumed grassland also in the 6th NFI. Consequently, no land-use transfers from "Grassland" were assumed. In this way all land-use transfers are included in this report.

Time-series

In this report data from the inventories carried out from 1986 through 2007 are used. The reported values for 1990 are based on data obtained between 1986 and 1993. The reported values for 1998 are based on data obtained during the 5-year cycle from 1994 through 1998. Values for subsequent years are based on the corresponding 5-year cycle. All calculations are based on data obtained from the same set of permanent plots. This procedure reduces the variation due to changes in the sample, and permits consistent and verifiable estimation of changes over time. By electing to report for the last year in the cycle any land use changes are reported when they are registered, and the reported values for a particular year will not change as additional years are added.

There are no annual data available in the NFI for the years between 1990 and 1998. The annual estimates of carbon stock, land use and land use change for the years from 1991 to

1997, inclusive, are based on the values for 1990 and 1998 using linear interpolation between these years. Because of the linear interpolation the calculated annual changes in carbon stock are all constant in this period, see Figure 7.6 (in Section 7.1.2)[8].

Conversions between cropland and forest land:
The (direct) conversions between these categories are small. Such a conversion is expected, however, due to abandonment of marginal agriculture land. An explanation may be that the transition goes via other land or grassland. These area changes are considered human induced.

Conversions between cropland and grassland:
Some conversion from cropland to grassland has been detected. The area changes are considered human induced.

Conversions between cropland and settlements:
There is some conversion from cropland to settlements. These changes are considered to be real, given that the total cropland area has been decreasing and urban area increasing also according to administrative records. The changes are human induced.

Conversions between cropland and wetland:
The conversions between these categories are negligible. The changes are human induced.

Conversions between cropland and other land:
The conversions between these categories are negligible. The changes are human induced.

Conversions between forest land and grassland:
The inventory data indicates some transition from forest land to grassland throughout the time-series. There are some conversions from grassland to forest land observed in the latest inventories. Such a transition is not unlikely, because there has been a reduction in animal grazing in many rural districts. Conversions between grassland and forest are considered as human induced.

Conversions between forest land and settlements:
There has been conversion from forest land to settlements between the forest inventories. These changes are in line with independent administrative records and are human induced. They are interpreted in this inventory as deforestation.

Conversions between forest land and wetland:
There have been recorded conversions from forest land to wetland and from wetland to forest land. These differences can be explained by changes in the classification of tree covered mires areas. The limit for classifying as mire is < 10 per cent crown cover. These actual changes are considered not human induced.

Conversions between forest land and other land:
There has been a conversion from other land to forest land. These conversions are most likely in areas close to the timberline. Changes from other land to forest land are real and are partly human induced (changes in grazing). Some changes can also be due to a warmer climate. The explanations for increases in forest around the timberline has been discussed by Hofgaard (1997a;b), who claims that most of the expansion of the mountain birch forests in Scandinavia

[8] Making the annual changes non-constant in the interpolation period would require a non-linear interpolation between 1990 and 1998

after the mid-20 Century, is due to change of land use as a result of diminished grazing pressure.

Conversions between grassland and settlements:
A few cases of change from settlements to grassland have been observed. This change is not significant and does not have any major practical consequences for the estimates of emissions and removals.

Conversions between grassland and wetland:
There have been a few conversions between wetland and grassland. Parts of this can be due to new areas used for grazing. The changes are small and negligible.

Conversions between grassland and other land:
There is some conversion from other land to grassland. The changes are small and negligible.

Conversions between settlements and wetland:
Conversions between settlements and wetland are small. These apparent conversions do not have any major consequences for the calculations of emissions and removals, as the result would be rather negligible.

Conversions between settlements and other land:
There has been some conversion from other land to settlements. This can be explained for example by road constructions. We assume that in these situations the other lands is vegetated. The changes are human induced.

Conversions between wetland and other land:
There is no recorded conversion from other land to wetland.

7.2.2.2. Land use changes prior to 1990

According to the Good Practice Guidance (IPCC, 2003), it has been recommended that, when a piece of land changes use, then it is followed in that 'changed status' for 20 years, with each year 1/20 of the CO2 and non- CO2 effects reported. Tier 3 modelling approaches may utilize different assumptions, but still with a conversion category of 20 years. That means, land-use changes that have taken place after 1970 may still have an impact on soil organic matter in 1990. There was no forest inventory intended to assess land-use changes in 1970, and the forest inventory at that time was not covering the whole country. To be able to make a rough indication of the overall trend in forest area, the areas of "productive forest" according to national classification has been presented in Table 7.5. The data are taken from the Census of Agriculture and Forestry 1967, 1979 and 1989. Because no data from permanent sample plots exists before 1986 and relatively small changes has been detected in total forest land, we have chosen not to take into account changes that may have occurred prior to 1990. This implies that stock changes in lands converted to forest are underestimated, but the biomass changes are included in the reporting category for "forest land remaining forest land".

Table 7.5 Estimates of productive forest land 1967-1989 (ha)

Region			
	1967	1979	1989
1	4 166 102	4 085 300	4 288 900
2	689 422	770 500	894 700
3	1 021 125	975 600a	1 255 200
4	522 110	744 000 b	514 300
Total	6 398 759	6 659 800	6 953 100

[a] *Trøndelag only*
[b] *Includes all of Nordland*

Single year changes are reported in the CRF-2009. The 20 years approach will be included after 2010 due to the completeness of NFI cycle 9.

7.2.2.3. Uncertainties

About 17 000 permanent plots are available from the NFI. These plots will be revisited during each 5 year period. Estimates for the specific period are made based on data obtained as 5 year averages. With the number of plots, the precision of the estimates (in relative terms) will be high for the common land-use classes. Although the NFI is carried out as a systematic sampling of plots, the formulas for simple random sampling can be used to provide approximate values for the precision of the area estimates.

The standard error of an area estimate with simple random sampling is:

$$std(\hat{A}_c) = A\sqrt{\frac{p(1-p)}{n}}$$

Where $\hat{A}_c$ is the area of a specific land-use category or transfer class, A is the total area of Norway (32,380,200 ha), p is the proportion of the land-use class, and n is the number of sample plots. In Table 7.6, some examples of standard errors are given for various cases, differentiated on proportion of the land-use category and the number of sample plots used.

Table 7.6 Examples of standard errors of area estimates, using a certain number (n) of sample plots in the calculations.

		Standard error					
		n=5000		n=10000		n=17000	
Proportion of area (p)	Corresponding area	(ha)	(%)	(ha)	(%)	(ha)	(%)
0.001	32 380	14 474	45	10 234	32	7 849	24
0.01	323 802	45 563	14	32 218	10	24 710	8
0.1	3 238 020	137 378	4	97 141	3	74 503	2
0.5	16 190 100	228 963	1	161 901	1	124 172	1

Table 7.6 shows that the relative errors of the uncommon categories are rather high. On the other hand, once a certain category becomes more frequent, the relative precision of its assessment will be higher. Thus, by using the permanent plots of NFI as a basis for the area estimation, the uncommon classes will be assessed with low accuracy. The system is sensible to the number of permanent plots. For sparse categories the current number of plots may be considered being close to a minimum. The uncertainties in emission and removal figures are substantially higher for all other land-use classes compared to forest. This is due to scarce of data available and all the assumptions needed to be done.

7.2.3. Census of Agriculture and auxiliary data

The data from the National Forest Inventory have been complemented with other statistical data, in particular for agriculture areas. These other data are less suited to derive exact land-use transitions.

Censuses of agriculture have been held at intervals of approximately 10 years from 1907 to 1969. Combined censuses of agriculture and forestry were held in 1979 and 1989. A separate Census of Agriculture was carried out in 1999. The census in 1999 included all units with at least 0.5 hectares of agricultural area in use and comprised 70 700 respondents.

Sample surveys of agriculture and forestry
In the periods between complete censuses, agricultural statistics are collected by annual sample surveys. The samples consist of about 11 500 - 13 000 units, which are drawn from the Farm register administered by the Norwegian Agricultural Authority. The samples are drawn on the basis of agricultural area in use and productive forest area. The structural variation between different counties is also taken into consideration, and the relative size of the samples differs both by county and by size of holding.

The sample surveys of agriculture and forestry provide figures for number of holdings and the size of agricultural area in use. Data concerning soil preparation are collected regularly, likewise information about labour force and working time on holdings.

Yield of agricultural crops
The statistics on yield of potatoes and coarse fodder are also based on sample surveys. The sample includes about 3 200 units registered with agricultural activity in the Farm register.

Statistics based on administrative registers
Since 1984 the annual statistics concerning *utilization of agricultural area and number of livestock* are based on information given by holders applying for governmental grants. For previous years these figures were based on sample surveys in agriculture.

Figures concerning sales of *concentrated feed, area subsidized for change of tillage, agricultural area transferred to non-agricultural use and producer prices* on certain agricultural products are given by Norwegian Agricultural Authority.

Statistics on *consumption of fertilizers* are based on data from the National Agricultural Inspection Service.

Area figures in Statistics Norway's agricultural statistics are more up to date than any other source, but do not have spatial coverage because of lacks in georeferencing (although most data are available at the municipality level). This means that the overall data for agricultural areas are of high quality, but they cannot be used to determine transitions between different land categories.

Statistics on *area burned in forest fires* are available from the Directorate for Civil Protection and Emergency.

Area data for *organic soils, peat extraction and others* are based on research projects at Bioforsk.

7.3. Forest land 5.A

7.3.1. Forest land remaining forest land – 5A1 (Key Category)

Forest is the most important land-use category with respect to biomass sequestration in Norway. According to the Tier 2 key category analysis (Section 7.1.3) this category is found to be a key category with respect to sequestration in living biomass, dead biomass, soils (mineral and drained organic) because of uncertainty in level and trend. The details of the biomass calculations will be described in Section 7.3.1.1. The same data will also be used to estimate losses of C when forest is converted to other land use classes or removals when forest is increasing.

7.3.1.1. Methodological issues

Change in carbon stock in living biomass

The IPCCs (2003) stock change method is used. The method implemented corresponds to Tier 3; a combination of national forest inventory data and models to estimate changes in biomass.

The reported carbon refers to the biomass of all living trees with a height of at least 1.3 m. Thus, small trees, shrubs and other vegetation, such as herbs are not included in the figures. The biomass of trees with a stem diameter larger then 50 mm measured 1.3 m above the ground is individually monitored. It is possible to match the biomass to land use of each tree. Both above ground and below ground biomass are reported. Above ground biomass is defined as living biomass above stump height (1 per cent of the tree height). The Swedish single tree allometric regression functions developed by Marklund (1987, 1988) are applied to data from the NFI for predicting the various tree biomass components; stem, stem bark, living branches, dead branches, needles (not leaves) of Norway spruce (*Picea abies*), Scots pine (*Pinus sylvestris*) and birch (*Betula pendula and Betula pubecens*). These species (including other coniferous about 1 per cent) constitute about 92 per cent of the standing volume (Larsson et al. 2007). Other, broad-leaved species constitute most of the remaining 8 per cent and the birch functions are applied to all broad-leaved species. Below ground biomass is defined as living biomass below stump height down to a root diameter of 2 mm and are estimated by Petersson and Ståhl's (2006) single tree allometric regression functions for the same tree species as for above ground living biomass. The living biomass is estimated consistently based on the same monitoring design, by using the same functions for the same tree species from the base year 1990 and onward.

The biomass for all trees larger than 50 mm diameter at breast height was calculated from their diameter and height measurements. Trees with a diameter less then 50 mm will be included in the calculations after 2010, when a full cycle of measurements are expected to be completed. It is planned to report biomass, land use and land use change for the entire country in 2014.

The calculated carbon stock in forest land from 1990 to 2007 is shown in Figure 7.5 and the calculation of the time-series is explained in Section 7.2.2.1.

Change in carbon stock in dead organic matter

The dynamic soil model YASSO as described in detailed by Liski et al. 2005 and applied to Norwegian conditions by de Wit et al. (2006), are used to calculated changes in carbon stock

in dead organic matter (Figure 7.8). Calculations of change in carbon stock (pools of biomass, dead organic matter) are done according to a Tier 3 method.

Change in carbon stock of dead organic matter due to litter from standing biomass, un-recovered fellings (trees that were felled but not removed from the forest), harvested residues and natural mortality, stumps and roots from harvested trees have been calculated from the growing stock, and annual harvest volume. The volume and increment estimates and amount of dead wood are taken from NFI and removals as forest harvest are from Statistics Norway. Dry matter biomass of different litter compartment (foliage, fine roots, branches, coarse roots, stems and stumps) are calculated using biomass expansion factors described for Norway in FAO/ECE (1985) and in Lethonen et al. (2004). The functions for biomass expansion factors are age dependent. Therefore, 100 year as mean age are used for harvested wood and 70 years for grooving stock volume.

Forest harvest (Figure 7.7 in Section 7.1.2) influences the amount of harvest waste and therefore also the estimate of "dead organic matter".

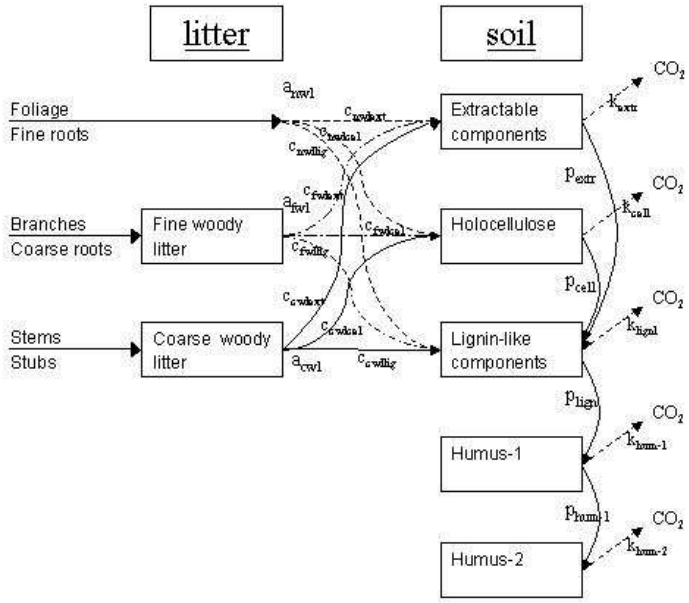


Figure 7.8. Carbon pools and fluxes in soil model Yasso. Values for the parameters are presented in Table 4 in de Wit et al. 2006.

Change in carbon stock in soils

The dynamic soil model YASSO as described in detailed by Liski et al. (2005) and de Wit et al. (2006), is also used to calculate changes in carbon stock in soil (Figure 7.8). The calculations are hence done according to a Tier 3 method. The model describes accumulation of soil organic matter and dead wood in upland forest soils and is designed to process data derived from forest inventories (Liski et al. 2005). The YASSO model does not distinguish between mineral and organic soil. The model requires estimates of litter production (dead organic matter) and basic climate data. The model has two litter compartments that relate to physical fractions of litter and five soil components that differentiate microbial decomposition and humification processes. The litter and soil compartments can be viewed as "dead wood" and "soil organic matter". With the current parameterisation (Liski et al., 2005) the model gives an estimate of the soil organic matter down to the depth of 1 m in the mineral soil. The

model requires regular input of different biomass components over years, and it is assumed that equilibrium of input and output is reached after some time and that the model is relevant for Norwegian conditions. The input values are described under *change in carbon stocks in dead organic matter*. Due to lack of soil carbon assessments the initial values for carbon content in soil was calculated assuming a steady state between soil organic matter and litter input at the first year of simulation. This was calculated by running YASSO under the initial conditions – climate and "litterfall"- since 1960 until the conditions in the soil compartments boxes were stable. The required factors as chemical composition, litter decomposition rates, transfer rates and fraction rates are taken from de Wit et al. (2006).

Drained organic soils used for forest will lead to a substantial loss of C, and abandoning this measure will after some time lead to a slow accumulation of soil C. Due to the general increase in forest we assume no such abandonment. The area of drained organic soil has been drastically reduced since the 1960s (Figure 7.9). This is due to economic conditions and an increased focus on preserving mires. There is no national data on the CO_2 loss from drainage, and hence the method used corresponds to IPCC (2003) Tier 1. The loss is expected to be less than for agriculture soils drained because of the contribution from forest waste. Due to lack of national emission factor the IPCC default factor for drained organic soils in managed forest (boreal), 0.16 Mg C/ha/year, is used. According to statistics from Statistics Norway the area of drained organic soils (total accumulated) was 245.5 kha in 2007. The estimated emissions are about 144 Gg CO_2.

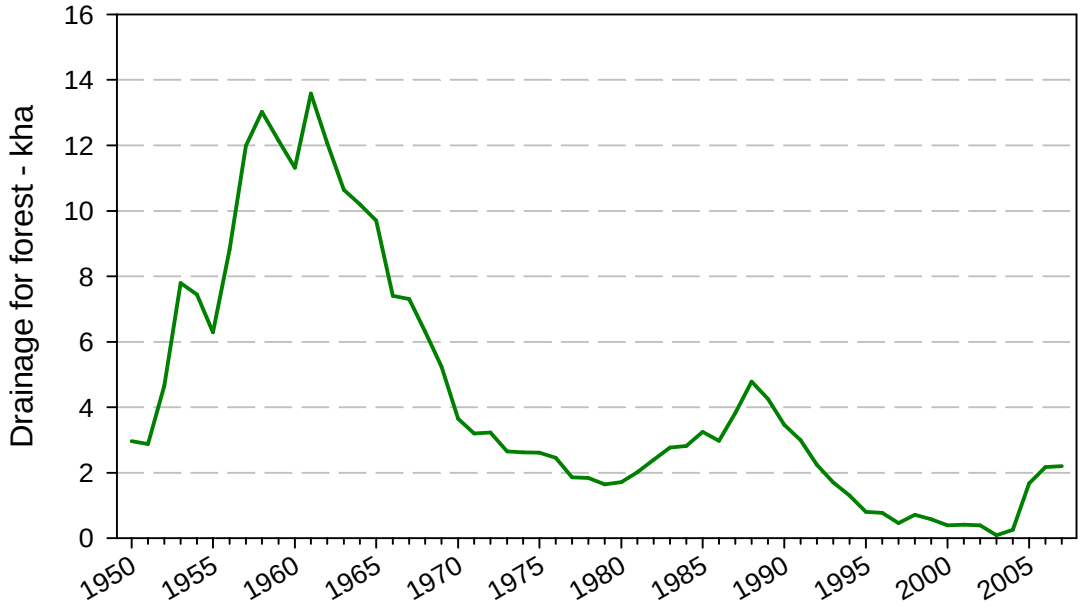


Figure 7.9. Drainage for forest. 1950-2007 (Source: Statistics Norway)

7.3.1.2. Recalculations

Compared to the submission of 2007 the whole time-series have been recalculated due to revision of the methods used to calculate total biomass of forest trees and land use change and updating of activity data.

The net removals for forest land remaining forest land was 27 693 Gg CO_2 in 2007.

Emissions of CH_4 and N_2O from the category were 0.01 Gg and 0.04 Gg, respectively (see Section 7.1.2)

In the centralized review of the 2005 NIR submission, the ERT suggested to separate emissions from removals (increases and decreases in stocks) in CRF table 5.A. This has been implemented for the report starting this year.

7.3.2. Land converted to forest land– 5A2 (Key Category)

The possible conversion under this category are the following: cropland converted to forest land, grassland converted to forest land, wetlands converted to forest lands, settlements converted to forest lands and other land converted to forest land. Land converted to forest land is found to be a key category only in the Tier 1 key category analysis. This is due to uncertainty in level and trend of the emissions of CO2.

7.3.2.1. Methodological issues

Change in carbon stock in living biomass

When a stand of trees reaches the predetermined minimum size and crown cover, the stand is measured and the living biomass is calculated according to a Tier 3 method. The estimated annual change in living biomass is reported.

Change in carbon stock in dead organic matter

Change in carbon stock in dead organic matter due to harvest residues and stumps and roots from harvested trees and natural mortality have been calculated. An average value for forest will automatically be assigned to the area when converted into “forest”.

Change in carbon stocks in soils

The methodologies used correspond to IPCC (2003) Tier 1 where emissions and removals are estimates considering the carbon stock before and after conversion and the duration of the transition. However, national data are used to the extent available.

Cropland converted to forest land

This conversion rarely goes directly most often it goes via “other land”. The conversion is expected to lead to uptake of carbon, because there has been a likely carbon loss on agriculture land due to management and because forest will accumulate carbon. Studies provided by Bioforsk on soil organic matter does not give any smaller values than cropland for a given soil type (the value also includes pasture and meadows). This may be due to uncertainties in the data, but it can also be explained by the fact that C losses are low in Norway due to a cold climate and because the most carbon rich soil is used for agriculture. We propose to not estimate any instant change in soil organic carbon, but to account for the C uptake by using the C accumulation data provided for forest soils.

Grassland converted to forest land

In the latest inventory cycle some transition between grassland and forest land have occurred. In this situation the carbon in soil is expected to increase. However, it is not possible to conclude that the soil organic carbon in forest soil on average is higher than in grassland soils (NIJOS, 2005). The reason for this may be the low rate of loss from grassland soils due to a cold climate. As the accumulation of carbon in forest soil is well documented (IPCC, 2003), we propose to apply the same factors for soil accumulation as for forest remaining forest and assume no direct change in soil organic matter due to the conversion.

Wetlands converted to forest land
There are conversions of wetland to forest land. We assume this is a gradually process where wooded mires over time reaches the Forest definition. As of today there is no available method to calculate carbon stock change in soil due to this slow process. Forestry in Norway has dramatically decreased its drainage of wetlands areas for tree planting over the last decades (Statistics Norway, 2005). The area drained in 1990 was 3.5 kha and only 0.2 kha in 2007.

Settlements converted to forest land
Conversions from settlements to forest are unlikely or small. For simplicity it is assumed that there is no change in carbon stock in soils (this is rationalised because any such conversion is expected to be in an area which is already dominated by forest, for example abandoned small farms).

Other land converted to forest land
This conversion will be on vegetated "other land" (addressed as "other wooded wetland" in Section 7.8). When this land is converted to forest, it is proposed to apply the carbon accumulation rates defined for forest remaining forest, assuming no change in soil organic carbon at the year of transition.

7.3.2.2. Recalculations

The whole time-series have been recalculated due to revision of the methods used to calculate total biomass of forest trees and land use change and updating of activity data.

In 2007 the land-use category land converted to forest land contributed to the total amount of removals with 330 Gg CO_2. Wetland converted to forest land was the largest contributor with 218 Gg CO_2.

7.4. Cropland 5B

7.4.1. Cropland remaining cropland – 5B1 (Key Category)

About 3 per cent of the total area of Norway is used as cropland. This category is found to be key category with respect to sequestration in soils (histosols) (Tier 2) because of uncertainty in level and trend, and with respect to liming (Tier 1).

Most of the area for agriculture is used for annual crops which imply that the carbon is not stored over a very long time in aboveground biomass. An exception is horticulture. Carbon stocks in soils can be significant (IPCC, 2003). Land conversion to cropland from forest, grassland or wetland usually results in a net loss carbon from biomass and soil to the atmosphere (IPCC, 2003). The soil carbon is, however, also affected by management practices (for example ploughing and fertilization) (Singh and Lal, 2004). In addition, Norwegian soils are limed to stabilize the pH. Liming contributes to improving the biomass production and the potential for carbon sequestration.

7.4.1.1. Methodological issues

Change in carbon stock in living biomass

The annual changes in carbon stocks of cropland remaining cropland can be estimated as the sum of changes in living biomass and soil. The method implemented corresponds to Tier 1 of IPCC (2003).

Changes in living biomass have only been considered for perennial woody crops. For annual crops, the increase of biomass in crops will equal loss from harvest and mortality the same year, and there is no net accumulation or loss. Perennial crops are used in horticulture. Statistics Norway collects data on the area of fruit trees (apple, pears, plum, cherry and sweet cherry). In general the area has been decreasing since 1990. There are no national data on their volume and carbon content. IPCC (2003) suggest default parameters for aboveground biomass carbon stock at harvest, biomass accumulation rate and biomass loss for temperate regions (it does not distinguish between vegetation types).

Changes in biomass in existing areas of fruit trees:

The IPCC default value for biomass accumulation rate is 2.1 Mg C/ha/year (IPCC, 2003). This gives an annual uptake corresponding to only 19 Gg CO_2 per year. The average age at harvest is somewhat lower than the IPCC default assumption (20-25 years). The average height is around 2 m and one tree occupies about 10 m^2 according to the Norwegian University of Life Sciences. The "harvest" can then be estimated at around 6.3 Gg C/ha. Because the existing areas are at balance, we propose to assume that there is no net uptake or loss from these areas.

Conversion from perennial crops to other land categories:

Because the area of fruit trees has decreased, there will be a net loss of CO_2 to the atmosphere which will be reported under the respective land conversions. There is no statistics indicating directly to what type of land it has been converted. It is likely that on the west coast the conversion is to grassland, in the eastern parts of the country the conversion may also be for grain production. In accordance with IPCC Tier 1 we assume that all carbon is lost at the year of harvest of the tree. The IPCC default value for carbon stock at harvest (temperate region) is 63 Mg C/ha. The resulting emissions are very small, see Table 7.7. It is reported under cropland converted to grassland (CRF 5.C.2.2.)

Table 7.7 CO_2 emissions due to reductions in fruit trees for agriculture production

	Area (ha)	**Annual uptake** (Mg)	**Annual C-loss** (Mg)	**CO_2 emissions** (Gg)
1989	3 267			
1990	3 267	6 861.3	0.0	0.0
1991	3 208	6 736.4	3 748.5	13.7
1992	3 148	6 611.4	3 748.5	13.7
1993	3 089	6 486.5	3 748.5	13.7
1994	3 029	6 361.5	3 748.5	13.7
1995	2 970	6 236.6	3 748.5	13.7
1996	2 910	6111.6	3 748.5	13.7
1997	2 851	5 986.7	3 748.5	13.7
1998	2 851	5 986.7	0.0	0.0
1999	2 791	5 861.7	3 748.5	13.7
2000	2 718	5 708.4	4 599.0	16.9
2001	2 611	5 483.3	6 753.6	24.8
2002	2 593	5 445.5	1 134.0	4.2
2003	2 385	5 009.3	13 085.1	48.0
2004	2 359	4 952.9	1 694.7	6.2
2005	2 305	4 839.5	3 402.0	12.5
2006	2 227	4 676.9	4 877.5	17.9
2007	2 264	4 754.4	0	0

**Data for 1990 -1998 have been interpolated*

Change in carbon stock in dead organic matter

This pool is considered insignificant (both the pool and changes in it) and no estimates are provided.

Change in carbon stocks in soils

A country specific methodology has been employed for these calculations. We use a Tier 2 method and national data, taking into account how management practices affect the soil organic carbon which is in accordance with the IPCC (2003).

The IPCC default method takes into account a reference SOC and changes in management practices (tillage and input). IPCC (2003) has proposed default factors for correcting changes caused by management practices and input of organic matter over a 20 year period. Singh and Lal (2004) have considered the effect of ploughing and other management on SOC content in soils. They conclude that the sequestration rate due to reduced tillage or increased N-application is higher in Norway compared to other countries, possibly due to lower temperatures and consequently lower rates of decomposition.

Erosion

Carbon in Norwegian cropland soils has been studied by Singh and Lal (2001;2004). Singh and Lal (2001) have estimated C loss by *accelerated erosion* of agriculture and pasture land. Erosion leads to less productivity and consequently less biomass returned to soil, and it removes C from the site to somewhere else. On the whole, soil erosion leads to C emissions. In Norway, soil erosion is mainly a problem in south-eastern regions of the country. Based on assumptions on ploughing practices and erosion rates from these, Singh and Lal (2001) have estimated a net erosion rate of 2.2 Mg/ha/years under autumn ploughing. The rate in other areas is 0.44 Mg/ha/years. They assumed 70 per cent autumn plowing and 30 per cent spring stubble, arriving at an average of 1.67 Mg/ha/year for 1999. The grass and pasture erosion rate is 67 kg/ha/year.

In line with Singh and Lal (2001) the following equation has been used to estimate the erosion:

*SOC loss = Area * soil loss * sediment delivery ratio * SOC * Enrichment ratio*

- Sediment delivery ratio is assumed to be 10 per cent.
- Enrichment ratio is assumed to be 1.35
- The mean carbon content of soils varies between regions, 27.3-58.7 g/kg, a value of 40 per cent has been used in the calculations.

(all these assumptions were taken from Singh and Lal (2001))

Finally, it is assumed that 20 per cent of the C transported by erosion is released to the atmosphere.

Other factors such as *Residue management, Crop rotations, Cover crops, Fertilizer and organic manure*, may contribute to acceleration or retardation in erosion (Singh and Lal, 2001). According to the discussion in NIJOS (2005) these factors are not accounted for in this report.

Tillage practices
Tillage practices have been changing over the last 10 years aiming at reducing N-leakages and runoff. Farmers are informed and rewarded for reducing the tillage rates in vulnerable areas, in particular autumn tillage (Bye, 2002 and 2005), see Figure 7.10. The fraction of area under autumn tillage was 82 per cent in 1989/2000, which was reduced to 43 per cent in 2001/2002 (based on annual surveys).

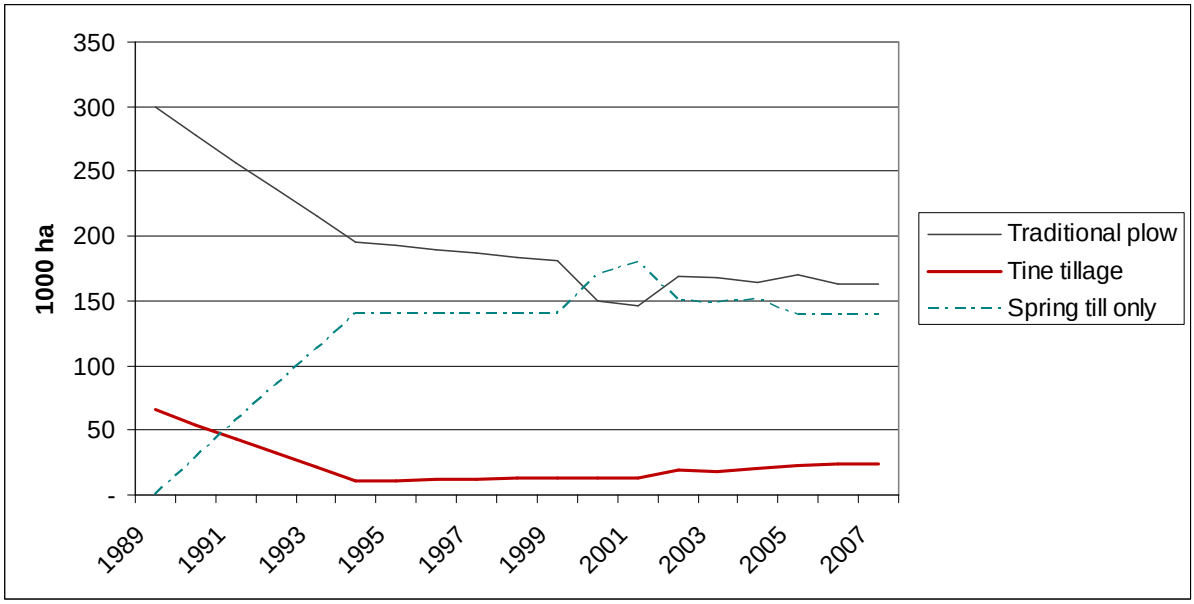


Figure 7.10. Tillage practices 1990-2007 (Statistics Norway)

Moving to autumn ploughing to tining has a very similar effect to minimum till. We assume that changes in tillage practices only have affected grain and oil crops (no change for potatoes and vegetables for example). Annual changes in management are taken from Statistics Norway (Bye, 2002 and 2005). The classes here are autumn till, shallow till, spring till (only) and no till. We have classified spring ploughing only as “minimum till”. Erosion emissions

will only be on new (< 25 years) agriculture land, however, the effect of sequestration due to reduced tillage will be on all land where changed tillage is practiced, but the effect of this conversion will be negligible after around 25 years. The IPCC (2003) suggests a time-period of 20 years, but national agriculture experts consider a 25 years horizon as more appropriate for Norway.

The basic erosion factor for agriculture land under traditional till (autumn ploughing) is 2.2 Mg/ha/year (Singh and Lal, 2001). This gives the following calculation:

*C loss by erosion (kg C/ha/year) = Erosion rate*C content*Delivery ratio*Enrichment ratio*

- Erosion rate = 2.2 Mg/ha/year
- C content = 40 g/kg
- Delivery ratio = 10 per cent
- Enrichment ratio = 1.35.
- C loss by erosion = 12 kg C/ha/year

We propose to use the factor (*12 kg C/ha/year)* only for newly cultivated agriculture areas over the last 25 years, because after that period the erosion loss will be negligible. Emissions and removals due to crop rotation have been ignored due to lack of data (NIJOS, 2005).

To estimate the erosion emissions statistics of new agriculture land from Statistics Norway have been used. All of this land is assumed used for grain production (grain area has been rather stable, while other crop production has been reduced). Further it is assumed that half of the new land is under autumn ploughing. In fact, a small amount is also used for grass production (may subtract “surface cultivated” area, around 5 per cent). To estimate the uptake due to reduced tillage we consider all area under no till, reduced till or tine. Because tine was common previously and the difference between tine and minimum till is small, we subtract the 1979 tine area. After 25 years no more gain in soil organic carbon should be assumed. The results are shown in Table 7.8.

*Table 7.8 Erosion emissions due to ploughing and uptake due to reduced ploughing in Norway**

	25 year old agriculture area (kha)	Erosion emissions (Gg)	Area under tine, no till or minimum till, subtracted 1979 tine area and part of the new agriculture area (kha)	Carbon uptake (Gg)
1990	151.6	1.50	0	0
1991	145.8	1.36	8.410	4.2
1992	139.7	1.21	19.766	9.9
1993	133.2	1.08	31.553	15.8
1994	128.7	0.96	42.924	21.5
1995	124.3	0.85	39.168	19.6
1996	118.8	0.81	41.505	20.8
1997	113.1	0.77	44.012	22.0
1998	106.5	0.72	46.947	23.5
1999	99.1	0.66	50.252	25.1
2000	92.1	0.61	82.754	41.4
2001	85.4	0.48	88.316	44.2
2002	78.1	0.42	65.484	32.7
2003	70.2	0.43	73.197	36.6
2004	71.4	0.44	76.757	38.4
2005	65.1	0.40	69.901	35.0
2006	58.4	0.35	75.477	37.7
2007	51.3	0.32	78.265	39.1

*The effect of cover crops have not been included in the table to avoid double counting as this measure is combined will changes in tillage practices. The green numbers indicate an update of activity data for that year.

For vegetables and potatoes we can assume the same erosion rate as traditional till (12 kg/ha/year). The reason is that when harvested roots are taken from the soil, a subsequent carbon loss will occur. The area of vegetables is around 15 118 ha. However, because the area of potatoes has been decreasing in the nineties, we assume that all area of vegetable and potatoes has been agriculture area for more than 25 years, and we assume no erosion loss of carbon.

Grassland

For grassland Singh and Lal (2001) propose a basic erosion rate of 0.067 Mg/ha/year applied to areas which are less than 25 years old. The following equation was used:

C loss by erosion (kg/ha/year) =Erosion rate C content*Delivery ratio*Enrichment ratio.*

- Erosion rate = 0.067 Mg/ha/year
- C content = 40 g/kg
- Delivery ratio = 10 per cent
- Enrichment ratio = 1.35

This gives an estimate of C loss by erosion equal to 0.36 kg/ha/year.

New area for pastures and meadows

New area for pastures and meadows are according to Statistics Norway at present around 4 166 ha annually. Assuming the same rate the last 25 years (was in fact higher previously) we get annual emissions that are very small (less than a Gg C). Some if this area may also be drained organic soils (see below).

Cropland on organic soils (histosols)

There is also a CO_2 loss due to cropland on *organic soils* (histosols). Conversion of wetlands to cropland is at present less common than previously. According to IPCC (2003) the accumulated area of organic soils should be multiplied with an emission factor. The default value for cold temperate region is 1.0 Mg C/ha/year. Bioforsk has calculated the area of farmed organic soil based on the frequency of organic soil among 500 000 soil samples.

Mixed organic-mineral soils (20-40 per cent organic matter)	42 000 ha
Peat soils (>40 per cent organic matter)	21 000 ha
Sum organic soils	63 000 ha

However, they expect organic soils to be underrepresented in their sampling. The real area of farmed organic soils is therefore assessed to be between 70 000 and 100 000 ha. The lower limit of area 70 000 ha is based on soil sampling surveys according to fertiliser management planning. The upper limit of area 100 000 ha is based on expert judgments. According to an ongoing revision these values are conservative. We plan to provide new values and an updated version of method used in the next NIR.

In this submission we have assumed 85 000 ha in the calculations. This number is smaller than previous estimates reported by Norway for estimating N_2O emissions. It is based on measurements of organic matter in soil and contrary to the previous estimate it takes into account that the C in soil is gradually decreased and after some decades the soil is no longer classified as organic. According to Bioforsk (Arne Gronlund, pers. Comm.) the soil database indicates the following distribution between crop types:

Grass: 86 per cent
Cereals: 9 per cent
Other crops (potatoes, vegetables, green fodder): 5 per cent

As soils samples are likely to be underrepresented on grass compared to cereals and more intensive productions, about 90 per cent of the farmed organic soils are used for grass. In this project we propose to assume that 10 per cent of the organic soil area is used for agriculture, the rest for grassland. For a discussion of emission factors, see “grassland remaining grassland” in Section 7.5.1.

This gives an annual emission of 208 Gg CO_2 from agriculture farmed organic soils (histosols).

7.4.1.2. Liming of agricultural soils – 5B1 (5IV) (Key category)

Liming of agricultural soils is found to be a key category only in the Tier 1 key category analysis. This is due to uncertainty in level and trend of the emissions of CO2.

Due mostly to low buffer capacity of soils, Norwegian soils may be limed using limestone (calcium carbonate - $CaCO_3$). This results in process emissions of CO_2, which traditionally have been included in the agriculture emission estimates. The estimate is based on the lime consumption as reported by “The Norwegian Agricultural Inspection Service” (for lakes “Directorate for Nature Management”). The emission factor is 0.44 tonne CO_2 per tonne calcium carbonate applied (SFT 1990). This emission factor is based on the stoichiometry of the lime applied and is consistent with IPCC (2003). The method is a Tier 1 with a country specific emission factor.

The total emissions from this source amounted to 68.6 Gg CO_2 in 2007 (Figure 7.11), which represent 0.12 per cent of Norway total GHG emissions. National total emissions have been reported yearly from 1990 and onwards, and are contained under the category "*5.B.1. Cropland remaining cropland - 5(IV) CO_2 emissions from agricultural lime application-Limestone $CaCO_3$*" in the CRF-tables.

7.4.1.3. Liming of lakes – 5G (5IV)

For several years many lakes in the southern parts of Norway has been limed to reduce the damages from acidification. The total emissions from this source amounted to 16.5 Gg CO_2 in 2007 (Figure 7.11), which represent 0.03 per cent of Norway total GHG emissions. The amount of calcium carbonate used for liming of lakes was collected from Directorate for Nature Management. The emission factor used is 0.44 tonne CO_2 per tonne calcium carbonate applied (SFT, 1990). The emissions are reported under "*5G. Other - Liming of lakes - 5(IV) CO_2 emissions from agricultural lime application - Limestone $CaCO_3$*".

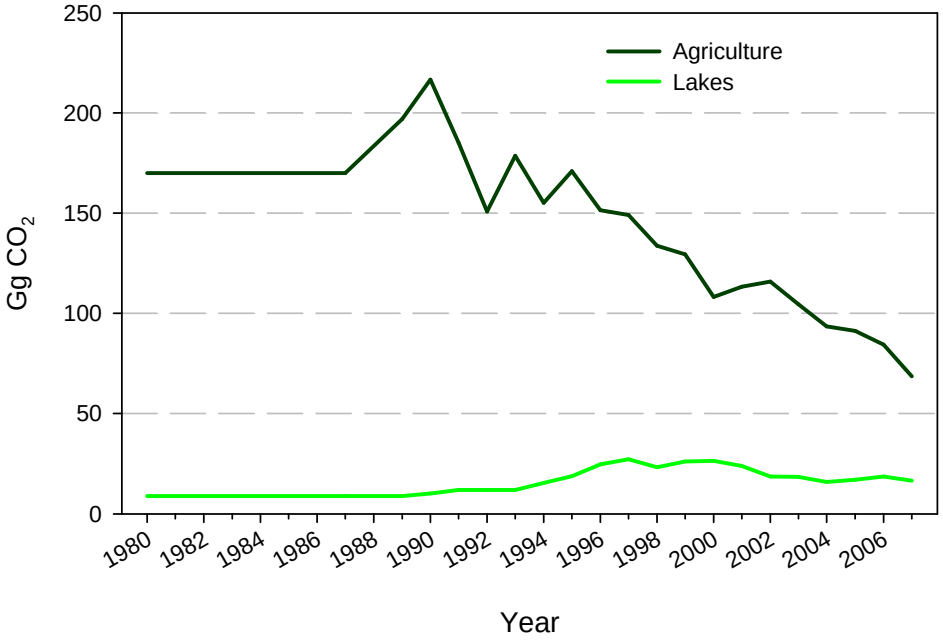


Figure 7.11. Emission of CO_2 caused by liming of agricultural soils and lakes. 1980-2007.

Table 7.9 Amount of lime applied to agricultural area and lakes, and corresponding CO_2 emissions. 1990-2007

	Agriculture		**Lakes**	
	Amount of lime applied (Mg)	**CO_2 emissions** (Gg)	**Amount of lime applied (Mg)**	**CO_2 emissions** (Gg)
1990	492 407	217	23 000	10
1991	421 163	185	27 000	12
1992	342 638	151	27 000	12
1993	406 129	179	27 000	12
1994	352 415	155	34 869	15
1995	388 365	171	42 738	19
1996	344 389	152	55 752	25
1997	338 898	149	61 856	27
1998	304 041	134	52 802	23
1999	294 150	129	59 193	26
2000	245 884	108	60 076	26
2001	257 696	113	54 118	24
2002	263 499	116	42 089	19
2003	237 631	105	41 833	18
2004	212 546	94	36 003	16
2005	207 325	91	38 684	17
2006	192 030	84	42 258	19
2007	155 859	69	37592	17

The ERT noted for the 2005 submission that Norway uses the same emission factor as that applied to cropland, as all lime is assumed to emit CO_2. The ERT recommended that Norway should provide additional information in the NIR to support the use of the agriculture emission factor for the application of lime to water. Norway response was that it did not see why lime in water should emit less CO_2 than lime in soil. These annual emissions are very minor. Until more information is available, Norway will wait to pursue this matter.

7.4.1.4. Recalculations

The whole time-series have been recalculated due to revision of the methods used to calculate land use change and updating of activity data.

The emissions from cropland remaining cropland were 117 Gg CO_2 in 2007. The emissions from this category in 2007 represented about 0.21 per cent of the total emissions from the LULUCF sector.

7.4.2. Land converted to cropland – 5B2

Administrative data show that since 1990, the annual conversion to agriculture land has been reduced from about 2 000 ha to 1 200 ha annually (Statistics Norway). There is a discrepancy between the administrative data and the land use change coming from the NFI. The NFI uses a system of permanent plots each representing approximately 900 hectares. The land converted to cropland is estimated from only a few plots that changes land use class each year. The statistical error from year to year is large. Most of the area is used for grass production, but part of the area (about 10 per cent) is annually used for cropland in crop rotation systems. The original land-use is not known, but it can be forest and to a limited extent wetlands.

7.4.2.1. Methodological issues

Land conversion to cropland from forest, grassland or wetlands usually results in a net loss carbon from biomass and soils to the atmosphere (IPCC, 2003).

Change in carbon stock in living biomass
When forest land is converted to cropland the losses will be calculated and all living biomass are lost the year of conversion. For all other land conversions we assume no changes in carbon stocks in living biomass.

Change in carbon stock in dead organic matter
When forest land is converted to cropland we assume all dead organic matter will be cleared. This emission is not estimated due to lack of data.

Change in carbon stocks in soils

Forest land converted to cropland
According to IPCC (2003) soil organic carbon in cultivated soils is generally less than in forest and other land use, so a conversion results in a net carbon loss (emissions). After some decades there will be equilibrium. The time and level of the equilibrium depend on soil, climate and management conditions. However, because Norwegian data indicate no major difference in soil organic carbon between forest and agriculture we assume no loss other than the losses which are depending on the management of the agriculture land after conversion (grassland, grain (tillage) or other use of the land).

Norwegian Forest and Landscape institute has estimated the mean carbon content in productive forest to 11.6 kg C/m^2. The corresponding mean value for all cultivated mineral soils (both grass and cropland) has been calculated at 14.1 kg C/m^2 by Bioforsk. The results indicate no difference in carbon content between forest and cultivated soils. The average value for agriculture land may, however, mask some differences between grassland and cropland.

Bioforsk has collected data on organic matter content of 3 920 farms in Norway, see Table 7.10.

Table 7.10 Organic matter and C in farm soil. Weight % (source: Bioforsk)

% grass area	Number of farms	Soil OM (%)	Organic C (%)
0	2 009	4.2	2.3
0-80	1 442	5.0	2.7
80-100	469	5.4	2.9

These data shows that the carbon content in general is lower in cropland compared to grassland (26 per cent). These differences are consistent with the proposed differences in erosion factors between cropland and meadows/pastures. The statistics do not allow for a more detailed analysis of differences and effect of crop rotations

Conversions from all other land use
Conversion from grassland to cropland is recorded in only a few years. However, it is expected that the conversion rather is *from* cropland to grassland, due to the abandonment of farms and because the areas of meadows and pastures have been increasing during the nineties at the cost of grain and potatoes.

Because the basic agriculture erosion factor is based on the one for grassland, we assume no immediate loss when land other than wetlands is converted to agricultural land. Losses are accounted for according to the changes in management (see cropland remaining cropland). Conversions between wetland to cropland are negligible. The conversion of peat land (wetlands) to agriculture land was addressed above, under cropland remaining cropland. The emissions are not immediate, but occur over time.

7.4.2.2. Recalculations

The whole time-series have been recalculated due to revision of the methods used to calculate total biomass of forests and land use change and updating of activity data.

Emissions from forest land converted to cropland are recorded for the whole time-series in this submission. In 2007, a small area was converted from forest land to cropland, but no losses of biomass were recorded.

7.5. Grassland 5C

According to the area definitions, grassland also includes pasture. Grasslands are used for harvest and pasture. Parts of the pasture land are in the mountains. Pasture practices have been changing over the last decades, gradually leading to altered vegetation (including expansion of forests and other wooded land).

7.5.1. Grassland remaining grassland – 5C1 (Key Category)

As for cropland, we consider changes in soil carbon. According to the Tier 2 key category analysis this category is identified as key category with respect to changes in carbon stocks in soils (histosols) because of uncertainty in level and trend. Changes in management have, however, influenced the vegetation on pastures. Gradually, some of this area will fall under the forest definition.

7.5.1.1. Methodological issues

Change in carbon stock in living biomass

No changes in living biomass are assumed for grassland remaining grassland because the mass of above ground biomass is small and is in a steady state in accordance with IPCC (2003) Tier 1. Changes in management have, however, influenced the vegetation on pastures. Gradually, some of this area will fall under the forest definition.

Change in carbon stock in dead organic matter

No chance in dead organic matter is assumed for this category because the mass of aboveground biomass is small and is in a steady state in accordance with IPCC (2003).

Change in carbon stocks in soils

As for cropland, we consider changes in carbon stocks in soil. Large amounts of carbon are stored in roots and soils. There have not been any major changes in management of grasslands (apart from pasture) in Norway. Consequently, that would justify ignoring carbon losses or uptake from mineral soils on existing grassland area. For grassland which is harvested (meadow) we have used the erosion factor of Singh and Lal (2001) of 0.78 kg C/ha/year. This factor should, however, only be applied to grassland which is younger than 25 years, see discussion under “cropland remaining cropland” in Section 7.4.1.

There will be a loss of carbon from grasslands on *organic soils*. As discussed for cropland, it is assumed that 90 per cent of organic soil used for agriculture production is used for grass production (organic soils are not suited for example for producing grain). The IPCC default emission factor is 0.25 Mg C/ha/year for cold temperate regions. However, according to Norwegian measurements emission can be larger because the age of the organic soils is lower than in Southern Europe. The average subsidence has been estimated by Bioforsk at 2 cm/year[9] which is equivalent to 20 Mg C/ha.[10] Some of this reduction is due to compaction and can be attributed to a sink in the height of the soil layer[11]. The soil loss also includes leaching of organic components in the drainage water. Based on measurements the emission losses of CO_2 from farmed organic soils in Sweden and Finland have been reported to be between 200 and 1 000 g CO_2-C/m^2/year (Final report from the EU Project Greenhouse Gas Emissions for Farmed Organic Soils (GEFOS). This corresponds to 2-10 Mg/ha/year. The assumptions on C-losses are also justified because a change in C/N ratio over time is observed. We propose using a loss factor of 10 Mg C/ha/year for high organic matter soil. For mixed organic soils the factor will be lower, we propose using 5 Mg C/ha/year (expert judgement).

Of the total area of 85 000 ha, 90 per cent were assumed used for grass. Of these 76 500 ha, we assume one third is highly organic, the rest is mixed. This gives an annual emission rate of 510 Gg C/year or 1 870 Gg CO_2. Using the IPCC emission factor, we obtain an emission estimate of 21 Gg C/year (78 Gg CO_2).

Given the importance of this estimate compared to other sources and the large difference from the IPCC default value, it is recommended to further improve the emission factor (measurements, modelling, literature). Other Nordic countries have similar agriculture practices. We will propose to reconsider the Norwegian emission factors in light of results conducted in Sweden and Finland.

Furthermore, the area is kept constant in the calculations. This is justified because new cultivation of organic soils is limited at present compared to the existing (existing areas is about 80 000 ha, new agriculture area is 1000 ha annually, but not all of this is organic soils). However, over time organic soils will be converted to mineral. Little is known about abandoned organic soils with respect to CO_2 uptake (and emissions of non-CO_2 GHG). Because the drained soil is considered marginal it will be abandoned before other soil types. This uptake has been ignored in the calculations due to lack of activity data, but may potentially be important and should be considered in the future.

Grassland is not limed (any possible liming is reported under cropland).

7.5.1.2. Recalculations

The emissions are considered constant from 1990 to 2007 since there have not been any major changes in management of grasslands in Norway during this period. The emissions from grassland remaining grassland is estimated to be 1 870 Gg of CO_2, which represents 3.4 per cent of the total emissions of greenhouse gases in Norway. Emissions of CH_4 and N_2O from the category are negligible.

[9] Meadow. The decrease in layer is larger on field grassland. However, organic soils are rarely used for the purpose.

[10] Assuming a soil density of 0.2 kg/l, and 50 per cent C.

[11] Assuming a soil density of 0.2 kg/l, and 50 per cent C.

7.5.2. Land converted to grassland – 5C2

According to IPCC (2003) the implications of converting other land to grassland is uncertain.

7.5.2.1. Methodological issues

Change in carbon stock in living biomass

Losses in biomass are only calculated for conversion of forest land to grassland. It is assumed that all living biomass is lost the year of conversion. For other land-use change we assume no net change in carbon of living biomass. This is justified because the IPCC (2003) defaults for aboveground biomass are quite similar for grassland and cropland. (5 Mg carbon/ha for cropland, 8.5 Mg dry matter/ha for grassland (boreal zone) equal to 4.2 Mg C/ha given a carbon content of 0.5).

Change in carbon stock in dead organic matter

We assume that all dead organic matter will be cleared when forest land is converted to grassland. It is not estimated due to lack of data. For all other conversions we assume no net change in carbon of dead organic matter.

Change in carbon stocks in soils

The soil organic carbon in grassland discussed under cropland is probably more representative for grassland and meadows close to the farm. The soil organic carbon in grazing land and unmanaged grassland is not known. However, much of the grassland will be in mountain areas where the soil organic carbon can be low.

Conversion of forest land to grassland

There are some transitions from forest land to grassland, but we assume no change in soil organic carbon if recorded.

Conversion of cropland to grassland

We propose to assume that there is no change in soil organic carbon when cropland is transferred to grassland, because the changes are small and exact data are lacking. Assuming that the grassland is nominally managed and the same level of fertilization, also the IPCC (2003) default method indicates no change. When cropland is converted to grassland the soil organic matter may change due to changes in management, for example ploughing and N-fertilization. The result is expected to be a net uptake. According to Statistics Norway the managed grassland area have increased in the nineties. Bioforsk confirms that farms with animals (and grass production) have a slightly higher soil organic carbon than those without (NIJOS, 2005). There are no data for grassland outside home fields, but they likely have a lower soil organic carbon. IPCC default Tier 1 method accounts for differences in soil organic carbon in the land use conversion according to changes in management. Assuming that the grassland is nominally managed and the same level of fertilization, also the IPCC (2003) default method indicates no change.

Conversion of wetland to grassland

See discussion on drained organic soils under “grassland remaining grassland” in Section 7.5.1.

Conversion of other land to grassland
We assume no emissions or removals due to changes in soil carbon when other land-use is converted to grassland.

7.5.2.2. Recalculations

The whole time-series have been recalculated due to revision of the methods used to calculate total biomass of forest trees and land use change and updating of activity data.
Emissions from this category were estimated at 0 Gg of CO_2 in 2007.

7.6. Wetlands 5D

Most of the wetlands in Norway are unmanaged mires, bogs and fens, as well as lakes and rivers. Managed wetlands include peat extraction and reservoirs (dams).

7.6.1. Wetlands remaining wetlands - 5D1

Wetlands remaining wetlands is only covered in appendix 3a.3 in the Good Practice Guidance (IPCC, 2003). That means that reporting is not mandatory. Consequently, changes in carbon stocks in unmanaged wetlands and reservoirs have not been considered in this report.

7.6.1.1. Methodological issues

Reservoirs
At present there exists no readily available water or land use change statistics related to dams or reservoirs. Reservoirs should be considered in the future due to the many hydroelectric power stations in Norway.

Peat extraction
Changes in carbon stocks for peat extraction are estimated with a Tier 1 method based on Swedish emission factors. According to Bioforsk, peat extraction in Norway is between 220 000 and 300 000 m^3/year (we assume no change in extraction). The extraction is around 5-10 cm/year. This corresponds to13 m^2/m^3. The total area harvested is consequently around 338 ha.

The IPCC default method considers only change in soil carbon during peat extraction. Changes in biomass and changes in soil carbon due to other processes associated with extraction (drainage, stockpiling, etc) are assumed to be zero at Tier 1. Extraction is assumed to enhance oxidation, leading to a continuing decrease in soil carbon. Although some of the extraction areas may belong to the temperate zone, we propose using the default emission factor for nutrient poor bogs in the boreal zone. The IPCC emission factor is 0.2 Mg C/ha/ · yr).

We propose using emission factors for Sweden (Uppenberg et al. (2001)). Prior to drainage and extraction the peat land acts as a small carbon sink (62-96 g/m^2/year). During extraction emissions will be around 10 Mg CO_2/ha/year (2.7 Mg C/ha/year), somewhat lower after drainage and before extraction. Because the age of the harvested area is not known, we apply the same emission factor for every year.

This gives an annual estimate of 0.9 Gg C or 3.4 Gg CO_2.

Wooded mire
Wooded mire according to Norway's national definition will be classified as forest, if the requirements of the international forest definition are met. The rest of wooded mire would be considered "other wooded wetland", and could form a subgroup under "wetlands". The living biomass is, however, negligible compared to forest, and the usefulness of forming such a category would be questionable.

Liming
Lakes are limed in Norway to stabilize the pH. The methodology is explained in Section 7.4.1.3 (see Table 7.9 and Figure 7.11). The corresponding emissions of CO_2 vary annually.

Other wetlands
Other wetlands are considered unmanaged, and no emissions and removals are estimated that is in line with IPCC 2003.

7.6.1.2. Recalculations

The total emission from wetland remaining wetland was 3.4 Gg CO_2 in 2007. This is the emission of peat extraction.

7.6.2. Land converted to wetlands - 5D2

No data are available on land converted to managed wetlands. In practice, this is only relevant for reservoirs. Land taken into use for peat extraction would normally be unmanaged wetlands.

As discussed in Section 7.2.2. recorded conversions to wetland are considered as artifacts and are not used in the calculations. To the extent the transitions are real; it is assumed that changes in SOC are small because the native vegetation is assumed close to wetlands.

Furthermore, conversion of forest land to wetlands is expected to be a slow process, because this involves re-growth of ditches and a steady increase in water level. Additionally, a conversion to the land use category 'wetlands' requires a reduction in tree cover, otherwise the land would still be considered forest. Clearly, drained forest must have been abandoned for some time in order to return to the land use category of wetlands.

We assume no loss or uptake of carbon when other land use is converted to wetland because we assume the features of these areas will approach those of wetlands. Furthermore, some of the reported changes are considered as reclassification.

7.7. Settlements 5E

7.7.1. Settlements remaining settlements – 5E1

Reporting of emissions and removals from this category is not mandatory. There are, furthermore, no data available in Norway to estimate the tree biomass. Changes in carbon stocks for settlements remaining settlements have consequently not been estimated.

7.7.2. Land converted to settlements – 5E2 (Key category)

IPCC (2003) suggests a method in which only forest biomass is considered. Thus, it is assumed that there are no carbon stock changes when land classes other than forest are converted to settlements. IPCC further suggests as a Tier 1 method that all biomass is lost in

the year of conversion. In principle there will also be losses when other wooded land is converted to settlements, but these have not been estimated due to lack of data. However, settlements on other wooded land can be expected to be on a small scale (for example mountain cabins and associated infrastructure). According to the Tier 2 key category analysis forest land converted to settlements is found to be a key category with respect to losses of living biomass because the biomass loss rate for these conversions was changed from 75 per cent to 100 per cent, leading to higher emissions.

There has been a rather large conversion from forest land to settlements between the forest inventories. These changes are likely real and are interpreted in this project as deforestation.

Change in carbon stock in living biomass
By using a Tier 3 method, we find that all the biomass is lost the year of conversion when forest land is converted to settlements.

Change in carbon stock in dead organic matter
We assume that all dead organic matter is cleared in this conversion. It is not estimated due to lack of data.

Change in carbon stocks in soils

Forest land converted to settlements:
When forests are converted to settlements it is reasonable to assume that soils will be disturbed in order to make the surface suitable for building purposes, for instance by levelling the surface and by removing the top soil. As most C is in the top soil, it seems reasonable to assume that most soil C will be lost in a short time. If there is any default value for soils under settlements, it can be assumed that the default forest soil value decreases to the default settlement value in 1 yr. We propose assuming that settlements have the same soil organic carbon as grassland, and use the same methodology as for cropland remaining cropland and the erosion factor for grassland by Singh and Lal (2001). We assume that the losses occur over 25 years, so the 25 years accumulated value should be used.

In this inventory no change in soil carbon has been assumed, due to uncertainty about the methodology.

Cropland converted to settlements:
There is some conversion from cropland to settlements. These changes are considered to be real, given that the total cropland area has been decreasing and urban area increasing also according to administrative records. We have assumed no change in soil organic carbon.

Grassland converted to settlements:
A case of change from to grassland to settlements has been observed. This change is not significant (assessed in one plot only). This conversion does, however, not have any major practical consequences for the estimates of emissions and removals. We have assumed no change in soil organic carbon.

Wetlands converted to settlements:
Conversions between wetlands and settlements are small. These apparent conversions may have been caused by subjective differences in classification of lands. However, they do not have any major consequences for the calculations of emissions and removals, as the result would be rather negligible.

Other land converted to settlements:
There has been some conversion from other land to settlements. This can be explained for example by road constructions. We assume that in these situations the other land is vegetated. We have assumed no change in soil organic carbon.

7.7.2.1. Recalculations

The whole time-series have been recalculated due to revision of the methods used to calculate total biomass of forest trees and land use change and updating of activity data. Emission from forest land converted to settlement was estimated to 116 Gg CO_2 in 2007.

7.8. Other lands 5F

7.8.1. Other land remaining other land – 5F1

7.8.1.1. Methodological issues

Change in carbon stock in living biomass
We assumed no change in carbon stock in living biomass. This is in accordance with IPCC (2003) because this land is considered unmanaged. For Norway this assumption may underestimate carbon uptake because vegetation is increasing in many areas due to reduced grazing and that the forested areas above the coniferous limit and of Finnmark County is excluded in the present report.

Change in carbon stock in dead organic matter
We assumed no change in carbon stock dead organic matter since the land is considered unmanaged.

Change in carbon stocks in soils
We assumed no change in carbon stock in soils since the land is considered unmanaged.

7.8.1.2. Recalculations

No emission/removals recorded.

7.8.2. Land converted to other land – 5F2

In the case of conversion from forest land, there will be a loss in biomass. In case the “other land” belongs to a category with some tree cover and has been assessed by the National Forest Inventory, the biomass can be estimated by repeated measurements.

7.8.2.1. Methodological issues

Change in carbon stock in living biomass
There will be a loss of biomass which can be calculated if the conversion is from forest or if there is some tree cover on the land which has been assessed by the NFI. If not, the biomass must be set at 0. In this report changes in living biomass is not reported since other wooded land is regarded unmanaged.

Change in carbon stock in dead organic matter
The same assumption as for living biomass would also be valid for dead organic matter.

Change in carbon stocks in soils

We assume no change in soil carbon when land is converted to other land. This is because no data exists and as discussed before, soil organic carbon for grassland and forest in Norway is quite similar. “Other wooded land” will often be in marginal areas where the soil organic carbon is lower than in agriculture land. However, the same will be true for forest or grassland in these areas.

7.8.2.2. Recalculations

The whole time-series have been recalculated due to revision of the methods used to calculate total biomass of forest trees and land use change and updating of activity data. There have been conversion of land to other land, mainly forest land have been converted, which have caused an emission of CO_2 through out the time-series. For 2007 the emission is not reported since other land is regarded unmanaged.

7.9. Other 5G

7.9.1. Liming of agricultural soils and lakes

Emissions of CO_2 from liming of agricultural soils and lakes are included in this category. The descriptions of the methodologies are contained in Section 7.5.1.

7.9.2. Harvested wood products

Norway has in previous years followed the IPCCs default approach when including emissions and removals from harvested wood products (HWP), and hence regarded harvested wood as emissions when removed from the forest. For the NIR2009 Norway has decided to report on net removals from HWP following the stock change approach. The reported net removals is however not included in the LULUCF category “5G-Other”, but reported separately in Annex VIII to this report.

7.10. Emissions of non-CO_2 gases

Changes in forest and other land use change will influence emissions of other greenhouse gases than CO_2. Emissions of methane (CH_4) are caused by fires. Changes in land-use may also change natural emissions, but according to the IPCC methodology these changes are not included in the accounting framework. Emissions of nitrous oxide (N_2O) are in addition to fires caused by soil organic matter mineralization, nitrogen input and cultivation of organic soils. Indirect emissions are not considered in this sector, but under agriculture. According to IPCC (2003) liming of forest and forest management may change N_2O emissions, but the effect is uncertain. Norwegian forest is, however, not subject to liming. The emissions of non-CO_2 gases are small (non-key) and default parameters and methods have been applied in most circumstances. Norwegian experts, and to some extent Swedish, have been contacted in search for improved information.

Emissions and removals in the Appendices of IPCC (2003) have only partly been included. Methodologies have been presented in NIJOS (2005) for further methodology development, but the corresponding emissions can be reported if national information is available. For the non-CO_2 GHG reservoirs can be a source in Norway, but the corresponding emissions have not been estimated.

7.10.1. Forests

N_2O is produced in soils as a by-product of nitrification and denitrification. Emissions increase due to input of N through fertilization and drainage of wet forest soil (IPCC, 2003). Forest management may also alter the natural methane sink in undisturbed forest soils (IPCC, 2003), but data does currently not allow a quantification of this effect. According to IPCC (2003) fertilizer input is particularly important for this process, but fertilization of forest is of little importance in Norway.

N_2O from fertilization

Because national emission factors for fertilization of forest soil are unavailable the estimate is based on Tier 1 and default emission factors.

$$N_2O\text{-}direct_{fertlizer} = (F_{Statistics\ Norway} + F_{ON})*EF_1 * 44/28$$

Where

$F_{Statistics\ Norway}$ = the amount of synthetic fertilizer applied to forest soil adjusted for volatilization as NH_3 and NO_x. Gg N.

F_{ON} = the amount of organic fertilizer applied to forest soil adjusted for volatilization as NH_3 and NO_x. Gg N.

EF_1 = Emission factor for emissions from N input, kg N_2O-N/kg N input.

There are national statistics on the area with fertilizer applied. This area is very small, only 7 km^2 in 2004 and 26 km^2 in 1990 (Statistics Norway, Forestry Statistics). The statistics do not specify whether this is synthetic or organic fertilizer. Furthermore, it does not say anything about the amount applied. Statistics Norway has supplied unpublished data on application on synthetic fertilizer for the period 1995-2005. The average ratio between the amount applied and the area fertilized was used to estimate the amount applied for 1990-1994. It is assumed that organic fertilizer is not applied to forest in Norway. To the extent that it is applied, the associated emissions will be reported under agriculture (this assumption is according to IPCC 2003). The amount of fertilizer applied is given as total weight. The nitrogen content is depending on the type used. According to Statistics Norway, 95 per cent NPK-fertilizer is used on wetlands. On dry land about half is NPK and the rest N-fertilizer. The N-content of these were taken from YARA (www.hydroagri.com).

The default emission factor is 1.25 per cent of applied N. There are no national data to improve this. 1 per cent of the N-applied is volatized as NH_3 (the ammonia model of Statistics Norway).

Table 7.11 Estimated emissions 1990-2007 from fertilization of forest

	Estimate of input of N, Mg			**Estimate of net amount of N applied, Mg**		**Estimated emissions N_2O, Mg**
	Wetland	Dry land				
1990	51	177		225		4.4
1991	77	271		344		6.8
1992	119	210		326		6.4
1993	77	150		225		4.4
1994	77	140		216		4.2
1995	90	138		226		4.4
1996	45	179		222		4.4
1997	21	200		219		4.3
1998	31	216		244		4.8
1999	44	183		225		4.4
2000	23	124		145		2.8
2001	20	100		119		2.3
2002	8	155		162		3.2
2003	1	71		72		1.4
2004	3	71		73		1.4
2005	32	61		92		1.8
2006	4	38		42		0.8
2007	1	68		68		1,3
Assumptions Nitrogen content	15%	22.5 %	Nitrogen volatilization	1 %	Emission factor	1.25 %

Source: Fertilizer consumption Statistics Norway, N-volatilization Statistics Norway, N-content YARA and emission factors IPCC

The resulting emissions are about 2-4 Mg N_2O per year, which is very small compared to the emissions from agriculture. The emission factor is highly uncertain. According to IPCC (2003), the range in emission factor can be from 0.25 per cent to 6 per cent. The amount of fertilizer applied to forest should be subtracted from the input to the calculation of emissions from agriculture, because that figure is based on the total fertilizer sale.

N_2O from drainage of forest soil

Drainage of organic soils generates emissions of N_2O in addition to CO_2. Drainage will also reduce methane emissions and even generate a sink (IPCC, 2003). However, data are unavailable to estimate this effect (IPCC, 2003) and there are no national data to estimate this. Given that the area drained in Norway currently is low, no estimate is given for methane. This methodology is given in an appendix in IPCC (2003) (for further methodology development). Because no national data are available, the estimation methodology for N_2O is based on IPCC (2003). It is assumed that all drainage is related to organic soils.

*N_2O emissions = Area of drained forest soil * emission factor*

The emission factor is taken from IPCC (2003). It is assumed that all soil is nutrient poor, the corresponding emission factor is 0.1 kg N_2O-N/ha/year (0.6 for nutrient rich). The range of emission factor is from 0.02 to 0.3 which is an indication of the large uncertainty of the estimate. The activity data is the area of drained forest soil provided by Statistic Norway. This is reported in CRF under *5.A.1 Forest land remaining forest land - 5(II) Non-CO_2 emissions from drainage of soils and wetlands - Organic soil - Area og N_2O Emissions.*

Table 7.12 shows area drained and N_2O emissions from drainage of forest soil from 1990 to

2007. Almost 250 000 ha have been drained accumulated. It is assumed that there is no rewetting of drained forest soils.

Table 7.12. Area drained and N_2O emissions from drainage of forest soil, 1990-2007.

Year	Area drained (accumulated 1000 ha)	Emissions N_2O (Gg)
1990	231.8	0.04
1991	234.8	0.04
1992	237.1	0.04
1993	238.8	0.04
1994	240.0	0.04
1995	240.8	0.04
1996	241.6	0.04
1997	242.1	0.04
1998	242.8	0.04
1999	243.4	0.04
2000	243.8	0.04
2001	244.2	0.04
2002	244.6	0.04
2003	244.7	0.04
2004	244.9	0.04
2005	245.1	0.04
2006	245.3	0.04
2007	245.5	0.04

N_2O and CH_4 from forest fires

No prescribed burning of forest takes place in Norway and all forest fires are due to accidents in dry periods (wildfires)[12]. According to IPCC (2003) the emissions of CO_2 from fires should be estimated, because the regrowth and subsequent sequestration are taken into account when it takes place. However, both the loss and uptake of CO_2 will be covered by the growing stock change based CO_2 calculations. The estimate provided in Table 7.14 is for comparison only and to be able to estimate other pollutants, and will not be used in the CO_2 calculations.

Data on area burned in forest fires are available from the Directorate for Civil Protection and Emergency Planning for 1993-2006 (Table 7.13). For 1990-1992 only data on the number of fires were available and these data were used to estimate the area burned based on the ratio for subsequent years. This method may be very inaccurate because the size of fires is very variable. Because the number of fires was higher in 1990-1992 than later, it is possible that the estimate for the base year is too high.

In accordance with the principles of this report emissions in all forest is reported. The area burned varies considerably from year to year due to natural factors (for example variations in precipitation). Assuming that the carbon content of biomass is 50 per cent, half of the biomass burned will end up as CO_2. There are no exact data on the amount of biomass burned per area. Normally, only the needles/leaves, parts of the humus and smaller branches are burned. We have assumed that there are 20 m^3 biomass per ha and that the mass of trees burned constitute

[12] There may be some trials of burning as part of forest management, but this is only performed in small scale and is ignored here.

25 per cent of this (this is consistent with IPCC (2003). It is also likely that there is about 1 m^3 dead-wood per ha that will be affected by the fire due to its dryness. It is difficult to assess how much of the humus is burned, and this is much dependent on forest type. There is about 7 500 kg humus per ha, we assume that 10 per cent of this is burned. This factor is, however, very dependent on the vegetation type. Most of the forest fires in Norway take place in pine forest with a very shallow humus layer.

Table 7.13 Forest fires in Norway 1990-2007

Activity data	Number of fires	Unproductive forest (ha)	Productive forest (ha)	Total area burnt (ha)
1990	578	679.6*	256.4*	935.9*
1991	972	1 142.8*	431.2*	1 574.0*
1992	892	1 048.8*	395.7*	1 444.4*
1993	253	135.5	88.3	223.8*
1994	471	123.6	108.1	231.7
1995	181	77.6	35.5	113.1
1996	246	169.7	343.8	513.5
1997	533	605.8	260.6	866.4
1998	99	164.7	110.3	275
1999	148	734.0	12.7	86.1
2000	99	142.6	29.3	171.9
2001	117	84.3	5.2	89.5
2002	213	124.7	95.8	220.5
2003	198	905.6	36.8	942.4
2004	119	84.6	32.3	116.9
2005	122	252.7	92.6	345.3
2006	205	3222.1.	660.7	3 882.7
2007	65	22.2	106.1	128.3

(Source: Directorate for Civil Protection and Emergency Planning)
*Area estimated by NIJOS (2005).
** The green number indicate updated activity data

Table 7.14. CO_2 emissions from forest fires, 1990-2007. Gg

Activity data	Living biomass	Dead wood CO_2 Gg	Humus CO_2 Gg	Total* CO_2 Gg
1990	17.2	0.9	1.3	19.3
1991	28.9	1.4	2.2	32.5
1992	26.5	1.3	2.0	29.8
1993	4.1	0.2	0.3	4.6
1994	4.2	0.2	0.3	4.7
1995	2.1	1.0	0.2	2.3
1996	9.4	0.5	0.7	10.6
1997	15.9	0.8	1.2	17.9
1998	5.0	0.3	0.4	5.7
1999	1.6	0.1	0.1	1.8
2000	3.2	0.2	0.2	3.6
2001	1.6	0.1	0.1	1.8
2002	4.0	0.2	0.3	4.5
2003	17.3	0.9	1.3	19.5
2004	2.1	0.1	0.2	2.4
2005	6.3	0.3	0.5	7.1
2006	71.2	3.6	5.3	80.1
2007	2.4	0.1	0.2	2.7

** These estimates are not included in the CRF*

There are no national data on emission factors for non-CO_2 gases from forest fires. Estimates of non-CO_2 gases emissions are therefore based on the C released as described in IPCC (2003). The following equation are used

CH_4 emissions = C * Emission ratio * 16/12
N_2O emissions = C * N/C ratio * Emission ratio * 44/28

Where C is the carbon released. IPCC (2003) suggests a default N/C ratio of 0.01. The methane emission ratio is 0.012 and for nitrous oxide 0.007.

Table 7.15 gives estimates of CH_4 and N_2O emissions from forest fires in the period 1990-2007.

Table 7.15. Estimates of CH_4 and N_2O emissions from forest fire. 1990-2007. Gg

	CH_4 Gg	N_2O Gg
1990	0.084	0.00058
1991	0.142	0.00097
1992	0.130	0.00089
1993	0.020	0.00014
1994	0.021	0.00014
1995	0.010	0.00007
1996	0.046	0.00031
1997	0.078	0.00054
1998	0.025	0.00017
1999	0.008	0.00005
2000	0.015	0.00016
2001	0.008	0.00006
2002	0.020	0.00014
2003	0.085	0.00058
2004	0.011	0.00007
2005	0.031	0.00020
2006	0.349	0.00240
2007	0.012	0.00010

** n.e = not estimated*

Conversion to forest land from cropland, grassland and settlements does, according to IPCC (2003), not alter the emissions of non-CO_2 greenhouse gases. Exceptions are in cases of fertilization and drainage as addressed above.

7.10.2. Cropland

Emissions from on-site and off-site burning of agricultural waste are reported under the agriculture sector and are not addressed here. Emissions from application of fertilizer and cultivation of organic soils are also reported under the agriculture sector. Conversion of forest, grassland and other land to cropland is expected to increase N_2O emissions. This is due to a mineralization of soil organic matter.

IPCC (2003) has proposed the following methodology:

*N_2O-N = Area converted to cropland last 25 years * N released by mineralization * Emission factor*

The best available data of new agricultural areas the last 25 years are taken from Census of Agricultural 1999 and Sample survey of agriculture and forestry 2002 (Statistics Norway 2003, 2002b). The time series are discontinued and interpolation are done between the following series 1970-1992, 1994-1998 and 1999-2001. Data are not available for later years. This area, however, also includes organic soils. The two data sets are inconsistent because the 1970-1992 dataset is also covering area with government support for drainage, while the 1994-1998 data covers the total area.

The N released by mineralization is estimated from the C released in mineral soils during conversion to cropland divided by the C:N ratio of soil organic matter (default is 15). According to Bioforsk the average C:N ratio in Norway is 13.4. The C-loss was based on the

erosion loss estimated under “cropland remaining cropland” (Section 7.4.1). The default emission factor from IPCC 2003 is 1.25 per cent.

Table 7.16 gives the accumulated area converted to cropland and related N_2O emissions from 1990 to 2007. As we can see, the area converted, and hence the emissions of both C and N_2O have decreased during the period.

Table 7.16. Accumulated area converted to cropland and related N_2O emissions. 1990-2007. Gg

	Accumulated area converted to cropland (kha)	Emissions C Gg	Emissions N_2O Gg
1990	151.6	1.50	0.002202
1991	145.8	1.36	0.001987
1992	139.7	1.21	0.00178
1993	133.2	1.08	0.001579
1994	128.7	0.96	0.001412
1995	124.3	0.85	0.001252
1996	118.8	0.81	0.00119
1997	113.1	0.77	0.001125
1998	106.5	0.72	0.001052
1999	99.1	0.66	0.000972
2000	92.1	0.61	0.000898
2001	85.4	0.48	0.000701
2002	78.1	0.42	0.000615
2003	70.2	0.43	0.000637
2004	71.4	0.44	0.000648
2005	65.1	0.40	0.000591
2006	58.4	0.35	0.000518
2007	51.3	0.32	0.000476

(Source: Statistics Norway)

7.10.3. Grassland

The effect of emissions from mineralization is very uncertain and is not accounted for. Fires in grasslands are ignored; the frequency of such fires is low in Norway. Fertilization of grassland may also alter the methane sink, but there are currently no data available to account for this.

7.10.4. Wetlands

Norway has many reservoirs due to hydroelectric power production. Flooding may generate emissions of CH_4 and N_2O. An emission methodology is given in an Appendix of IPCC (2003) for further methodology development. There is an ongoing national project (SINTEF and STATKRAFT) to estimate emissions from reservoirs. There will, however, not be any results from this project during the next year, and more measurements are needed to increase the representatively. N_2O emissions from organic soils managed for peat extraction can be estimated based on Uppenberg et al. (2001). Emission factors after drainage and before extraction range from 0.02-0.1 g/m^2. The first years after extraction has started (6-7 years) the range is 0.2-1 g/m^2, later on reduced to 0.01-0.05 g/m^2. Because the age of the land is not known we propose using a factor of 0.05 g/m^2 for all years.

The area was estimated in Section 7.2.2. This gives us an estimate of 0.2 Gg N_2O.

According to the same study peat extraction reduces CH_4 emissions (2-40 g/m^2 before drainage and 0.2-4 after). In line with IPCC 2003 this reduction is not accounted for in the calculations.

7.11. Uncertainties

The NIJOS 2005 report identified several large uncertainties in the estimates. The uncertainties are particularly large for emissions of non-CO_2 gases and CO_2 from soil (except forest soil). For these categories of emissions and removals also often the activity data are uncertain. Changes in soil organic carbon are difficult to monitor due to up scaling problems, lack of time-series and lack of management data. Nevertheless, we are able to conclude that emissions of non-CO_2 gases are small. Also lack of knowledge of the history of a piece of land causes problems. More measurements and more use of models could contribute to reductions in these uncertainties. Uncertainties are also large for other wooded land (tree covered land that does not meet the forest definition) and for Finnmark County which until recently has not been included in the National Forest Inventory. These changes are expected to be small. Also reservoirs should be further investigated due to the importance of dams in Norway (hydroelectric power stations). Estimates for these have not been included in the study. Data are, however, quite certain for stock changes in forest remaining forest which constitute the largest removal of the inventory.

Annex II presents the uncertainty analysis of the Norwegian GHG emission inventory undertaken for the previous NIR submission. Due to the unavailability of LULUCF data at the time of the analysis, emission data for 2003 was used. The uncertainty estimates for many LULUCF categories are not of the same quality as the rest of the inventory. More information about the uncertainty estimates for LULUCF is given in the NIJOS 2005 report. By including the LULUCF sector the results from the analysis show a total uncertainty of 14 per cent of the mean both in 1990 and in 2004, against 7 per cent without LULUCF. The doubling of uncertainty is caused mainly by forest biomass and grassland histosols.

The largest uncertainties are related to N_2O from fertilizer use and land disturbances, where the uncertainty will be larger than 100 per cent. Also the estimate of CO_2 from farmed organic soils is very uncertain, using the data from Sweden and Finland as an indicator the uncertainty is more than 100 per cent. Also CO_2 from agriculture soils are quite uncertain, by more than 100 per cent. CO_2 from liming is in the other hand well determined as the application is monitored and the emission factor is based on stoichiometry.

7.12. Source-specific QA/QC and verification

The Norwegian Forest and Landscape Institute undertakes a control assessment each year to check data quality and ensure consistent methodology in the survey. Furthermore, it completes the QA/QC report as an integrated part of their National system report.
Statistics Norway examines the various statistical data for consistency over time.
The Norwegian Forest and Landscape Institute is in charge of archiving all data from the calculations of emissions and removals from LULUCF. Statistics Norway is in charge of ensuring consistency between LULUCF and non-LULUCF categories and ensures there is no double-counting of emissions or removals between these.

7.13. Recalculations

The whole time-series have been recalculated due to revisions of the methods used to calculate total biomass of forest trees and land use change and updating of activity data. The method for calculating change in living biomass on land converted to "Forest" differs from last year's submission. Now estimates for only the annual change in living biomass are reported for these areas. The method used to recalculate changes of carbon stock in dead organic matter and for soil is the same as reported in 2008.

All calculations in this submission are based on data obtained from the same set of permanent plots through out the whole time-series. This procedure reduces the variation due to changes in the sample, and permits consistent and verifiable estimation of changes over time.
In earlier submission we used the mid-year of the NFI cycles as reporting year, causing a change in results the last two years as additional years were added to the time-series. By electing to report for the last year in the cycle any land use changes are reported when they are registered, and the reported values for a particular year will not change as additional years are added (assuming the same methods used over years).

Since there are no annual data available in the NFI for the years between 1990 and 1998, the annual estimates of carbon stock for the years from 1991 to 1997, inclusive, are based on the values for 1990 and 1998 using linear interpolation between these years (se figure 7.5). Because of the linear interpolation the calculated annual changes in carbon stock are all constant in this period (se figure 7.6). The use of moving average based on the 5-year cycle, starting in 1998, results in the relative large changes of CO_2-equivalents between 1998 and 1999 for the current submission (see table 7.17). In the 2007 submission this occurred between 1997 and 1998 that was due to using the mid year as the reporting year.

Table 7.17. Recalculations in 2009 submission compared to the 2007 and 2008 submission. Gg CO2 removals (the emission of CH4 and N2O are not included in 2007).

Year	Submission 2007	Submission 2008	Current Submission 2009	% change 2007-2008	% change 2008-2009
1990	-14 734	-13 704	-12 304	-7.0	-10.2
1991	-14 191	-12 919	-11 506	-5.9	-10.9
1992	-14 451	- 12 507	-11 094	-9.0	-11.3
1993	-14 060	- 12 772	-11 358	-13.5	-11.1
1994	-14 723	- 12 260	-10 847	-9.2	-11.5
1995	-13 935	- 13 101	-11 684	-16.7	-10.8
1996	-14 367	- 12 454	-11 034	-13.3	-11.4
1997	-13 980	- 12 770	-11 353	- 8.7	-11.1
1998	-19 864	- 12 673	-11 180	- 32.2	-11,8
1999	-20 079	- 16 277	-13 806	- 18.9	-15.2
2000	-25 326	- 23 495	-17 092	- 7.6	-27.3
2001	-27 375	- 25 982	-18 954	- 5.1	-27.0
2002	-27 901	- 30 956	-23 720	9.9	-23.4
2003	-25 220	-31 720	-25 709	25.8	-19.0
2004	-25 517	-31 079	-25 899	21.8	-16.7
2005	-27 232	- 34 482	-27 934	26.6	-19.0
2006		- 27 850	-22 558		-19.0
2007			-25 895		

7.14. Planned improvements

To confirm the extent of the area of forest and other wooded land at higher altitudes, NFI started in 2005 to establish a limited number of NFI plots above the coniferous forest limit. A complete forest inventory is conducted on these plots. It is not yet decided whether a complete 3x3 grid of plots will be installed in the future, or if the sampling intensity will remain at a lower level in this region.

In Finnmark County, the NFI started in 2005 to conduct a full forest inventory on plots in the 3x3 km grid in coniferous forest. NFI planes to use a less dense plot grid for forest land and other wooded land that are mainly stocked with birch. The land use of mountainous areas are also planned to be assessed according to the NFI manual. The plan is that the inventories of these areas will end in 2013, and planned to be included in the 2014 report.

The NFI started in 2007 to use national aerial photographs (ortophotos) to supplement the field survey to update and check land cover statistics and land cover change statistics by assessing plots from the 3×3 km grid that was not assessed as Forest in earlier inventories. More than 2000 plots will be checked each year, and those with a tree cover will be visited in the field. This method is used for wooded land above the coniferous forest limit, in mountainous areas and for Finnmark County. The statistics from the NFI and the aerial photographs will give statistics for all land use classes for the whole country. Current ortophotoes are made available through a web-based service (www.norgeibilder.no). In addition to the land use classification from the 6th NFI (1986-1993) old and new aerial photographs will be use to establish land use of each plot in the base year 1990.

In 2005 the NFI started to assess trees with a diameter less then 50 mm. These trees will be included in the calculations after 2010, when a full cycle of measurements are expected to be completed.

In order to meet the reporting requirements of LULUCF the Norwegian NFI system is expanding its coverage beyond areas conventionally considered to be productive forest area. The development of new and improved methods for reliable back-casting of biomass and land-use class is currently taking place. The aims are to adjust the land-use classification to be better aligned with the LULUCF classification, establishing a reliable 1990-status, and improved estimates for the annual change in living biomass from 1990 up to today.

Land use changes to forest land are reported as single year changes in the CRF-2009. The 20 years approach are planned to be included after 2010 due to the completeness of NFI cycle 9.

It is planned to report biomass, land use and land use change for the entire country in 2014.

During 2009 it is planned to evaluate the methods used for assessing emissions and removals for cropland and grassland.

8. Waste

8.1. Overview

This sector includes emissions from landfills (6A), wastewater handling (6B) and small scale waste incineration (6C). Waste incineration from plants with energy utilization is accounted for under 1A (Energy combustion). Waste incineration included here are emissions of other greenhouse gases than CO_2 from methane flared at landfills and combustion of hospital waste in hospital incinerators and cremations.

The emissions of greenhouse gases from the waste sector were relatively stable during the early 1990s, with emission level between 1.7-1.8 million tonnes CO_2-equivalents (Section 2.3). From 1998 emissions declined and in 2007 emissions were almost 27 per cent lower than in 1990. In spite of increasing amounts of waste the emissions of CH_4 from landfills has decreased. This is due to a number of measures to reduce the amount of organic waste deposited and to increase the collection and combustion of methane from landfills. The most important measures are requirement to collect methane from landfills, the introduction of a tax on final treatment of waste from 1999 and a prohibition of depositing easy degradable organic waste gradually introduced from year 2000.

Solid waste disposal on land (i.e. in landfills) is the main category within the waste sector, accounting for about 89 per cent of the sector's total emissions. Wastewater handling and waste incineration account for approximately 11 and less than 0.01 per cent respectively. Since emissions from incineration with energy utilization are reported under energy combustion, the emissions reported here under waste incineration are almost non-existing. The waste sector accounted for 2.4 per cent of the total GHG emissions in Norway in 2007.

8.2. Managed Waste Disposal on Land – CH_4 – 6A1 (Key Category)

8.2.1. Description

CH_4 and non-fossil CO_2 are emitted during biological decomposition of waste. This transformation of organic matter takes place in several steps. During the first weeks or months, decomposition is aerobic, and the main decomposition product is CO_2. When there is no more oxygen left, the decomposition becomes anaerobic, and methane emissions start to increase. After a year or so, CH_4 emissions reach a peak, after that the emissions will decrease over some decades (SFT (1999b) and Barlaz (2004)).

The emissions of methane have decreased slightly since 1997 due to reduction of the amount of degradable waste disposed at disposal sites. This reduction in emissions is the result of several measures which were introduced in the waste sector particularly in the 1990s. With some few exceptions, it is prohibited to dispose easy degradable organic waste, sewage sludge included, at landfills in Norway. In 1999 a tax was introduced on waste delivered to final disposal sites. In 2006 this tax was 416 NOK per tonne waste disposed at landfill sites with double side and bottom lining (rising to 434 NOK per tonne in 2008 and 447 in 2009), and 542 NOK per tonne waste disposed at landfills without double lining (rising to 566 NOK per

tonne in 2008 and 583 in 2009). In addition, landfills receiving biodegradable waste (waste containing degradable organic carbon (DOC)) are required to collect and treat landfill gas. In 2007 a total of 57 landfills had installed a landfill gas extraction system, and approximately 22 ktonnes of methane was recovered. In addition, the amounts of waste recycled have increased significantly since 1990. The total amount of waste generated has increased with about 45 per cent from 1995 to 2007, but due to the increase in material recycling and energy utilization in the period there has not been a similar increase in degradable waste to landfills.

In 2005 Statistics Norway took over the responsibility for the methane calculating model. Then considerable deviations were discovered between Statistics Norway's improved waste statistics, and the waste statistics from 1998-99 used in the model. In addition, an error in the calculation of manufacturing waste deposited at the industrial disposal sites was discovered. This could be of great importance to the calculated methane emissions. It was on this background Statistics Norway in November 2005 started a quality check of the waste calculations in the methane model (Skullerud 2006). By a mistake, the industrial sludge was not adjusted for wood content; this has now been corrected for all years. In addition, it was also by a mistake corrected for a DOC content of 320 kg/tonnes, instead of 400 kg/ tonne of waste. Further improvements of Statistics Norway’s waste statistics have been made, due to an improved allocation of landfilled industrial waste to material (SSB 2006 and 2008). The main change from the previous year builds on a new survey on waste from service industries, combined with sorting analyses on mixed household waste and literature studies of industrial and household mixed waste composition. Future improvements must be expected as well, which may affect the calculated methane emissions. However, future changes in historical waste amounts are believed to be of minor importance to the calculated methane emissions.

Statistics Norway's quality check of the methane calculations also comprises an updating of the decomposition time for wood, paper and easy degradable waste, and new data series for extraction of methane from Norwegian landfills.

Emissions of CH_4 from solid waste disposal are key category in level and trend due to uncertainty in AD and EF.

8.2.2. Methodological issues

In 1999, the Norwegian Pollution Control Authority (SFT) developed a model for calculating methane emissions from landfills (SFT 1999b). The model was based on the IPCC theoretical first order kinetics methodologies (IPCC 1997b) and the method was consistent with the IPCC Good Practice Guidance. The effect of weather conditions had also been taken into account.

However, both the former Norwegian and the IPCC 1997 model contain a mathematical error. As the rate of reaction decreases over the year, the average rate of reaction over the year has to be found. This is done through integration and neither the former Norwegian model, nor the IPCC 1997 model, contained such integration. The result was that with a half-life time of 10 years the emissions were underestimated by 3.5 per cent. The models were also complicated and difficult to understand, and gave a poor view into the calculations. Therefore a new model taking account of these issues was developed in 2004. Methane emissions are in the new model calculated from the amount deposited every year, and the amounts added at the end (SFT 2005).

This new model starts with the calculation of the amount of dissimilating $DDOC_m$ (mass of dissimilatable organic carbon = the part of DOC (degradable organic carbon) that will dissimilate (degrade) under anaerobic conditions) contained in the amount of material being landfilled. This is done in exactly the same way as in the former Norwegian model.

As this is a first order reaction, the amount of product formed will always be proportional to the amount of reactant. This means that it is of no concern to the process when the $DDOC_m$ came into the landfill. As far as we know the amount of $DDOC_m$ in the landfill at the start of the year, all years can be considered to be the first calculating year. This simplifies calculations. With reaction start set to be on January 1 the year after landfilling, the "motor" of the new calculating model has been made out of these two very simple equations:

$$(8.1) \quad DDOC_{mdiss} = (DDOC_{ma(ly)} + DDOC_{md}) * (1- e^{\wedge}\text{-}k)$$
$$(8.2) \quad DDOC_{ma} = (DDOC_{ma(ly)} + DDOC_{md}) * e^{\wedge}\text{-}k.$$

Equation (8.1) calculates DDOCmass dissimilating ($DDOC_{mdiss}$), from the not dissimilated DDOC mass accumulated from last year ($DDOC_{ma(ly)}$), plus DDOC mass landfilled last year ($DDOC_{md}$). Equation (8.2) calculates the DDOCmass accumulated as not dissimilated ($DDOC_{ma}$), for next year's calculations from the same basis as equation (8.1).

After that the amount of dissimilated $DDOC_m$ has been found, CH_4 produced and CH_4 emitted is found by using the same set of procedures and factors as in the former model.

The full set of equations is found below. If the reaction is set to start in the year of landfilling, separate calculations have to be made for that year and two extra calculating equations will have to be added. They are included in the equations below.

To calculate $DDOC_{md}$ from the amount of material

$$(8.3) \quad DDOC_{md} = W * MCF * DOC * DOC_f$$

To calculate $DDOC_m$ accumulated in the SWDS

$$(8.4) \quad DDOC_{ml} = DDOC_{md} * e^{\wedge}\text{-}k*((13-M)/12)$$
$$(8.5) \quad DDOC_{ma} = DDOC_{ma(ly)} * e^{\wedge}\text{-}k + DDOC_{ml}$$

To calculate $DDOC_m$ dissimilated

$$(8.6) \quad DDOC_{mdi} = DDOC_{md} * (1-e^{\wedge}\text{-}k*((13-M)/12))$$
$$(8.7) \quad DDOC_{mdiss} = DDOC_{ma(ly)} * (1-e^{\wedge}\text{-}k) + DDOC_{mdi}$$

To calculate methane produced from DDOC dissimilated

$$(8.8) \quad CH_{4\ prod} = DDOC_{mdiss} * F * 16/12$$

To calculate methane emitted

$$(8.9) \quad CH_4 \text{ emitted in year } T = (\sum CH_{4\ prod}(T)) - R(T)) * (1-OX)$$

Where:

W	: amount landfilled
MCF	: Methane Correction Factor
M	: Month number for reaction start. (January 1, year after landfilling, M=13)
DOC	: Degradable Organic Carbon
DOC_f	: Fraction of DOC dissimilating, anaerobic conditions
DDOC	: Dissimilatable Organic Carbon, anaerobic conditions
$DDOC_{md}$	: DDOC mass landfilled
$DDOC_{ml}$	: DDOC mass left not dissimilated from DDOCm landfilled, year of landfilling
$DDOC_{ma}$	: DDOC mass left not dissimilated at end of year
$DDOC_{ma(ly)}$	: DDOC mass accumulated from last year
$DDOC_{mdi}$	: DDOC mass dissimilated from DDOCm landfilled, year of landfilling
$DDOC_{mdiss}$	: DDOC mass dissimilated in calculation year
$CH_{4\ prod}$	: CH_4 produced
F	: Fraction of CH_4 by volume in generated landfill gas
16/12	: Conversion factor from C to CH_4
R(T)	: Recovered CH_4 in year of calculation
OX	: Oxidation factor (fraction).

8.2.3. Activity data

The amount of different waste materials is compiled in annual surveys carried out by Statistics Norway. These data are used as input into the model used to calculate methane emissions. For the new model, historic data have been recalculated from the former waste category basis, to a material waste basis. The model is based on types of materials, for instance food waste, paper, wood and textiles. All waste sources, including business, industry, and construction and demolition sector, are included in the waste statistics.

Municipal landfills
Historical data for years before 1973 on municipal solid waste deposited are based upon:

9. New statistics on municipal waste, divided into household waste and industrial waste (1974 to 1997)
10. Estimates based on population
11. Assumption that less people were connected to public waste management during the forties and fifties.

Since 1974 the amount of municipal waste is based upon questionnaires and linear interpolation. Surveys were held in 1974, 1980, 1985 and every year from 1992 to 1995. The amount of waste going to landfills is allocated to material based on sorting analyses. For the period 1995-2007 the amounts of waste is taken from the waste accounts, with three exceptions:

- Wood content in sludge deposited at industrial sites is added to the amount of deposited wood from the waste accounts.

- Textiles are supposed to consist of 50 per cent plastic (SFT 2005b). The plastic fraction of deposited textiles is therefore subtracted from the amount of deposited textiles and added to deposited plastic.
- The material category "Other" is supposed to contain 13 per cent of biodegradable waste, which is added to the amount of paper.

Industrial disposal sites
Historical data for industrial waste for years before 1970 are made by extrapolation using the same trend as for municipal waste. After 1970, literature studies and information from the industrial waste study from the years 1993, 1996 and 1999 have been used. Linear interpolation is used for the years where data are missing.

Data from each landfill site with methane recovery units are compiled by the County Governors and reported to the Norwegian Pollution Control Authority. These data are imported into the national model for calculating methane from landfills.

Data from each landfill site with methane recovery units are compiled by the County Governors and reported to SFT. These data are imported into the national model for calculating methane from landfills.

8.2.4 Emission factor

The emission factors used in the Norwegian model are a mixture of country-specific factors and IPCC defaults values. Table 8.1 shows some of the variables used in the calculations of methane emissions from solid waste disposals.

Table 8.1 Variables used in the calculations of methane from landfills.

	Type of waste			
Variables	Food waste	Paper	Wood	Textiles
$t_{1/2}$ (half life time)	3,7 years	11,6 years	23,1 years	11,6 years
DOC	0.150 Mg/Mg	0.400 Mg/Mg	0.400 Mg/Mg	0.400 Mg/Mg
DOC_f (Part of DOC dissimilating)	0.5	0.5	0.5	0.5
Ox. Methane oxidized in top layer	0.1	0.1	0.1	0.1
F. Part of methane in generated landfill gas	0.5	0.5	0.5	0.5

Source: SFT (2005a) and Skullerud(2006)

8.2.5 Uncertainties

Uncertainty estimates for greenhouse gases are presented and discussed in Annex II.

The importance of the uncertainties in calculations of methane from landfills will decrease with decreased source contribution and improved IPCC default parameter values, but most likely it will still remain among the main uncertainties in the Norwegian GHG inventory.

8.2.6 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 are carried out and corrections are made if any kinds of

errors are found. If there is a change in the trend of methane recovered from a landfill site, the site is contacted to identify a plausible explanation. Corrections are made if there is no plausible explanation of the change.

8.2.7 Recalculations

Revised activity data. Figures on disposed waste in Statistics Norway's waste statistics, in particular the distribution between different waste types, used to calculate CH_4 emissions, have been altered for the whole time period 1990-2006. There is a continuous process to improve the waste statistics. The most recent figures have caused a major reduction in national CH_4 emissions. The annual reduction grew successively through the period, from 1.0 ktonnes CH_4 in 1990 to 7.3 ktonnes in 2006. The annual percentage reduction in emissions from landfills increased from 1.2 per cent in 1990 to 11.3 per cent in 2006. The impact of the change on total national CH_4 emissions rose from 0.3 per cent in 1990 to 3.5 per cent in 2006.

8.2.8 Planned improvements

There is for the moment no planned activity that will improve the data quality for NIR 2010.

8.3 Unmanaged Waste Disposal Sites – 6A2

In Norway landfilling of solid waste has been regulated and controlled for some decades, and unmanaged landfills are from before 1970. Furthermore, the methane emissions for all years have been calculated from the total amounts of landfilled materials. Therefore Norway does not separately report emissions from unauthorized/unmanaged SWDSs.

8.4 Wastewater handling - 6B

8.4.4 Description

Emissions of CH_4 and N_2O from Wastewater handling has been relative stable during the 1990 to 2006, with a small increase for CH_4. The emission trend for this period is described in Section 2.3.

According to the Tier 2 key category assessment for 2006, emissions of N_2O from wastewater handling are key category in level.

8.4.5 Methodological issue

CH_4
Emissions of methane from domestic and commercial waste water have been calculated. Emissions from water consumption in food processing industries (breweries, dairies and slaughterhouses) are included for all years since 1990 as recommended by the review team in 2007. Emissions of methane from industries with their own waste water treatment plants are small, because the plants are mainly aerobic or the methane gas is being recovered. CH_4 from domestic sludge is calculated together with the waste water emissions.

Emissions of methane from domestic waste water are calculated according to the IPCC default methodology:

$$(8.10) \quad E_i = N_i * D * B_0 * MCF$$

E: Emissions of methane
N: Population in Norway
D: Organic load in biochemical oxygen demand (kg BOD/1000 persons/year)
B_0: Maximum methane-producing capacity (kg CH_4/kg DC)
MCF: Methane conversion factor
$_i$: Year

Emissions of methane from water consumption in each food processing industries are calculated using the same equation as for domestic water, except that for COD is estimated based on water consumption multiplied with mg COD/l wastewater.

$$(8.11) \quad E_i = W_i * COD_i * B_0 * MCF$$

E: Emissions of methane
W: Water consumption/economic turnover (million NOK)
COD: Organic load in chemical oxygen demand (kg COD/unit wastewater)
B_0: Maximum methane-producing capacity (kg CH_4/kg DC)
MCF: Methane conversion factor
$_i$: Industry

N_2O
For this source emissions of nitrous oxide from domestic and commercial wastewater have been calculated. Until this year only N_2O emissions from the part of the population that is connected to large waste water treatment plants (>50 pe) have been estimated. As recommended by the review team Norway now estimates N_2O emissions from human sewage, which is not treated in sewage treatment plants.

Emissions of N_2O from det part of the population not connected to large waste water plants (> 50 pe) are estimated by Tier 1 method. Emissions are calculated using the Equation:

$$(8.12) \quad N_2O_{(S)} = Protein \times Frac_{NPR} \times NR_{PEOPLE} \times EF_6$$

$N_2O_{(s)}$: N_2O emissions from human sewage (kg N_2O -N/ yr)
Protein: annual per capita protein intake (kg/person/yr)
NR_{PEOPLE} : Number of people not connected to treatment plants
EF_6: emissions factor (default 0.01 (0.002-0.12) kg N2O -N/kg sewage- N produced)
$Frac_{NPR}$: Fraction of nitrogen in protein (default = 0.16 kg N/kg protein)

The N_2O from sewage sludge applied on fields is included under Chapter 6, Agriculture. For the part of the population connected to large treatment plants N_2O, emissions are calculated from nitrification/denitrification that occurs in the pipelines and the N_2O emissions that occur as a by-product in biological nitrogen-removal plants. The estimates are based on the amount of nitrate supplied to the pipelines. This is assumed to be a more precise method than the recommended IPCC method that is based on the annual per capita protein intake. For the part of the population that is not connected to treatment plants, the N_2O emissions are estimated as

recommended by the IPCC review team using the IPCC method that is based on the annual per capita protein intake.

8.4.6 Activity data

CH_4
Data for the number of residents in Norway are given from Statistics Norway's population statistics. The IPCC default value of 18 250 kg BOD/1000 persons/year is used for D, the degradable organic component in the waste, for all years.

Industrial wastewater from breweries, dairies and slaughterhouses are released into domestic sewer systems. Emissions of methane from industries with their own wastewater treatment plants are small, because the plants are mainly aerobic or the methane gas is being recovered.

As recommended by the review team Norway has estimated emissions of CH_4 from food processing industry. The estimations are based on water consumption, in NACE 15 for the year 2004 (Stave, 2006) and information from National Accounts on Gross values from industry (NACE 15) in constant 2000 prices for the period 1990 to 2006.

Data for the economic turnover in million NOK for each industry are given from Statistics Norway's National Accounts on Gross values from industry (NACE 15).

N_2O
Data for the number of people in Norway not connected to waste water treatment are obtained from the waste water statistics at Statistics Norway. We know the number of inhabitants connected to large treatment plants (>50 pe) for the years after 1990, and the number of inhabitants connected to small treatment plants (<50 pe) for the years 2002 to 2004. We have also received the percentage connected for 1990, which were 75 per cent. For the years between 1990 and 2002 the percentage connected is interpolated.

Number of people not connected = Number of inhabitants * Number of inhabitants connected to small treatment plants / number of inhabitants connected to large treatment plants.

A yearly estimate for the amount of nitrate supplied to the pipelines is obtained from the waste water statistics at Statistics Norway. These figures are used for estimating N_2O emissions from the part of the population connected to waste water treatment plants.

Data for the amount of nitrogen that is removed in the biological step in the actual wastewater plants is obtained from the waste water statistics at Statistics Norway. An oversight of which plants that removes nitrogen is given by The Norwegian Pollution Control Authority (SFT).

8.4.7 Emission factor

CH_4
The IPCC emission factor for B_0 of 0.6 kg CH_4/kg DC is used. The methane conversion factor (MCF) is, according to good practice, given by the fraction of BOD that will ultimately degrade anaerobically. Country-specific MCF factors are estimated by Statistics Norway for the years 2000-2005, based on the part of the population connected to tanks with anaerobic conditions. The factors are from Statistics Norway (waste water statistics), and corresponds to the fraction of the waste water plants that are categorized as "Sealed tank" and partly the category "Separate toilet system".

The MCF factor is about 0.01 (1 per cent) for the years after 2000. We assume that in 1990, 2 per cent of the population were connected to anaerobic treatment systems for waste water and that the share gradually has decreased until 2000. From our best knowledge we therefore assume that the MCF-factor of 0.02 is reflecting the condition in 1990 and that the factor for 1990 is consistent with the calculated factors for 2000-2005.

Emissions from water consumption in food processing industries are calculated using the average MCF–factor (0.01) for wastewater. The IPCC emission factor for B_0 of 0.6 kg CH_4/kg DC is used. The COD factors for the different groups are taken from IPPC 2006 and some are average factors made by Statistics Norway. Based on the water consumption and Gross values from industry in 2004 we know the water consumption per economic turnover. The same factor is used for all years for the different products, see table 8.2. The table also show the default COD factors for the different products. COD factors for manufacture of animal feeds and dry general food products are the average of all the others.

Table 8.2 The developed water consumption coefficients and chemical oxygen demand in m^3/million NOK and mg/l

	m^3/mill NOK	COD mg/l
Manufacture of meat products and cooking oil	125	2.9
Manufacture of fish products	476	2.5
Manufacture of fruit, vegetables and grain mill products	499	5.2
Manufacture of dairy products	314	1.5
Manufacture of animal feeds	154	2.72
Manufacture of dry general food products	170	2.72
Manufacture of beverages	317	1.5

Source: IPPC and Statstics Norway

N_2O

For the part of the population that is connected to treatment plants the N_2O emissions are calculated by multiplying the total amount of nitrate supplied to the pipelines by the IPCC default emission factor of 0.01 kg N_2O-N/kg sewage-N produced. The conversion factor of N_2O-N to N_2O is 1.57.

For the part of the population that is not connected to treatment plants the emissions factors are as follow: The IPCC emission factors for EF_6 of 0.01kg N_2O/kg sewage-N produced is used, and the fraction of nitrogen in protein, $Frac_{NPR}$, is 0,16 kg N/kg protein. Protein is annual per capita protein intake (kg/person/year). A report from the Directorate for Health and Social Affairs estimates the amount of daily per capita protein intake for Norway for 1997 (Johansson and Solvoll, 1999). There has not been done any other survey like this, where the daily per capita protein intake for Norway has been estimated. In 1997 the daily per capita protein intake for Norway was 86 gram, which gives 31.39 kilo per year. For the years 1990, 1995, 2000, 2003 and 2004 the Directorate for Health and Social Affairs has made estimations of the potential protein intake for the population. (Sosial og helsedirektoratet, 2006)

This is estimated based on the equation:

(8.13) Potential protein intake = production + import - export

These estimation dos not reflect that actual consumption is lower because not everything is eaten, since parts of the food ends up as waste. Lars Johanson at the Directorate for Health

and Social Affairs recommends that Norway use the 31.39 kilo per person for 1997 and that Norway uses the trend in potential protein intake when making the time series. Statistics Norway has estimated the intermediate years by interpolation. This is shown in the table 8.3.

Table 8.3 Potential protein intake, and estimated protein intake, in g/person/day, kg/person/year, for the years 1990-2005

Year	Potential protein intake g/per/day	kg/pers/ year	Index 1997 =100	Estimated protein intake kg/per/year
1990	**94**	34.3	100.2	31.5
1991	93.8	34.2	100.0	31.4
1992	93.6	34.2	99.8	31.3
1993	93.4	34.1	99.6	31.3
1994	93.2	34.0	99.4	31.2
1995	**93**	33.9	99.1	31.1
1996	93.4	34.1	99.6	31.3
1997	93.8	34.24	**100**	***31.39***
1998	94.2	34.4	100.4	31.5
1999	94.6	34.5	100.9	31.7
2000	**95**	34.7	101.3	31.8
2001	96	35.0	102.3	32.1
2002	97	35.4	103.4	32.5
2003	**98**	35.8	104.5	32.8
2004	**101**	36.9	107.7	33.8
2005	99	36.1	105.5	33.1

Sorce: Statistics Norway and the Directorate for Health and Social Affairs (numbers in bold in column 2)

N_2O emissions occur as a by-product in biological nitrogen-removal plants. It is assumed that 2 per cent of the nitrogen removed from plants will form N_2O. This country-specific emission factor is given in SFT (1992), and the assumption is based on measurements in plants and comparisons with factors used in Sweden. The amount of N removed at the plant is multiplied with 0.02 and then multiplied with the factor of 1.57 for conversion of N-removed to N_2O-N.

8.4.8 Uncertainties

Uncertainty estimates for greenhouse gases are presented and discussed in Annex II.

The uncertainty in AD is estimated to ±1 per cent for CH_4 and ±25 per cent for N_2O. Uncertainty in EF for has been estimated to ±70 per cent both for CH_4 and N_2O.

8.4.9 Source spesific QA/QC and verification

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

8.4.10 Recalculations

6 B1 Industrial waste water handling
Revised emission factor. The methane conversion factor (MCF) used to calculate CH_4 emissions from industrial waste water handling has been revised for 2004-2006, taking into account the use of sealed tanks for black water.

Revised activity data. CH_4 emissions from production of food articles in 2006 have been adjusted somewhat, due to updated value figures used in the calculations.

8.4.11 Planned improvements

There is for the moment no planned activity that will improve the data quality for NIR 2010.

8.5 Waste incineration – CO_2 – 6C

8.5.4 Description

Emissions from waste incineration in district heating plants are reported under energy (IPCC 1A1a), as the energy is utilised, and therefore described in Chapter 3. In 2006, there were 16 waste incineration plants where household waste is incinerated. In addition, some incineration plants burn waste other than household waste, mainly wooden waste, paper, pasteboard and cardboard. These emissions are reported and described under energy (IPCC 1A2d). Waste, other than household waste, is also used as energy source in some manufacturing industries. In this chapter, the focus will be on waste reported in IPCC sector 6C. This includes emissions from flaring, except flaring from energy sectors, and emissions from cremation and hospital waste. The emission trend from 1990 to 2006 is described in Section 2.3.

8.5.5 Methodological issues

Emissions from flaring of landfill gas by landfills are estimated. However, CO_2 emissions from flaring of landfills are not included in the inventory, as these are considered as being of biogenic origin. The emissions are estimated by multiplying the amount of gas flared with the emission factors shown in Table 8.2. Emissions from flaring of natural gas by production of methanol were earlier estimated and reported under 6C. These emissions are now reported under 2B5, see notes under recalculations. The amount of gas used in flaring is multiplied by appropriate emission factors, found in Table 8.2.

Emissions from cremation are estimated by emission factors multiplied with activity data. Earlier this was true for hospital waste as well, but from 2007 hospital waste has been incinerated in municipal plants and emissions are reported under energy.

8.5.6 Activity data

Landfill gas
The total amount of landfill gas extracted each year is reported by landfills to the Norwegian Pollution Control Authority. Statistics Norway subtracts the amount utilized for district heating and thermal power, which is given by the energy statistics in Statistics Norway. To find the amount flared of the remaining landfill gas, a fraction given from a survey of waste statistics from Statistics Norway is used. This survey is made every third year, but is planned to be annual in the coming years. CO_2 emissions from flaring of landfills are not included in the inventory, as these are considered as being of biogenic origin.

Natural gas
The amount of natural gas flared by the production of methanol is now reported under 2B5, see recalculations.

Hospital waste
The amount of hospital waste was reported to Statistics Norway for the years 1998 and 1999. For the period 1990-1997 the average for 1998 and 1999 has been used. After 1999 there has

been no collection of hospital waste data. Due to the lack of better information, the waste amount for 1999 has been used to calculate the emissions for subsequent years. The hospital incinerators have gradually been closed down, mainly due to new limits of emission. From 2007 and onwards there has been no hospital incinerators running. Today hospital waste is incinerated in incinerators for municipal waste and emissions are included under 1A1a).

Cremation
The number of cremated bodies is taken from the death statistics at Statistics Norway (Statistical Yearbook). Further it is assumed that 40 per cent is dry substance. The weight of a coffin is set to 25 kilogram.

8.5.7 Emission factors

Table 8.4 Emission factors for flare, cremation and hospital waste incineration

Component	Flare Landfill gas kg/tonnes	Cremation Tonnes/body	Hospital waste Tonnes/tonnes
CO_2	0	0	0.3
CH_4	0.37	0.00001176	0.00023
N_2O	0.0015	0.0000147	0.000035

8.5.8 Uncertainties

Activity data
Uncertainty estimates for greenhouse gases are presented and discussed in Annex II.

No new data on the amount of hospital waste has been reported since 1999. The amount of hospital waste the subsequent years may vary from the data reported in 1998 and 1999. Uncertainty has been estimated to ±30 per cent. Since 2007 there have been no hospital incinerators.

Emission factors
Uncertainty estimates for greenhouse gases are presented and discussed in Annex II.
If the composition of the hospital waste is different to the waste the emission factors are based on, the calculated emissions will be incorrect. Combustion engineering and processes also influence the emissions. Uncertainty is estimated to ±30 per cent. See Annex II.

8.5.9 Source specific QA/QC and verification

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

8.5.10 Recalculations

6 C1 Biogenic waste incineration
Revised activity data. Figures on methane flared have been reduced somewhat for 2002-2006, which has resulted in marginally lower emissions of CH_4 and N_2O for these years.

8.5.11 Planned improvements

There is for the moment no planned activity that will improve the data quality for NIR 2010.

9. Recalculations

9.1 Overall description of recalculations

The Norwegian greenhouse gas emission inventory has in 2009 been recalculated for the entire time series 1990-2006 for all components and sources, to account for new knowledge on activity data and emission factors and to correct for discovered errors in the calculations. There is also a continous process for improving and correcting the inventory and the documentation of the methodologies employed, based on questions and comments received in connection with the annual reviews. The figures in this inventory are therefore, as far as possible, consistent through the whole time series.

The driving force for making improvements in the emission inventory is to meet the reporting requirements in the UNFCCC Reporting Guidelines on Annual Inventories as adopted by the COP by its Decision 18/CP. In addition, it is important for decision makers and others to have accurate emission estimates as basis for making decisions of what measures to introduce to reduce emissions.

There is only one major recalculation of greenhouse gases in the 2009 submission:

1. CH_4 emissions from waste disposal have been reduced for the whole time period 1990-2006, due to a revision of figures on disposed waste in Statistics Norway's waste statistics. In particular, data on the distribution between different waste types has been improved. There is a continuous process to improve the waste statistics, and there have been several previous recalculations for emissions from waste disposal due to revised waste statistics.. The most recent figures have caused a major reduction in national CH_4 emissions. The annual reduction grew successively through the period, from 1.0 ktonnes CH_4 in 1990 to 7.3 ktonnes in 2006. The annual percentage reduction in emissions from landfills increased from 1.2 per cent in 1990 to 11.3 per cent in 2006. The impact of the change on total national CH_4 emissions rose from 0.3 per cent in 1990 to 3.5 per cent in 2006.

9.2 Specific description of the recalculations

9.2.1 Energy

The recalculations performed in the energy sector concern primarily the year 2006. This is mainly due to changes in the energy statistics. The figures used in the 2008 submission were based on preliminary figures on energy use. Now the energy statistics include final energy consumption figures from the statistics on energy use in the manufacturing industries. Also some other final energy figures on energy use have been included. Changes in the emission figures due to such changes in the energy statistics will not be commented on specifically under each IPCC code.

1A 1a Public electricity and heat production

- Revised data. Changes in figures for energy use in 2003-2006, due to the inclusion of a plant for which data previously were lacking, have caused a minor increase in the emissions.

1A 1b Petroleum refining

- Reallocation. Emissions erroneously registered as solid have been moved to liquid.

1A 1c Manufacture of solid fuels and other energy industries

- Correction of error. CO_2 emissions from one plant have been reduced 2000-2006, due to the correction of a previous double counting. In addition, there is a marginal reduction in CH_4 emissions 2005-2006, due to the correction of a previous error in registered emissions from one plant.

1A 2a Iron and steel

- Revised data: CO_2 emissions reported from one plant, which previously were registered as combustion emissions, have now been split between process and combustion for the whole period 1990-2006, thus causing a reduction in combustion emissions. At the same time, the total figures for the plant have been reduced for 1991-2005. For another plant, the figures have been adjusted somewhat downwards for 1998-2001 and 2005.

1A 2 b Non-ferrous metals

- Revised activity data. Figures on LPG use at one plant have been reduced for 2003 and increased for 2004-2005, causing corresponding changes in emissions of CO_2, CH_4 and N_2O.

1A 3 a Civil aviation

- Revised activity data. Changes in the distribution between LTO air traffic under and above 100 metres, has caused alterations for CH_4 emissions, in accordance with differences in emission factors.

1A 3 b i-iii Road transport

- Revised activity data. Revised figures on vehicle-kilometres and fuel consumption for the period 2003-2006, have caused changes in emissions from road traffic.

1A 3 e Other transportation; off-road vehicles and other machinery

- Revised activity data. The figure on auto diesel used in equipment has been somewhat increased, and thus causing higher emissions.

1A 4 a Commercial/institutional

- Revised activity data. Figures on methane flared have been reduced somewhat for 2002-2006, thus causing marginally higher emissions of CH_4 and N_2O for these years from utilised methane.

1B 2a iv Refining and storage

- Revised data. Minor reduction in indirect CO_2 emissions from one plant 2005-2006 because of lower NMVOC emissions, due to revised reporting from this plant.

1B 2a v Distribution of oil products

- Revised data. Minor changes in indirect CO_2 emissions, due to new calculations of NMVOC from petrol distribution, based on updated information on time for installation of vapour recovery units. Revised figures for 1991-1992 and 1994-2006. The figures have been reduced for 1992 and 1997 and increased for other years.

1B 2b5 Natural gas, other leakage

- Revised data. Somewhat higher indirect CO_2 emissions in 2006, because of revised emission figure for NMVOC from one plant.

1B 2c2.2 Venting and flaring; flaring gas

- Revised data. Changes in figures for energy use in 2004-2006, due to the inclusion of a plant for which data previously were lacking, have caused a minor increase in the emissions.

9.2.2 Industrial processes

2A 3 Limestone and dolomite use

- Additional activity. Minor emissions of CO_2 from a brick producing plant, previously not estimated, have been included for the whole period 1990-2006.

2A 7 Other mineral production

- Additional activity. Minor emissions of CO_2 from a fibreglass producing plant, previously not estimated, have been included for the whole period 1990-2006.

2B 2 Nitric acid production

- Revised data. Reported figure on N_2O emissions from one plant in 2006 has been altered.

2B 5 Other, plastic

- Revised data. Minor change in indirect CO_2 emissions from one plant in 2006, due to altered figure for reported NMVOC emissions.

2 C 1 Iron and steel production

- Revised data: As stated under 1A2a, CO_2 emissions from one plant, which previously were registered as combustion emissions, have now been split between process and combustion for the whole period 1990-2006, thus causing an increase in process emissions.

2 C 2 Ferroalloys production

- Correction of error. CO_2 emissions from some plants have been adjusted slightly downwards for 2006, as the previous figures also included combustion emissions. As combustion emissions also were calculated separately in the 2008 submission, a double counting has accordingly been corrected.

2 C 5 Other metal production

- Revised data: Reported CO_2 figures 2005-2006 from one anode producing plant have been somewhat reduced.

2 F Consumption of halocarbons and SF_6

- Revised activity data. Revisions of activity data for 2005 and 2006 for several gases contributed to minor changes (< 1 per cent) in estimated emissions. Activity data on imports of PFC-218 and HFC-134 for earlier years were also revised, but had insignificant effect on the estimated emissions from HFCs and PFCs.

3 A-D Solvents

- Revised method and data. For the whole period 1990-2006, indirect CO_2 emissions from solvents have risen by 10-25 ktonnes, due to the implementation of a new estimation method for NMVOC emissions from solvents that led to increased NMVOC emissions.

9.2.3 Agriculture

4 A Enteric fermentation

- Revised activity data. Minor increase in CH_4 emissions in 2006, due to revised figure for number of reindeer.

4 B Manure management

- Revised activity data. Minor changes in CH_4 emissions in 2006, due to revised figure for number of reindeer. Changes in N_2O emissions 2004-2006, due to revised data in the model that calculates NH_3 emissions.

4 D Direct soil emission

- Revised activity data. Minor changes in N_2O emissions 2006 due to revised figure for number of reindeer, use of sludge in agriculture and use of fertilizer. In addition, a revision in the model that estimates emissions of NH_3 (new figure for intermixture of water in manure) leads to a minor adjustment. .
- 4 D.1.4. Revised activity data. Minor changes in N_2O emissions 1996-2006, due to revised crop figures.
- 4 D.1.2. Revised factor. New loss factor 2004-2006 for spreading in the model that calculates NH_3 emissions.
- 4 D.2.1 Revised data. New data 2004-2006 in the model that calculates NH_3 emissions.
- 4 D.3.2 Revised data. New data 2004-2006 in the model that calculates NH_3 emissions.

9.2.4 Waste

6 A Solid waste disposal on land

- Revised activity data. Figures on disposed waste in Statistics Norway's waste statistics, in particular the distribution between different waste types, used to calculate CH_4 emissions, have been altered for the whole time period 1990-2006. There is a continuous process to improve the waste statistics. The most recent figures have caused a major reduction in national CH_4 emissions. The annual reduction grew successively through the period, from 1.0 ktonnes CH_4 in 1990 to 7.3 ktonnes in 2006. The annual percentage reduction in emissions from landfills increased from 1.2 per

cent in 1990 to 11.3 per cent in 2006. The impact of the change on total national CH_4 emissions rose from 0.3 per cent in 1990 to 3.5 per cent in 2006.

6 B1 Industrial waste water handling

- Revised emission factor. The methane conversion factor (MCF) used to calculate CH_4 emissions from industrial waste water handling has been revised for 2004-2006, taking into account the use of sealed tanks for black water.
- Revised activity data. CH_4 emissions from production of food articles in 2006 have been adjusted somewhat, due to updated value figures used in the calculations.

6 C1 Biogenic waste incineration

- Revised activity data. Figures on methane flared have been reduced somewhat for 2002-2006, which has resulted in marginally lower emissions of CH_4 and N_2O for these years.

7 Land-Use, Land-Use Change and Forestry sector

The whole time-series have been recalculated due to revisions of the methods used to calculate the total biomass of forest trees and land use change, and updating of activity data. The method for calculating change in living biomass on land converted to "Forest" differs from last year's submission. Now estimates for only the annual change in living biomass are reported for these areas. The method used to recalculate changes of carbon stock in dead organic matter and for soil is the same as reported in 2008.

Table 9.1 Recalculations in 2009 submission compared to the 2007 and 2008 submission. Gg CO_2-equivalents (the emissions of CH_4 and N_2O are not included in 2007)

Year	2007 submission	2008 submission	Current submission 2009	% change 2007-2008	% change 2008-2009
1990	-14 734	-13 704	-12 304	-7.0	-10.2
1991	-14 191	-12 919	-11 506	-5.9	-10.9
1992	-14 451	-12 507	-11 094	-9.0	-11.3
1993	-14 060	-12 772	-11 358	-13.5	-11.1
1994	-14 723	-12 260	-10 847	-9.2	-11.5
1995	-13 935	-13 101	-11 684	-16.7	-10.8
1996	-14 367	-12 454	-11 034	-13.3	-11.4
1997	-13 980	-12 770	-11 353	- 8.7	-11.1
1998	-19 864	-12 673	-11 180	- 32.2	-11.8
1999	-20 079	-16 277	-13 806	- 18.9	-15.2
2000	-25 326	-23 495	-17 092	- 7.6	-27.3
2001	-27 375	-25 982	-18 954	- 5.1	-27.0
2002	-27 901	-30 956	-23 720	9.9	-23.4
2003	-25 220	-31 720	-25 709	25.8	-19.0
2004	-25 517	-31 079	-25 899	21.8	-16.7
2005	-27 232	-34 482	-27 934	26.6	-19.0
2006		-27 850	-22 558		-19.0
2007			-25 895		

9.3 Implications of the recalculations

9.3.1 Implications for emission levels

Table 9.2 shows the effects of recalculations on the emission figures for the greenhouse gases 1990 – 2006. Table 9.3 shows the effect on recalculations on the emission figures for HFCs, PFCs and SF_6. 1990 - 2006.

Table 9.2 Recalculations in the 2009 submission compared to the 2008 submission. CO_2, CH_4 and N_2O. ktonnes CO_2-equivalents

	CO_2			CH_4			N_2O		
	2008 submission	2009 submission	Difference (%)	2008 submission	2009 submission	Difference (%)	2008 submission	2009 submission	Difference (%)
1990	34774.5	34791.6	0.0	4635.1	4614.6	-0.4	4718.5	4718.5	0.0
1991	33370.8	33378.7	0.0	4692.5	4662.1	-0.6	4573.2	4573.2	0.0
1992	34187.4	34180.4	0.0	4766.2	4724.1	-0.9	4012.7	4012.7	0.0
1993	35902.4	35906.5	0.0	4849.5	4794.2	-1.1	4241.8	4241.8	0.0
1994	37857.1	37881.0	0.1	4937.3	4867.1	-1.4	4338.5	4338.5	0.0
1995	37785.0	37812.7	0.1	4934.3	4847.7	-1.8	4404.1	4404.1	0.0
1996	40876.9	40898.4	0.1	4972.4	4868.1	-2.1	4454.7	4454.7	0.0
1997	40990.1	40996.8	0.0	5009.3	4888.9	-2.4	4462.1	4462.1	0.0
1998	41109.9	41116.9	0.0	4897.4	4764.5	-2.7	4541.6	4541.6	0.0
1999	41970.6	41980.5	0.0	4764.2	4621.4	-3.0	4752.8	4752.8	0.0
2000	41576.8	41590.9	0.0	4907.9	4759.0	-3.0	4517.7	4517.7	0.0
2001	42940.2	42968.0	0.1	4922.5	4772.1	-3.1	4429.2	4429.2	0.0
2002	42002.9	42038.1	0.1	4752.1	4603.4	-3.1	4618.5	4618.5	0.0
2003	43317.9	43356.9	0.1	4777.0	4628.2	-3.1	4467.0	4466.8	0.0
2004	43845.8	43902.7	0.1	4741.4	4594.7	-3.1	4624.7	4624.7	0.0
2005	42861.3	42907.0	0.1	4582.0	4433.5	-3.2	4734.6	4737.5	0.1
2006	43258.6	43336.6	0.2	4407.7	4259.3	-3.4	4372.5	4398.2	0.6

Table 9.3. Recalculations in the 2009 submission compared to the 2008 submission. HFCs, PFCs and SF_6. ktonnes CO_2-equivalents

	HFCs			PFCs			SF_6		
	2008 submission	2009 submission	Difference (%)	2008 submission	2009 submission	Difference (%)	2008 submission	2009 submission	Difference (%)
1990	0.02	0.02	0.00	3370.40	3370.40	0.00	2199.78	2199.78	0.00
1991	0.11	0.11	0.00	2992.92	2992.92	0.00	2079.15	2079.15	0.00
1992	0.34	0.34	0.00	2286.92	2286.92	0.00	705.03	705.03	0.00
1993	2.42	2.42	0.00	2297.72	2297.72	0.00	737.71	737.71	0.00
1994	9.20	9.20	0.00	2032.47	2032.47	0.00	877.98	877.98	0.00
1995	25.82	25.82	0.00	2007.74	2007.74	0.00	607.79	607.79	0.00
1996	52.24	52.24	0.00	1829.08	1829.08	0.00	574.10	574.10	0.00
1997	86.52	86.52	0.00	1632.94	1632.94	0.00	579.86	579.86	0.00
1998	129.82	129.82	0.00	1485.53	1485.53	0.00	726.74	726.74	0.00
1999	180.56	180.56	0.00	1388.46	1388.46	0.00	873.96	873.96	0.00
2000	238.36	238.36	0.00	1317.90	1317.90	0.00	934.42	934.42	0.00
2001	303.71	303.71	0.00	1328.63	1328.63	0.00	791.20	791.20	0.00
2002	362.68	362.68	0.00	1437.60	1437.60	0.00	238.30	238.30	0.00
2003	402.84	402.84	0.00	909.10	909.10	0.00	234.86	234.86	0.00
2004	439.42	439.42	0.00	879.94	879.94	0.00	275.68	275.68	0.00
2005	481.68	482.16	0.10	828.65	828.65	0.00	312.03	312.03	0.00
2006	518.44	521.29	0.55	742.50	742.50	0.00	212.09	212.09	0.00

9.3.2 Implications for emission trends

Table 9.4 shows the impact of the performed recalculations on the emission trends 1990-2006.

Table 9.4 Trends in emissions 1990-2006. 2009 submission compared with 2008 submission. GHG. Per cent change 1990-2006

	Total GHG	CO_2	CH_4	N_2O	PFCs	SF_6	HFCs
2009 submission	7.60	24.56	-7.70	-6.79	-77.97	-90.36	2 844 176
2008 submission	7.67	24.40	-4.91	-7.33	-77.97	-90.36	2 828 646

The most important change in emissions in this submission, compared with the one from 2008, is reduced figures on emissions of CH_4 from waste disposal. As the total annual methane emission reduction increased through the period (1.2 per cent in 1990, compared to 11.3 per cent in 2006), the total percentage emission reduction from 1990 to 2006 has grown considerably, by 2.79 per cent. The growth in emission trend for CH_4 has to some degree been counteracted by reduced N_2O emissions. Due to increased figures on use of diesel in motorized equipment, N_2O emissions in 2006 have risen compared with the previous submission, thus causing a lower emission reduction from 1990, compared with the previous submission. For CO_2 the emission growth from 1990 to 2006 is somewhat higher, whereas there are only minor changes in the emission trend for HFCs, and no changes for PFCs and SF_6. The gap between 1990 and 2006 for all the six greenhouse gases together has been reduced by 38 000 tonnes CO_2 equivalents since the previous calculation.

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About SFT

The Norwegian Pollution Control Authority (SFT) is a government agency with 300 employees and is based in Oslo. We report to the Ministry of Environment. We work for a world without pollution. We implement government pollution policy, and we are guides, guardians and a driving force for a better environment. Our most important fields of work include climate change, hazardous substances, water and the marine environment, waste management, air quality and noise

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